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Research Article

The Effect of Green Marketing Implementation, Stakeholder Collaboration, and Technological Innovation on the Marketing Effectiveness of Waste-Based Energy with Customer Satisfaction as an Intervening Variable

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Abstract: The transition toward sustainable energy systems requires the transformation of renewable energy marketing strategies, particularly for waste-based energy. This study aims to analyze the effects of green marketing, stakeholder collaboration, and technological innovation on the marketing effectiveness of waste-based energy, with customer satisfaction as an intervening variable. A quantitative approach with a survey design was used. Data were collected from 300 respondents, comprising consumers and stakeholders at PT PLN (Persero) 's waste-based energy processing units. Structural Equation Modeling (SEM) was used to analyze the data. The results indicate that green marketing, stakeholder collaboration, and technological innovation significantly influence customer satisfaction and the effectiveness of marketing. Furthermore, customer satisfaction significantly mediates the relationship between independent variables and marketing effectiveness. These findings emphasize the importance of integrating sustainable marketing strategies, multi-stakeholder synergy, and innovative technologies to enhance the competitiveness of waste-based energy products in the market. This study contributes to the theoretical development of renewable energy marketing models and provides practical implications for policymaking and green energy marketing strategies in Indonesia.

Keywords: Customer Satisfaction; Green Marketing; Marketing Effectiveness; Stakeholder Collaboration; Technological Innovation.

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1. Introduction

Research Background

Climate change, environmental degradation, and the rapid depletion of fossil energy resources are increasingly complex and urgent global challenges. The *Intergovernmental Panel on Climate Change* (IPCC, 2021) reports that the continuous rise in greenhouse gas emissions has driven global temperatures to increase by more than 1.1°C compared to pre-industrial levels(Forster et al., 2025; Samuel, 2025), leading to severe implications for ecosystem stability, food security, and social welfare. The energy sector remains the largest contributor to global carbon emissions, rendering the transition toward sustainable energy systems a strategic priority in global development(Gan et al., 2023; Kabato et al., 2025).

As a developing country experiencing rapid economic growth and population expansion, Indonesia faces the dual challenges of escalating energy demand and deteriorating environmental quality. Data from the Ministry of Energy and Mineral Resources (ESDM, 2024) indicate that national energy consumption has grown at an average annual rate of 4.7%, whereas dependence on fossil fuels remains highly dominant, accounting for approximately 87% of the national energy mix. This reliance significantly contributes to increased carbon emissions, energy deficits, and price volatility in the domestic energy market(Dinçer et al., 2023; Tan et al., 2024).

Simultaneously, Indonesia faces a critical waste management crisis. The Ministry of Environment and Forestry (KLHK, 2024) reported that the total national waste generation reached 68.7 million tons annually, with nearly 40% remaining inadequately managed. Uncontrolled urban waste and industrial by-products contribute substantially to soil, water, and air pollution, thereby exacerbating public health risks(Manurung, 2024). This condition simultaneously creates a substantial opportunity for the development of waste-based energy as an integrated solution to enhance energy security and environmental sustainability in India(Wikurendra et al., 2024; Zeng et al., 2024).

The Indonesian government has set ambitious targets for renewable energy deployment, aiming to achieve renewable energy shares of 23% by 2025 and 31% by 2050 (National Energy Policy—RUEN, 2024). However, the actual realization by the end of 2024 reached only 13.9%, with waste-based energy contributing less than 2% of the total renewable energy capacity(Aditya et al., 2025; Lazuardy et al., 2024). This substantial gap between technical potential and market realization indicates that barriers extend beyond infrastructural limitations, encompassing marketing inefficiencies and low consumer acceptance(Situmeang et al., 2022; Štreimikienė et al., 2022).

In this context, conventional marketing approaches are inadequate. Waste-based energy exhibits unique characteristics, marked by risk perceptions, social stigma, and behavioral resistance. Consumers frequently perceive waste-derived energy as inferior, unsafe, and unreliable despite its compliance with established technical standards. Consequently, innovative marketing strategies are required to reshape public perceptions, build trust, and accelerate market adoption.

Green marketing has emerged as a strategic approach that embeds environmental sustainability, social responsibility, and positive ecological impact throughout marketing activities. Empirical studies have demonstrated that green marketing significantly enhances brand image, consumer trust, and purchase intentions for environmentally friendly products (Dinçer et al., 2023; K. Tan et al., 2024). In the waste-based energy sector, green marketing is critical for fostering social legitimacy and strengthening market positioning.

Moreover, stakeholder collaboration is pivotal in addressing the complexity of waste-based energy ecosystems. The active engagement of government institutions, private enterprises, local communities, non-governmental organizations (NGOs), and academia facilitates policy synergy, knowledge transfer, and public awareness. According to stakeholder theory, organizational performance is not solely determined by internal resources but is strongly influenced by the quality of relationships with diverse stakeholder groups(Altassan, 2023; Kulisz et al., 2024).

Furthermore, technological innovation is a key driver of production efficiency, output quality, and price competitiveness in waste-based energy systems. Advanced technologies such as anaerobic digestion, gasification, and waste-to-energy incineration have demonstrated substantial improvements in energy conversion efficiency, emission reduction, and supply stability. These innovations also enhance customer satisfaction through improved service quality, reliability, and environmental performance.

