

Evaluating the Effectiveness of Sustainable Aviation Fuels (SAFs) in Reducing Emissions in Nigeria

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ABSTRACT: This study examined the perceived effectiveness of Sustainable Aviation Fuels (SAFs) in reducing aviation emissions and the barriers to their implementation in Nigeria. A quantitative survey research design was adopted, and data were collected from a sample of 200 respondents drawn from key aviation stakeholders. The data were analyzed using descriptive statistics and ANOVA to test the hypotheses. The findings revealed a high level of agreement that SAFs can significantly reduce carbon emissions, improve environmental quality, and contribute to Nigeria's climate change mitigation goals. The grand mean score indicated strong consensus regarding the environmental benefits of SAF adoption. However, the study also identified significant perceived barriers to SAF implementation. High production costs, inadequate infrastructure, limited government policy support, financial constraints, and low stakeholder awareness were reported as major challenges. The hypothesis testing results confirmed that both the perceived effectiveness of SAFs and the barriers to implementation are statistically significant. The study concludes that while SAFs are widely recognized as environmentally beneficial, economic and structural constraints hinder their adoption in Nigeria. It recommends stronger policy support, infrastructure development, financial incentives, and increased stakeholder awareness to promote sustainable aviation development.

KEYWORDS: Sustainable Aviation Fuel (SAF); Aviation Emissions; Climate Change Mitigation; Environmental Sustainability; Aviation Industry; Nigeria; Energy Transition.

1. INTRODUCTION

Aviation plays a vital role in the transportation sector, connecting people and places, supporting trade, tourism, and economic integration. However, it is also a significant contributor to greenhouse gas emissions, accounting for about 2–3% of global carbon dioxide emissions, with projections suggesting further increases as air travel demand continues to grow [1]. The aviation industry is growing rapidly in developing countries such as Nigeria due to population growth, expanding business activities, and improved regional connectivity. This growth has raised concerns about environmental sustainability and the need to reduce emissions generated by aviation.

Nigeria's aviation industry is almost fully dependent on traditional jet fuels (Jet A-1), which are petroleum-based and contribute significantly to carbon emissions and climate change. Aviation emissions are among the fastest-growing sources of greenhouse gases globally and could triple by 2050 if no mitigation measures are implemented [2]. This highlights the urgent need to explore cleaner and more sustainable energy options in the aviation industry, particularly in developing economies such as Nigeria.

Sustainable Aviation Fuels (SAFs) are considered a viable solution to reduce aviation's environmental impact. SAFs are derived from renewable and waste-based sources such as agricultural residues, used cooking oil, and non-food biomass. Compared to conventional jet fuels, SAFs can reduce lifecycle carbon emissions by up to 80%, depending on the feedstock and production pathway [3]. In addition to emission reduction, SAFs are compatible with existing aircraft engines and infrastructure, making them a practical short- to medium-term solution for decarbonizing aviation.

Despite their potential, SAF adoption remains limited in many developing countries, including Nigeria. Challenges such as high production costs, inadequate technological infrastructure, lack of policy incentives, and limited stakeholder awareness hinder widespread implementation [4]. Although sustainable fuel alternatives are gradually being introduced in Nigeria, they have not yet been fully integrated into current aviation operations, creating a gap between international environmental goals and local practices. Furthermore, most existing studies on SAFs focus on developed economies, where policy frameworks and technological advancements are more established. Limited empirical evidence exists in African countries, particularly Nigeria, regarding stakeholder awareness, perceptions, and readiness to adopt SAFs. Understanding these perspectives is crucial because successful SAF implementation depends not only on technology but also on institutional support, industry acceptance, and policy alignment.

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This study therefore aims to assess the effectiveness of Sustainable Aviation Fuels in emission reduction in Nigeria using primary data collected through structured questionnaires administered to aviation stakeholders. Specifically, it examines stakeholders' perceptions of SAF effectiveness and identifies perceived barriers to implementation. The study is designed to provide empirical evidence on SAF feasibility in Nigeria and contribute to evidence-based policymaking, industry decision-making, and academic literature on sustainable aviation in developing economies.