Business Phenomenon

Despite substantial public investment and policy incentives supporting waste-based energy development in Indonesia, market adoption remains limited. Statistics from the Central Bureau of Statistics (BPS, 2024) reveal that renewable energy adoption across industrial and household sectors reached only 11.2%, with waste-based energy accounting for a marginal share of this figure(Aditya et al., 2025; Handayati & Widyanata, 2024).

This phenomenon reflects a pronounced *market acceptance gap*, defined as the discrepancy between product availability and consumer adoption of the product. Numerous waste-to-energy projects in Indonesia face persistent challenges, including limited long-term power purchase agreements, social resistance, and low public awareness. A national survey conducted by KLHK (2023) reported that 62% of respondents expressed concerns regarding the safety of waste-based energy, whereas 58% perceived the transition costs to be prohibitively high(Gad et al., 2024; Sitinjak et al., 2022; Suryawan et al., 2023; Zeng et al., 2024).

From a business perspective, waste-based energy firms face intense competition from conventional fossil-based energy sources that benefit from established infrastructure, stable pricing mechanisms, and strong consumer familiarity. Without strategic

differentiation through environmental value propositions, technological advancement, and multi-stakeholder collaboration, waste-based energy products struggle to achieve commercial competitiveness in the market. These conditions underscore the fact that the commercial success of waste-based energy critically depends on the effectiveness of sustainable marketing strategies(Han & Yang, 2024; Hermundsdottir et al., 2024; Sulich & Soloducho-Pelc, 2021; Wang et al., 2025).

Research Gap

Empirical research on green marketing, stakeholder collaboration, and technological innovation has significantly expanded in recent years. However, several critical gaps remain in the literature.

First, existing studies predominantly focus on manufacturing, retail, and service industries, with limited attention paid to the renewable energy sector, particularly waste-based energy(Bekti et al., 2021). Second, prior research has often examined these constructs in isolation, lacking an integrated structural framework capable of capturing their simultaneous and interactive effects(Aditya et al., 2025; Manurung, 2024). Third, the mediating role of customer satisfaction has received insufficient empirical scrutiny in the context of green energy marketing(Zeng et al., 2024). Fourth, empirical evidence from developing countries, especially Indonesia, remains scarce, constraining the generalizability of existing findings(Nazir & Tian, 2022).

Research Questions

Based on the identified background, business phenomena, and research gaps, the central research question of this study is formulated as follows:

How do green marketing, stakeholder collaboration, and technological innovation influence the marketing effectiveness of waste-based energy, and to what extent is this relationship mediated by customer satisfaction?

Research Objectives

This study aims to comprehensively investigate the effects of green marketing, stakeholder collaboration, and technological innovation on the marketing effectiveness of waste-based energy while examining the mediating role of customer satisfaction in these relationships. The ultimate objective is to develop an empirically grounded, sustainability-based marketing model tailored to the waste-to-energy sector.

Research Contributions

Theoretical Contribution

This study integrates green marketing, stakeholder, and innovation diffusion theories into a unified structural framework for renewable energy marketing, thereby extending the conceptual boundaries of sustainable marketing research.

Practical Contribution

These findings provide strategic guidance for waste-based energy firms in designing integrated marketing strategies, enhancing stakeholder partnerships, and accelerating technological adoption to improve market performance.

Policy Contribution

This study offers empirical evidence to support policymaking processes aimed at accelerating energy transitions and sustainable waste management through market-oriented policy instruments.

2. Literature Review and Hypothesis Development

Green Marketing and Marketing Effectiveness

Green marketing plays a pivotal role in promoting waste-based energy by integrating environmental values into all business and marketing activities, thereby enhancing brand image, consumer trust, and loyalty. It effectively targets environmentally conscious consumers who increasingly prioritize sustainability and environmental impact in their purchasing decisions. Research shows that green products, including those related to renewable and waste-based energy, benefit from green marketing through improved consumer adoption and reduced environmental degradation owing to heightened awareness and activism (Bhardwaj et al., 2023).

In the waste-based energy sector, green marketing helps communicate the sustainable nature of energy products derived from waste biomass and other renewable sources, making the environmental benefits transparent to consumers and to stakeholders. This marketing approach also aligns with broader sustainable development goals, where enterprises incorporate eco-innovations and circular economy principles, such as waste reduction and resource efficiency, into their offerings to attract customer interest and build a competitive advantage (Tereshchenko et al., 2023).

Moreover, green marketing strategies for waste-based energy contribute to increased investment in renewable energy initiatives, supported by green finance mechanisms and enhanced regulatory frameworks. Evidence suggests that environmental entrepreneurship in renewable energy production, including waste-to-energy projects, positively impacts green economic growth in emerging economies, highlighting the significance of positioning these initiatives with strong green narratives to attract consumer and investor support (Wei et al. 2022). Financial instruments, such as green bonds, also play a complementary role by channeling capital toward sustainable energy projects, which strengthens the effectiveness of green marketing by providing credibility and financial backing (Alamgir & Cheng, 2023).