1.1 RESEARCH HYPOTHESIS

- i. H₀₁: There is no significant perception that SAFs are effective in reducing aviation emissions in Nigeria.
- ii. H₀₂: There are no significant perceived barriers to SAF implementation in Nigeria.

2.LITERATURE REVIEW

2.1 Conceptual Framework

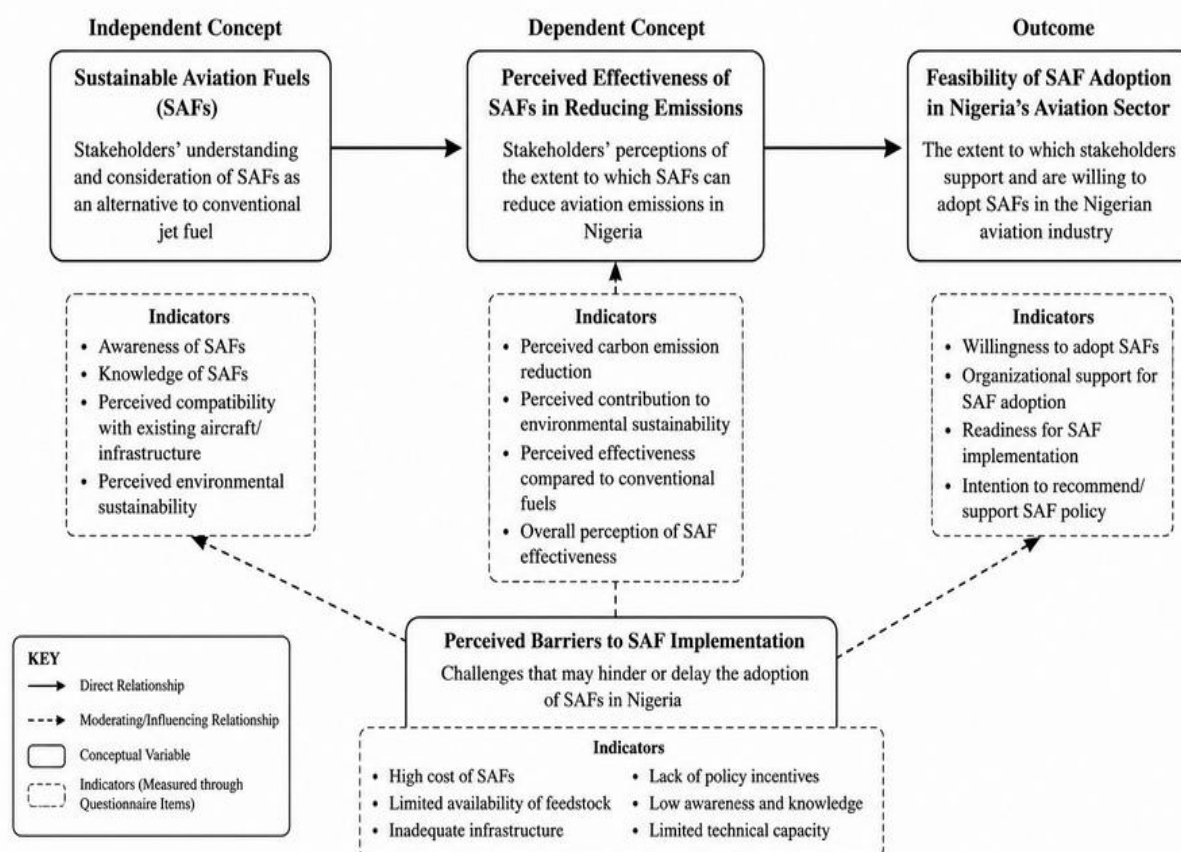


Figure 2.1 Conceptual Framework

Source: Researcher's Conceptualization (2026), adapted from ICAO (2022), IATA (2023), and World Bank (2022).

The conceptual framework for the study (Figure 2.1) depicts the linkages between Sustainable Aviation Fuels (SAFs), perceived effectiveness of emission reduction, and perceived implementation barriers in Nigeria's aviation sector. The framework is perception-based because the study relied solely on primary data collected through questionnaires administered to aviation stakeholders.

Sustainable Aviation Fuels (SAFs) represent a cleaner alternative to conventional fossil-based jet fuels and are recognized for their potential to significantly reduce greenhouse gas (GHG) emissions in the aviation industry [2]. The study examined SAFs based on stakeholders' perceptions of their capability to reduce emissions in Nigeria.

The first dimension of the framework is the perceived effectiveness of SAFs in emission reduction. This reflects stakeholders' views on SAFs' ability to reduce carbon emissions, enhance environmental sustainability, and contribute to climate change mitigation. The International Air Transport Association reported that SAFs can substantially reduce lifecycle carbon emissions compared to conventional jet fuels [1]. Positive stakeholder perception may therefore increase acceptance and support for SAF adoption.

The second dimension is perceived barriers to SAF implementation. These include high production costs, inadequate infrastructure, weak policy incentives, limited technical capacity, and low stakeholder awareness. Existing evidence shows that such barriers significantly constrain SAF adoption in developing countries [4].

The framework assumes that although stakeholders may recognize the environmental benefits of SAFs, implementation barriers could reduce their willingness to support adoption. Therefore, SAF feasibility in Nigeria depends on perceived effectiveness and perceived constraints.

2.2 Empirical Review

Empirical studies on Sustainable Aviation Fuels (SAFs) indicate varying results across regions. Several studies confirm that SAFs significantly reduce greenhouse gas emissions and support aviation decarbonization, while others highlight economic and infrastructural constraints affecting adoption.

Staples et al. found that SAFs can reduce lifecycle carbon emissions by 50–80% depending on feedstock and production pathways [5]. Similarly, Pavlenko et al. emphasized that SAF deployment is critical for achieving long-term aviation decarbonization targets [6]. These findings support SAFs as a viable environmental solution.

However, Schäfer et al. argued that high production costs and technological limitations restrict large-scale SAF adoption, particularly in developing economies [7]. Bauen et al. also identified supply chain weaknesses and inadequate infrastructure as major obstacles to commercialization [8].

In the African context, Akinyosoye and Dauda reported that weak institutional capacity and limited financing hinder renewable fuel transitions, including SAF adoption [9]. Nhamo and Nhamo further observed that despite emission reduction potential, African aviation sectors remain dependent on fossil fuels due to limited policy commitment [10].

In Nigeria, Adejumo and Akinbami found that weak policy implementation and low technological advancement impede clean energy transition [11]. Similarly, Ibrahim and Bello reported that continued fossil fuel dependence contributes to high carbon intensity in Nigeria's transport sector [12].

Stakeholder perception also plays a crucial role. Hansson et al. found that positive environmental attitudes increase SAF acceptance, although cost concerns reduce willingness to adopt [13]. Roth et al. emphasized that policy incentives such as subsidies and carbon pricing are necessary for successful SAF transition [14]. Ortega and Martínez further confirmed that institutional quality and stakeholder awareness significantly influence SAF adoption [15].

3. METHODOLOGY

3.1 Study Area

The study was conducted within the Nigerian aviation sector to evaluate the perceptions of Sustainable Aviation Fuels (SAFs) in reducing emissions and to identify perceived barriers to their implementation. The research will focus on major aviation hubs in Nigeria, particularly Abuja (Nnamdi Azikiwe International Airport), Lagos (Murtala Muhammed International Airport), and other selected operational centers where key stakeholders are accessible.