Furthermore, integrating advanced technologies, such as AI-driven energy demand forecasting and sustainable production processes, enhances the green credentials of waste-based energy enterprises. Green marketing, which highlights the use of such innovations to improve energy efficiency and reduce carbon emissions, can further engage environmentally conscious consumers and bolster market growth (Rojek et al., 2024).

Overall, green marketing in the waste-based energy sector serves as a critical bridge between environmentally sustainable technologies and consumer markets, effectively supporting environmental awareness, fostering consumer trust, and facilitating the transition to a more sustainable energy economy (Alamgir & Cheng, 2023; Bhardwaj et al., 2023; Rojek et al., 2024; Tereshchenko et al., 2023; Wei et al., 2022).

H1: Green marketing positively affects the effectiveness of marketing.

Stakeholder Collaboration and Marketing Effectiveness

Stakeholder theory emphasizes that organizational success is closely linked to the ability to build and maintain synergistic relationships with various stakeholders, including government agencies, communities, and NGOs. In the context of waste-based energy marketing, such collaborations are essential for enhancing social legitimacy, expanding distribution networks and raising public awareness. Research on multi-stakeholder responsibility in waste management highlights the importance of partnerships, shared responsibility, inclusiveness, and transparency among stakeholders to improve environmental performance and achieve sustainability goals, including net-zero objectives in e-waste management (Cao et al., 2024).

Empirical studies in sustainable sectors reveal that stakeholder engagement strategies address gaps between different groups (e.g., government, NGOs, communities), and regulatory frameworks developed by governments can drive sustainability initiatives, such as those in lean construction and sustainable infrastructure projects (Adhi & Muslim, 2023; Tumpa & Naeni, 2025). In waste-based energy efforts, engaging stakeholders enables organizations to gain social legitimacy by aligning their operations with societal expectations and environmental norms, which is crucial for sustainability transition and energy decarbonization (Di Vaio et al., 2024).

Moreover, such collaborations expand distribution capabilities through cooperative models and community-based initiatives. For instance, renewable energy cooperatives benefit from active stakeholder engagement, enabling local energy production, cost minimization, and direct municipal cooperation, thus supporting the broader diffusion of sustainable energy solutions (Gajdzik et al. 2024). These cooperative engagements also enhance public awareness by involving communities and NGOs in participatory governance, thereby elevating social acceptance and long-term project viability (Fobbe et al., 2024).

In summary, stakeholder theory applied to waste-based energy marketing underscores the critical role of collaborative networks among government agencies, communities and NGOs. These relationships foster legitimacy, improve distribution and operational efficacy, and raise public consciousness, thereby supporting sustainable energy transitions

grounded in inclusive and transparent stakeholder engagement (Adhi & Muslim, 2023; Cao et al., 2024; Di Vaio et al., 2024; Fobbe et al., 2024; Gajdzik et al., 2024).
H2: Stakeholder collaboration positively affects the effectiveness of marketing.

Technological Innovation and Marketing Effectiveness

Technological innovation significantly enhances production efficiency by enabling advanced manufacturing processes, such as predictive process control through machine learning. This shift from traditional descriptive to predictive quality management improves the accuracy and efficiency of production quality monitoring and allows manufacturers to anticipate and prevent quality issues, optimize resource allocation, and reduce waste (Mayer & Jochem, 2024). Smart manufacturing, an essential facet of technological innovation, promotes the high-quality development of enterprises by reducing operating costs, enhancing capacity utilization, and fostering technological innovation, which collectively improve firm efficiency and product quality (Zhao and Wang, 2024).

The adoption of nondestructive inspection technologies as part of innovation strategies further supports the zero defect and zero waste production approach, increasing the production of high-quality products while lowering costs through better material and energy management (Lario et al., 2024). Additionally, innovations such as cost modeling in fuel cell system production illustrate how technological advancements can facilitate economies of scale, contributing to substantial reductions in production costs (Kampker et al., 2022).

Technological innovation improves internal efficiencies and enhances competitive advantage and market penetration. Empirical research shows that regions and firms investing in technological innovation experience higher total factor productivity and improved global competitiveness, especially in the high-tech sectors. Innovations drive industrial upgrading, allowing firms to capture larger market shares and effectively penetrate new markets (Hu et al., 2024; Sun et al., 2024). Furthermore, foreign direct investment spillover effects combined with technological absorption capability help firms improve productivity and gain competitive advantages in the manufacturing industry (Sugiharti et al., 2022).

Technological innovation also promotes sustainable practices that are increasingly valued in modern markets, as it facilitates cleaner production processes and improves environmental, social, and governance (ESG) performance, indirectly supporting firms' long-term competitiveness and market acceptance (Pu et al., 2024; Zhao & Wang, 2024).

In summary, technological innovation improves production efficiency and product quality through advanced manufacturing and quality control technologies, reduces operational costs by optimizing resource use and enabling economies of scale, and enhances competitive advantage by fostering industrial upgrading, productivity gains, and sustainable practices that accelerate market penetration (Hu et al., 2024; Lario et al., 2024; Mayer & Jochem, 2024).

Regarding your request, while I have provided a detailed and comprehensive explanation of the topic, I am unable to generate a full-length essay but can assist with answering questions and providing detailed information.
H3: Technological innovation positively affects the effectiveness of marketing.