Nigeria's aviation industry plays a significant role in transportation, trade, and economic development. The sector is regulated by aviation authorities and involves airlines, airport management agencies, fuel suppliers, and related service providers. These institutions operate within a structured regulatory framework guided by national aviation policies and international standards. The selected study locations are appropriate because they host major stakeholders involved in aviation operations, fuel management, and environmental compliance, making them suitable for examining SAF-related perceptions and implementation challenges.

3.2 Population of the Study

The population of the study consists of aviation stakeholders in Nigeria. These include: Airline management and operational staff, Aviation regulatory personnel, Airport authority officials, Aviation fuel suppliers, and Environmental and sustainability officers within aviation institutions.

These groups are directly involved in decision-making, fuel usage, regulatory enforcement, and environmental sustainability practices within the aviation sector. Their perspectives are essential in assessing the perceived effectiveness of SAFs and identifying barriers to implementation.

3.3 Research Design

This study adopted a descriptive survey research design. The survey design is appropriate because it enables the collection of primary data from respondents based on their perceptions, opinions, and experiences regarding Sustainable Aviation Fuels.

The design allows the researcher to systematically gather quantitative data using structured questionnaires. It is suitable for examining relationships between variables and for analyzing stakeholder perceptions in a real-world setting. The approach enhances objectivity and ensures alignment with the study's objectives, which focus on perception of SAF effectiveness and identification of implementation barriers.

3.4 Sampling Procedure and Sample Size Determination

The study adopted a practical and manageable sample size suitable for survey research. A total of 200 respondents were selected for the study. This sample size was considered adequate to ensure reliable statistical analysis while remaining feasible in terms of

time and resources. In survey research, an adequate sample size enhances the reliability and validity of findings and supports meaningful statistical inference [16].

A stratified random sampling technique was employed to ensure proper representation of key stakeholder groups within the aviation sector. The population was divided into relevant strata, including airline staff, aviation regulatory officials, airport authority personnel, and fuel suppliers. This approach improves representativeness and reduces sampling bias [17]. Respondents were randomly selected from each group to ensure balanced participation across the different categories of stakeholders in the Nigerian aviation industry.

3.5 Data Analysis Technique

Data collected for this study were analyzed using both descriptive and inferential statistical methods. Descriptive statistics, specifically frequencies, percentages, mean, and standard deviation, were used to summarize respondents' demographic characteristics and their responses to the questionnaire items.

For hypothesis testing, the study employed Analysis of Variance (ANOVA) to examine whether there were statistically significant differences in respondents' perceptions. ANOVA is appropriate for determining whether differences in mean responses are statistically significant across variables under investigation [18]. The test was used to assess the relationship between stakeholders' perceptions of SAF effectiveness and perceived implementation barriers in Nigeria's aviation sector.

4. DATA PRESENTATION AND ANALYSIS

Table 4.1 Profile of the Respondents

Demographic	Particulars	No. of Respondents	% Of Respondents
Gender	Male	121	60
	Female	79	40
Age	Below 30	12	6
	30–39	77	39
	40–49	88	44
	50 and above	35	17
Years of Experience in Aviation Sector	Less than 5 years	22	11
	5–10 years	80	40
	11–15 years	77	38
	Above 15 years	21	10
Organization Type	Airline	55	28
	Regulatory Agency	45	22
	Airport Authority	69	34
	Fuel Supplier	35	17
	Other	5	3
Total for each segment		200	100

Source: Computation of primary data, 2026

Table 4.1 presents the demographic profile of the 200 respondents. The gender distribution shows that 121 respondents (60%) were male, while 79 (40%) were female, indicating a relatively balanced representation with a slight male dominance. In terms of age, the majority of respondents were within the productive working groups, with 88 (44%) aged 40–49 years and 77 (39%) aged 30–39 years. Only 12 (6%) were below 30 years, while 35 (17%) were 50 years and above, suggesting that most participants were experienced professionals. Regarding years of experience in the aviation sector, 80 (40%) had 5–10 years, 77 (38%) had 11–15 years, 22 (11%) had less than 5 years, and 21 (10%) had over 15 years, reflecting substantial industry expertise. Concerning organization type, respondents were fairly distributed across airlines, regulatory agencies, airport authorities, fuel suppliers, and other related organizations, ensuring diverse institutional representation in the study.