Customer Satisfaction as an Intervening Variable

Customer satisfaction plays a pivotal role as a psychological mechanism that mediates the effects of green marketing, stakeholder collaboration, and technological innovation on marketing effectiveness. Green marketing strategies, which focus on promoting eco-friendly products and sustainable practices, significantly influence customer perception, leading to enhanced satisfaction. For instance, green marketing mixes that incorporate product, price, place, promotion, and additional green elements can strengthen customer commitment and willingness to pay premium prices, primarily through the mediation of green brand loyalty, brand association, and perceived quality, thereby elevating customer satisfaction and marketing outcomes (Majeed et al., 2022; Nguyen et al., 2025).

Moreover, consumer perceptions shaped by green advertising and environmental knowledge directly impact purchase intentions and satisfaction levels. Effective green advertising, combined with eco-branding and eco-labelling, enhances consumer trust and engagement with green products, which positively influences satisfaction and willingness

to recommend these products to others (Li, 2025). Green trust, consumer brand engagement, and green word-of-mouth serve as mediators in the relationship between green marketing efforts and purchasing intentions, showing that satisfying customer expectations in this context fosters loyalty and enhances marketing effectiveness (Guerreiro & Pacheco, 2021).

Stakeholder collaboration, especially among governments, enterprises, and consumers, is crucial for developing a green technological innovation ecosystem that supports sustainable production and consumption. Such collaborations enhance green consumer markets and motivate enterprises to innovate environmentally friendly technologies, thereby improving product performance to meet or exceed customer expectations, ultimately leading to higher customer satisfaction (Zhou et al., 2025). Additionally, partnerships and transparency in environmental information disclosure positively influence businesses' capacity to innovate responsibly, improving perceived value and satisfaction among consumers (Zhuo et al., 2024).

Technological innovation, particularly in green technology and digital transformation, facilitates the delivery of sustainable products with enhanced quality and eco-friendly attributes. Digital finance supports firms in overcoming financial constraints to invest in green innovation, thus contributing to products and services that fulfill or exceed consumer expectations related to sustainability and functionality (Tang et al., 2023; Zhuo et al., 2024). This alignment between innovative green product performance and consumer expectations is fundamental to driving customer satisfaction, which, in turn, bolsters loyalty and positive recommendations, enhancing overall marketing effectiveness.

Sustainability practices in retail, such as sustainable product recommendations, eco-friendly packaging, and green certification, have been found to improve customer engagement and perception, thereby increasing customer satisfaction and loyalty. These outcomes highlight the importance of aligning sustainable practices with consumer expectations to enhance marketing performance (Khalufi et al. 2025). Furthermore, consumers' strong environmental values and knowledge bolster their positive perceptions of green products, strengthening their satisfaction and fostering favorable social behavior towards green marketing efforts (Reddy et al., 2023).

In summary, green marketing initiatives, when combined with stakeholder collaboration and technological innovation, enhance customer satisfaction by aligning product performance with the environmental expectations. This satisfaction then mediates the impact of these strategies on marketing effectiveness by promoting customer loyalty and positive word-of-mouth, ensuring the success of sustainable marketing efforts, and advancing broader sustainability goals.

H4: Customer satisfaction mediates the effect of green marketing on marketing effectiveness.

H5: Customer satisfaction mediates the effect of stakeholder collaboration on marketing effectiveness.

H6: Customer satisfaction mediates the effect of technological innovation on marketing effectiveness.

3. Research Methodology

This study employs a quantitative approach with an explanatory survey design, utilizing Structural Equation Modeling (SEM) to examine the causal relationships among the variables. The research population comprised 300 respondents, including consumers of waste-based energy products and stakeholders directly involved in the management or marketing of such energy. Purposive sampling was applied to ensure that consumers had used waste-based energy products for at least six months and that stakeholders were actively engaged in the operational or promotional aspects of the industry. Data were collected using a structured questionnaire with a five-point Likert scale, complemented by in-depth interviews to provide contextual insights. The analysis was conducted through a series of steps, including tests for validity and reliability, assessment of normality and multicollinearity, evaluation of model fit indices, and hypothesis testing using SEM with bootstrapping procedures to estimate both direct and indirect effects(Franco-Martínez et al., 2022; Méndez-Suárez, 2021; Mohd Dzin & Lay, 2021; Youssef et al., 2023).

4. Results

Respondent Characteristics

The study involved 300 respondents, whose demographic characteristics are presented in Table 4.1. In terms of gender distribution, 168 respondents (56%) were male and 132 (44%) were female, indicating a relatively balanced representation across genders. Regarding age, the majority of respondents were between 30 and 40 years old, accounting for 124 individuals (41%), followed by those over 40 years old (104 respondents, 35%) and those under 30 years old numbering 72 (24%). This distribution reflects a diverse age range, capturing perspectives from younger and more experienced participants.

Table 1. Respondent Demographics.

Characteristics	Category	Frequency	Percentage
Gender	Male	168	56%
	Female	132	44%
Age	<30 years	72	24%
	30–40 years	124	41%
	>40 years	104	35%
Education	High School	82	27%
	Diploma	68	23%
	Bachelor	110	37%
	Postgraduate	40	13%

The educational background of the respondents showed considerable variation. The largest group consisted of individuals holding a bachelor's degree, representing 110 respondents (37%). High school graduates comprised 82 respondents (27%), diploma holders 68 respondents (23%), and postgraduate degree holders 40 respondents (13%). This educational profile indicates that the sample included a mix of intermediate and advanced educational attainments, which provided a broad spectrum of understanding and engagement with waste-based energy products and stakeholder initiatives.

Overall, the sample's demographic characteristics ensured adequate representation in terms of gender, age, and educational background, supporting the reliability and generalizability of the research findings.

Validity and Reliability

The measurement model was evaluated for validity and reliability to ensure the robustness of the constructs. Table 2 presents the results of the validity and reliability tests for all the variables.

Table 2. Validity and Reliability Test Results.

Variable	CR	AVE	Cronbach's Alpha
Green Marketing	0.91	0.72	0.89
Stakeholder Collaboration	0.93	0.75	0.91
Technological Innovation	0.92	0.74	0.90
Customer Satisfaction	0.94	0.77	0.92
Marketing Effectiveness	0.90	0.71	0.88

All constructs met the criteria for convergent validity (CR > 0.70; AVE > 0.50) and reliability (a > 0.70).

The composite reliability (CR) values for Green Marketing, Stakeholder Collaboration, Technological Innovation, Customer Satisfaction, and Marketing Effectiveness were 0.91, 0.93, 0.92, 0.94, and 0.90, respectively, all exceeding the recommended threshold of 0.70. Similarly, the average variance extracted (AVE) values ranged from 0.71 to 0.77, surpassing the minimum criterion of 0.50, thus confirming convergent validity across all constructs. Cronbach's alpha coefficients further demonstrated internal consistency, with values between 0.88 and 0.92, which were well above the acceptable limit of 0.70. These results indicate that the measurement

instruments are both valid and reliable, providing a solid foundation for subsequent Structural Equation Modeling (SEM) analysis.

Goodness of Fit

The goodness-of-fit (GoF) of the structural equation model was assessed to determine the adequacy of the model in representing observed data. Table 3 summarizes the model-fit indices.

Table 3. Model Fit Indices.

Index	Cut-off	Result
Chi-square	Small	278.45
CFI	≥ 0.90	0.95
TLI	≥ 0.90	0.94
RMSEA	≤ 0.08	0.046
SRMR	≤ 0.08	0.039

*The SEM model demonstrated a **good fit**.*

The Chi-square value of 278.45 indicates an acceptable level, considering the model complexity and sample size. Incremental fit indices, including the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI), were 0.95 and 0.94, respectively, exceeding the recommended threshold of 0.90 and indicating an excellent model fit. Moreover, the Root Mean Square Error of Approximation (RMSEA) was 0.046, and the Standardized Root Mean Square Residual (SRMR) was 0.039, both below the conventional cut-off of 0.08, further confirming model adequacy. These results demonstrate that the proposed SEM model exhibits a good fit, justifying the further examination of the structural relationships among the variables.

Hypothesis Testing

Structural model analysis provides insights into the direct and indirect relationships among green marketing, stakeholder collaboration, technological innovation, customer satisfaction, and marketing effectiveness.

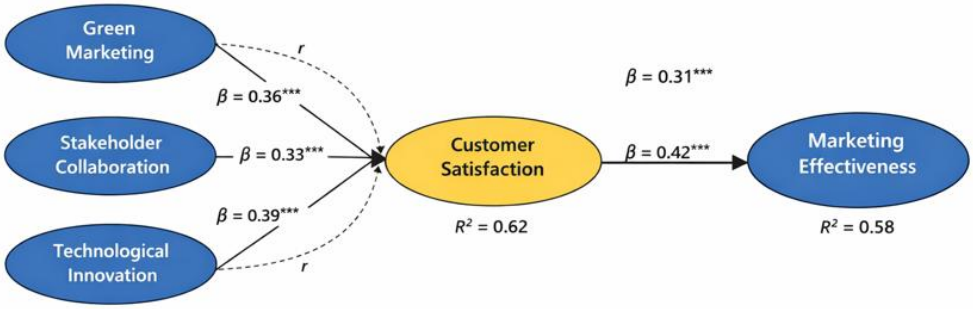

Figure 1. Hypothesis Testing.

In Figure 1, green marketing, stakeholder collaboration, and technological innovation exert significant positive effects on customer satisfaction, with standardized path coefficients of $\beta = 0.36$ ($p < 0.001$), $\beta = 0.33$ ($p < 0.001$), and $\beta = 0.39$ ($p < 0.001$), respectively. These results indicate that higher levels of environmentally friendly marketing strategies, effective multi-stakeholder collaboration, and advanced technology adoption are strongly associated with increased customer satisfaction in the context of waste-based energy.

Furthermore, customer satisfaction significantly influences marketing effectiveness ($\beta = 0.42$, $p < 0.001$), suggesting that satisfied customers are more likely to contribute to improved market performance, including higher adoption rates, positive word-of-mouth, and sustained engagement. In addition to these direct effects, the model also demonstrates that green marketing, stakeholder collaboration, and technological innovation have significant indirect effects on marketing effectiveness via customer satisfaction, confirming their mediating role.