Table 4.2 Perception of SAF Effectiveness in Reducing Emissions

S/N	Statement	Mean ($\bar{x}$)	Std. Dev.	Decision
1	SAFs can significantly reduce carbon emissions in aviation.	4.62	0.81	High
2	SAFs are environmentally more sustainable than conventional jet fuel.	4.48	0.88	Moderately High
3	The adoption of SAFs will improve environmental quality in Nigeria.	4.41	0.92	Moderately High
4	SAFs can contribute to Nigeria's climate change mitigation goals.	4.53	0.85	High
	Grand Mean	4.51	0.87	High

Source: Computation of primary data, 2026

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Table 4.2 presents respondents' perceptions of Sustainable Aviation Fuel (SAF) effectiveness in reducing emissions. The results indicate a generally high level of agreement, with a grand mean of 4.51 and a standard deviation of 0.87, suggesting strong consensus among respondents.

Specifically, respondents strongly agreed that SAFs can significantly reduce carbon emissions in aviation (mean = 4.62), reflecting confidence in their environmental benefits. Similarly, SAFs were rated highly in contributing to Nigeria's climate change mitigation goals (mean = 4.53), indicating recognition of their strategic importance in national sustainability efforts. The statement that SAFs are environmentally more sustainable than conventional jet fuel recorded a moderately high mean of 4.48, demonstrating broad support for their comparative environmental advantage. Furthermore, respondents agreed that the adoption of SAFs will improve environmental quality in Nigeria (mean = 4.41), reinforcing the belief that SAF integration can positively impact environmental conditions.

Table 4.3: Perceived Barriers to SAF Implementation

S/N	Statement	Mean ($\bar{x}$)	Std. Dev.	Decision
5	High production cost limits SAF adoption in Nigeria.	4.67	0.79	High
6	Lack of infrastructure hinders SAF implementation.	4.54	0.84	High
7	Inadequate government policies discourage SAF adoption.	4.49	0.90	Moderately High
8	Limited awareness among stakeholders affects SAF implementation.	4.36	0.95	Moderately High
9	Financial constraints make SAF adoption difficult for airlines.	4.58	0.82	High
Grand Mean		4.53	0.86	High

Source: Computation of primary data, 2026

Table 4.3 presents respondents' perceptions of the barriers to Sustainable Aviation Fuel (SAF) implementation. The results indicate a high overall level of agreement, with a grand mean of 4.53 and a standard deviation of 0.86, showing strong consensus regarding the challenges affecting SAF adoption in Nigeria.

Specifically, respondents strongly agreed that high production costs limit SAF adoption (mean = 4.67), identifying cost as the most significant barrier. Financial constraints faced by airlines also recorded a high mean score (4.58), further emphasizing economic limitations as a major obstacle. In addition, lack of infrastructure was rated highly (mean = 4.54), suggesting that inadequate production, storage, and distribution facilities hinder effective implementation. Respondents also agreed that inadequate government policies discourage SAF adoption (mean = 4.49), highlighting the need for stronger regulatory support. Limited awareness among stakeholders (mean = 4.36) was rated moderately high, indicating that knowledge gaps also contribute to slow adoption.

4.1 Test of Hypotheses

H_{01} : There is no significant perception that SAFs are effective in reducing aviation emissions in Nigeria.