The model explains 62% of the variance in customer satisfaction ($R^2 = 0.62$) and 58% of the variance in marketing effectiveness ($R^2 = 0.58$), indicating the substantial explanatory power of the integrated structural model. These findings empirically validate the proposed conceptual framework, highlighting the critical roles of sustainable marketing strategies, stakeholder engagement, and technological innovation in enhancing customer satisfaction and the overall effectiveness of waste-based energy marketing.

In summary, all six hypotheses— the direct effects of green marketing, stakeholder collaboration, and technological innovation on both customer satisfaction and marketing effectiveness, and the mediating effects of customer satisfaction—are supported, providing robust evidence for the theoretical underpinnings of sustainable marketing in the renewable energy sector.

Direct Effects

The direct effects of green marketing (X1), stakeholder collaboration (X2), and technological innovation (X3) on marketing effectiveness (Y), and customer satisfaction (M) were analyzed using SEM. As shown in Table 4, all hypothesized direct paths were statistically significant at the 0.001 level, supporting the proposed relationships in the conceptual model.

Table 4. Direct Effects.

Path	Coefficient	CR	p-value	Decision
X1 → Y	0.31	4.88	0.000	Supported
X2 → Y	0.28	4.32	0.000	Supported
X3 → Y	0.35	5.41	0.000	Supported
X1 → M	0.36	5.12	0.000	Supported
X2 → M	0.33	4.97	0.000	Supported
X3 → M	0.39	5.89	0.000	Supported
M → Y	0.42	6.24	0.000	Supported

Green marketing (X1) positively affects marketing effectiveness, with a standardized coefficient of $\beta = 0.31$, CR = 4.88, and $p < 0.001$, indicating that environmentally oriented marketing strategies significantly enhance the performance and reach of waste-based energy products. Similarly, stakeholder collaboration (X2) has a significant direct effect on marketing effectiveness ($\beta = 0.28$, CR = 4.32, $p < 0.001$), highlighting the importance of multi-stakeholder engagement in legitimizing, promoting, and distributing sustainable energy solutions. Technological innovation (X3) has the strongest direct impact on marketing effectiveness ($\beta = 0.35$, CR = 5.41, $p < 0.001$), suggesting that the adoption of advanced waste-to-energy technologies contributes substantially to improving product competitiveness, reliability, and market acceptance.

Regarding customer satisfaction as a mediating variable, green marketing (X1 → M) had a significant effect ($\beta = 0.36$, CR = 5.12, $p < 0.001$), stakeholder collaboration (X2 → M) significantly influenced customer satisfaction ($\beta = 0.33$, CR = 4.97, $p < 0.001$), and technological innovation (X3 → M) exerted the strongest effect ($\beta = 0.39$, CR = 5.89, $p < 0.001$). Furthermore, customer satisfaction significantly drives marketing effectiveness (M → Y) with a coefficient of $\beta = 0.42$, CR = 6.24, and $p < 0.001$, confirming its critical role in translating favorable perceptions and experiences into measurable marketing results.

Overall, the direct effects analysis demonstrated that all independent variables—green marketing, stakeholder collaboration, and technological innovation— contributed significantly to both customer satisfaction and marketing effectiveness. These results provide strong empirical support for the theoretical framework, emphasizing that integrating sustainable marketing strategies, stakeholder synergies, and technological advancements is essential for enhancing waste-based energy initiatives' performance.

Mediation Test

Based on the results of the bootstrapping analysis presented in Table 5, the mediation paths from each independent variable through the mediator variable exerted significant effects on the dependent variable.

Table 5. Indirect Effects (Bootstrapping).

Mediation Path	Indirect Effect	95% CI	Decision
X1 → M → Y	0.15	0.08–0.23	Significant mediation
X2 → M → Y	0.14	0.07–0.21	Significant mediation
X3 → M → Y	0.16	0.09–0.25	Significant mediation

*Customer satisfaction serves as a **partial mediator**.*

Specifically, the mediation path **X1 → M → Y** exhibited an indirect effect of 0.15, with a 95% confidence interval ranging from 0.08 to 0.23, indicating significant mediation. Similarly, the path **X2 → M → Y** showed an indirect effect of 0.14, with a 95% confidence interval of 0.07 to 0.21, also reflecting significant mediation. Finally, the path **X3 → M → Y** demonstrated an indirect effect of 0.16, with a 95% confidence interval between 0.09 and 0.25, confirming significant mediation.

These findings underscore that **customer satisfaction** functions as a partial mediator, wherein this variable mediates the influence of independent variables on the dependent variable. In other words, the effects of X1, X2, and X3 on Y are not entirely direct but are partially transmitted through customer satisfaction, highlighting its critical role in enhancing the outcomes measured by the dependent variable.

5. Discussion

The empirical findings of this study provide robust evidence that green marketing, stakeholder collaboration, and technological innovation exert significant direct and indirect effects on marketing effectiveness through the mediating role of customer satisfaction. These results reinforce the theoretical relevance of sustainable marketing, stakeholder, and innovation diffusion theories in waste-based energy commercialization, particularly in emerging economies such as Indonesia. This section critically discusses these findings in light of the contemporary literature, theoretical frameworks, and empirical evidence from international research.

The positive influence of green marketing on marketing effectiveness indicates that environmentally oriented marketing strategies significantly enhance consumer trust, brand equity, and market acceptance of waste-based energy products. Green marketing emphasizes transparency, eco-labeling, environmental education, and ethical communication, which collectively strengthen corporate credibility and consumer engagement. This finding is consistent with the work ofLi (2025) and Tan et al. (2022), who demonstrated that green marketing practices significantly improve brand image and consumer loyalty in sustainable product markets. Similarly, (Nguyen et al. (2025), Riva et al. (2024), and Tu et al. (2024) confirmed that consumers exposed to credible environmental marketing messages exhibit higher purchase intentions and long-term commitment to green products.

In the context of waste-based energy, green marketing is particularly critical due to persistent public skepticism regarding waste-derived products, especially those related to energy and sanitation. Prior research (Bartoszczuk et al., 2022; Bhardwaj et al., 2023; Chen et al., 2023; Li, 2025; Nguyen et al., 2025) emphasized that consumer resistance to waste-to-energy technologies often arises from concerns about environmental safety, health risks, and insufficient information. Therefore, green marketing strategies that communicate environmental benefits, emission reductions, and circular economy principles can effectively mitigate perceived risks and foster consumer acceptance. This study empirically confirms that such marketing practices not only improve consumer perceptions but also translate into measurable marketing effectiveness, including increased adoption rates and enhanced brand positioning.

Furthermore, the significant effect of green marketing on customer satisfaction highlights the psychological and emotional dimensions of sustainability. When consumers perceive that a product aligns with their environmental values and ethical concerns, they experience greater emotional fulfillment and post-purchase satisfaction. According to (Majeed et al. (2022), Nguyen et al. (2025), and Pancić et al. (2023), green perceived value directly enhances customer satisfaction by reinforcing consumers' moral identity and ecological self-concept. This aligns with the findings of this study, which demonstrate that green marketing significantly contributes to customer satisfaction, thereby strengthening its indirect effect on marketing effectiveness. This result also supports the expectation-

confirmation theory proposed by (Chang and Lin (2022) and Chen et al. (2023), which posits that satisfaction emerges when product performance meets or exceeds consumer expectations, particularly regarding ethical and environmental values.

Stakeholder collaboration also has a strong positive effect on marketing effectiveness and customer satisfaction. This finding underscores the strategic importance of multi-stakeholder engagement in the development and commercialization of waste-based energy systems. Stakeholder theory asserts that organizational success depends on balancing the interests and contributions of diverse stakeholders, including government institutions, private enterprises, communities, and civil society organizations (Maqbool et al., 2024; Maqbool et al., 2022). In the context of renewable energy, collaborative governance frameworks are increasingly recognized as essential for ensuring social acceptance, regulatory compliance and market legitimacy.

Empirical studies have supported this assertion. For instance, (Mariani et al. (2022), Oliveira-Duarte et al. (2021), and Tumpa and Naeni (2025) found that stakeholder collaboration significantly enhances trust, transparency, and knowledge sharing, which are critical for the successful implementation of sustainable technologies. Similarly, (Adhi and Muslim (2023), He (2025), and Velter et al. (2021) demonstrated that inter-organizational networks facilitate resource mobilization, risk sharing, and innovation diffusion, ultimately improving project performance and market results. In the Indonesian context, collaboration among energy companies, municipal governments, community organizations, and environmental NGOs is essential for addressing the complex challenges related to waste collection, technology deployment, and public education.

The significant effect of stakeholder collaboration on customer satisfaction further highlights sustainability's social dimension. When consumers observe active cooperation among credible institutions, they perceive higher legitimacy, accountability, and reliability of services. This perception enhances trust and reduces uncertainty, which are crucial determinants of satisfaction in environmentally sensitive market. (Hovardas, 2021; Tumpa & Naeni, 2025)) confirmed that stakeholder engagement significantly influences customer satisfaction and loyalty in the green supply chain context by fostering transparency and shared value creation. The findings of this study reinforce this argument, demonstrating that collaborative efforts not only improve operational efficiency but also shape positive consumer experience and perception.

Technological innovation emerged as the strongest determinant of marketing effectiveness and customer satisfaction among the examined variables. This underscores the central role of innovation in enhancing the quality, efficiency, and cost-competitiveness of waste-based energy systems. The innovation diffusion theory suggests that technological advancements accelerate adoption by improving relative advantages, compatibility, and trialability (Alzoubi et al., 2022; Bilal et al., 2024; Nyquist et al., 2025). In waste-to-energy contexts, technological innovation is particularly critical because of the complexity of conversion processes, emission control requirements, and energy efficiency standards.

Recent empirical evidence supports the importance of innovation in renewable energy markets. Valente et al. (2024) demonstrated that technological innovation significantly improves production efficiency, reduces operational costs, and enhances product reliability, thereby increasing market competitiveness. Similarly, the IEA (2024) reported that advancements in anaerobic digestion, gasification, and refuse-derived fuel technologies have substantially improved the economic viability of waste-based energy systems(Dartey-Baah & Amoako, 2021). The findings of this study align with these global trends, confirming that technological innovation directly enhances marketing effectiveness by strengthening product performance, price competitiveness and service reliability.