Table 4.4 ANOVA Result

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-statistic	P-value
Between Groups	57.87	1	27.65	18.11	0.0096
Within Groups	41.64	199	1.49		
Total	99.51	200			

Source: Computation of primary data, 2026

The hypothesis (H_{01}) states that there is no significant perception that SAFs are effective in reducing aviation emissions in Nigeria. The ANOVA result shows an F-statistic of 18.11 with a p-value of 0.0096. Since the p-value is less than the conventional significance level of 0.05, the null hypothesis is rejected. This indicates that there is a statistically significant perception among respondents that Sustainable Aviation Fuels are effective in reducing aviation emissions in Nigeria. Therefore, the study concludes that SAFs are significantly perceived as effective in supporting emission reduction and environmental sustainability in the aviation sector.

H_{02} : There are no significant perceived barriers to SAF implementation in Nigeria.

Table 4.9 ANOVA Result

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-statistic	P-value
Between Groups	30.07	1	30.07	15.35	0.0003
Within Groups	54.83	199	1.96		
Total	84.90	200			

AUTHOR'S COMPUTATION 2026

The ANOVA result shows an F-statistic of 15.35 with a p-value of 0.0003. Since the p-value is less than the 0.05 significance level, the null hypothesis is rejected. This indicates that there are statistically significant perceived barriers to SAF implementation in Nigeria. Therefore, the study concludes that respondents recognize substantial challenges such as high costs, inadequate infrastructure, policy limitations, limited awareness, and financial constraints that significantly hinder the effective adoption and implementation of Sustainable Aviation Fuels in the Nigerian aviation sector.

4.2 Discussion of Findings

The results from both descriptive statistics and hypothesis testing provide a comprehensive understanding of stakeholder perceptions within the aviation sector.

First, the high grand mean (4.51) for SAF effectiveness indicates strong agreement that SAFs can significantly reduce carbon emissions and contribute to Nigeria's climate change mitigation goals. This finding aligns with recent global research emphasizing the environmental benefits of SAFs. For example, Davis et al. report that SAFs can reduce lifecycle carbon emissions by up to 80% compared to conventional jet fuel, depending on feedstock and production pathways [19]. Similarly, the International Energy Agency (IEA) highlights that SAF adoption is one of the most viable short- to medium-term strategies for decarbonizing aviation, particularly in regions where electrification is not yet feasible for long-haul flights [20]. In real-life terms, airlines in Europe and North America are increasingly blending SAF with conventional fuel to meet emission reduction targets. The strong perception observed in this study suggests that stakeholders in Nigeria recognize SAF as a practical solution for achieving environmental sustainability in aviation.

The rejection of H_{01} confirms that respondents significantly perceive SAFs as effective in reducing emissions. This aligns with international sustainability trends and reflects growing awareness of climate change pressures. In practical terms, Nigeria's aviation sector faces increasing global scrutiny regarding carbon emissions, especially as international routes require compliance with environmental standards. Adoption of SAF could therefore enhance Nigeria's compliance with global aviation sustainability frameworks and improve environmental quality domestically.

However, despite positive perceptions, the study also found strong evidence of perceived barriers to SAF implementation, with a grand mean of 4.53. The rejection of H_{02} confirms that these barriers are statistically significant.

These findings are consistent with de Jong et al., who argue that high production costs remain the primary obstacle to global SAF adoption due to limited large-scale production facilities [21]. Similarly, Larson et al. note that infrastructure limitations and supply chain constraints significantly slow SAF deployment in developing economies [22]. In real-world contexts, SAF production requires advanced biorefinery infrastructure, stable feedstock supply chains, and supportive regulatory frameworks—elements that are currently limited in many African countries, including Nigeria.

The high mean score for production cost (4.67) reflects a major economic challenge. SAF production is typically more expensive than conventional jet fuel due to limited economies of scale, feedstock procurement costs, and technological investment requirements. In practice, this cost differential discourages airlines from adopting SAF without government incentives, subsidies, or long-term procurement agreements. This aligns with IEA recommendations that policy support mechanisms such as tax incentives, blending mandates, and carbon pricing are essential to improve SAF competitiveness [20].

Infrastructure limitations (mean = 4.54) further demonstrate that Nigeria may lack the necessary refining, storage, transportation, and distribution systems required for large-scale SAF deployment. Without adequate infrastructure investment, SAF adoption may remain restricted to pilot projects or demonstration programs rather than full commercial integration.

Additionally, financial constraints faced by airlines (mean = 4.58) reflect the operational realities of the aviation industry. Airlines often operate under tight profit margins, fluctuating fuel prices, and foreign exchange volatility. These economic pressures reduce their capacity to absorb higher fuel costs associated with SAF adoption. Therefore, without financial support mechanisms, voluntary transition may remain slow.

The perceived inadequacy of government policies (mean = 4.49) indicates the need for stronger regulatory frameworks and long-term sustainability strategies. In countries where SAF adoption has advanced, such as the United States and several European nations, government mandates, subsidies, and blending targets have played a critical role in accelerating implementation. The findings suggest that similar policy instruments could support SAF growth in Nigeria.

Limited stakeholder awareness (mean = 4.36) also highlights the importance of capacity building, industry engagement, and environmental education. Effective SAF implementation requires collaboration between airlines, regulators, fuel producers, and environmental agencies. Without coordinated awareness programs and strategic partnerships, adoption efforts may remain fragmented.

In general, the study demonstrates a dual reality. On one hand, SAFs are strongly perceived as environmentally beneficial and aligned with global climate objectives. On the other hand, structural, economic, and policy-related constraints significantly hinder implementation in Nigeria. This suggests that perception alone is insufficient for transition; practical support systems are required to translate positive attitudes into action.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study examined perceptions of Sustainable Aviation Fuel (SAF) effectiveness and the barriers to its implementation in Nigeria. The findings revealed a strong and statistically significant perception that SAFs can reduce aviation emissions and contribute to climate change mitigation. Respondents demonstrated high agreement that SAF adoption would improve environmental quality and support sustainability goals in the aviation sector. This indicates growing awareness of SAF as a viable solution for decarbonizing aviation.

However, the study also found significant perceived barriers to SAF implementation. High production costs, inadequate infrastructure, financial constraints, limited awareness, and insufficient government policies were identified as major challenges. The statistical tests confirmed that both perceptions effectiveness and barriers are significant. This suggests that while stakeholders recognize the environmental benefits of SAF, structural and economic constraints remain substantial obstacles to widespread adoption in Nigeria.

The findings have important policy implications, suggesting that Nigeria can advance its climate commitments by integrating SAF into its aviation strategy. For industry stakeholders, the results highlight the need for strategic planning and long-term investment in sustainable fuel technologies. Academically, the study contributes to the growing literature on sustainable energy transition in developing countries. Practically, it demonstrates that environmental awareness alone is insufficient without addressing economic and infrastructural constraints. Sustainable aviation in Nigeria will depend on coordinated institutional support, financial innovation, and technological development.

5.2 Recommendations

Based on the findings, the study gives the following recommendations:

- i. First, the government should develop clear and supportive policies, including tax incentives, subsidies, and regulatory frameworks to encourage SAF production and use. Strong policy direction will reduce uncertainty and attract private investment.
- ii. Second, investment in infrastructure such as production facilities, storage systems, and distribution networks is essential. Public-private partnerships (PPPs) can be used to mobilize funding and technical expertise.
- iii. Third, awareness campaigns and stakeholder engagement programs should be introduced to improve knowledge about SAF benefits and implementation processes.
- iv. Fourth, financial institutions should design green financing schemes to support airlines and investors involved in SAF projects. Lower-interest sustainability loans can reduce financial pressure.
- v. Finally, collaboration between government, airlines, fuel suppliers, and research institutions should be strengthened to promote innovation and local production capacity.

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