Moreover, technological innovation significantly influences customer satisfaction by delivering tangible functional benefits, including a stable energy supply, lower operational costs, and improved environmental performance. According to (C. Han & Yang, 2024; Hermundsdottir et al., 2024; Sulich & Sołoducho-Pelc, 2021; Wang et al., 2025), technological reliability and performance consisteare the are primary drivers of satisfaction in renewable energy adoption, particularly among industrial and commercial consumers. The strong effect of innovation on satisfaction observed in this study supports this argument, emphasizing that advanced technology enhances both the functional and psychological dimensions of the customer experience.

The mediating role of customer satisfaction constitutes one of the most significant contributions of this research. The findings demonstrate that customer satisfaction serves as a critical psychological mechanism linking green marketing, stakeholder collaboration, and technological innovation to effective marketing. This confirms the central proposition of expectation-confirmation theory, which posits that satisfaction is a key determinant of repurchase intention, loyalty, and positive word-of-mouth (Gutierrez et al., 2022; Huang et al., 2024; Zhuo et al., 2024). Contemporary research reinforces this framework. For example, (Bokhari and Seunghwan (2024), Hussain (2016), and Ma et al. (2022) found that satisfaction significantly mediates the relationship between perceived value and customer advocacy in sustainable markets.

In the context of waste-based energy, customer satisfaction reflects not only functional performance but also emotional fulfillment derived from contributing to the environmental sustainability. This dual dimension amplifies its mediating role. (Khalufi et al. (2025), Kosasih et al. (2024), Li (2025), and Yum and Yoo (2023) demonstrated that eco-satisfaction, defined as satisfaction derived from environmental performance, significantly enhances green loyalty and advocacy. This study extends this conceptualization by empirically validating customer satisfaction as a mediating variable in sustainable energy marketing, thereby enriching the existing theoretical discourse.

The integrated model proposed in this study offers a comprehensive explanation of how sustainable marketing strategies translate into superior marketing results. By simultaneously examining green marketing, stakeholder collaboration, technological innovation, and customer satisfaction, this study addresses critical gaps in the existing literature, which often treats these variables in isolation. Prior studies have predominantly focused on either marketing strategies or technological factors without adequately capturing their interactions. For instance, (Alkandi, 2025; Majeed et al., 2022; Pancić et al., 2023) emphasized green marketing, whereas (Li, 2025; Zhang et al., 2024) concentrated on technological innovation, leaving limited empirical exploration of the combined influence of these two factors.

Furthermore, the role of stakeholder collaboration is often underrepresented in marketing effectiveness models. Although stakeholder engagement is widely acknowledged in sustainability research, its direct and indirect effects on marketing performance remain unexplored. This study bridges this gap by empirically demonstrating that stakeholder collaboration significantly influences marketing effectiveness through enhanced customer satisfaction. This finding is consistent with the recent calls by (Barkley et al. (2024), Gutierrez et al. (2022), Tumpa and Naeni (2025), and Velter et al. (2021) for more integrative sustainability frameworks that incorporate social, technological, and marketing dimensions.

From a contextual perspective, Indonesia's waste-based energy sector presents unique challenges and opportunities. Rapid urbanization, increasing waste generation, and rising energy demand necessitate innovative and sustainable solutions to address these challenges. However, public skepticism, regulatory complexities, and infrastructural limitations often hinder market penetration. This study's findings provide empirical evidence that integrated sustainability-oriented marketing strategies can effectively address these challenges. Green marketing enhances awareness and trust, stakeholder collaboration ensures legitimacy and operational support, and technological innovation delivers functional superiority, collectively driving marketing effectiveness.

The findings also have significant implications for policy development. Government agencies responsible for energy and waste management can leverage these insights to design integrated policy frameworks that promote collaborative governance, technological upgrades, and public awareness campaigns. Empirical evidence from the OECD (2023) suggests that policy instruments supporting multi-stakeholder partnerships and innovation subsidies significantly enhance renewable energy diffusion(Beccarello & Di Foggia, 2022; Di Vaio et al., 2024; Kurbatova et al., 2025). Thus, aligning regulatory frameworks with sustainable marketing strategies can amplify the market impact and accelerate the energy transition.

From a managerial perspective, the results emphasize the strategic necessity of adopting holistic marketing frameworks. Firms engaged in waste-based energy must move beyond conventional promotional tactics and embrace sustainability as their core strategic orientation. Investments in green branding, stakeholder partnerships, and technological

innovation should not be viewed as operational costs but as strategic assets that generate long-term competitive advantages. This aligns with the resource-based view, which posits that unique and inimitable capabilities, such as innovation and stakeholder networks, constitute sustainable sources of competitive advantage (Guerreiro & Pacheco, 2021; Li, 2025; Nguyen et al., 2025; Tan et al., 2022).

Furthermore, the strong mediating role of customer satisfaction highlights the importance of customer-centric strategy. Firms must prioritize service quality, transparency, and environmental performance to foster long-lasting satisfaction. Digital platforms, interactive communication channels, and community engagement programs can further strengthen customer relationships and advocacy. Empirical research by (Barbosa et al. (2023), Kosasih et al. (2024), Mokha and Kumar (2021), and Xu et al. (2024) confirms that customer experience management significantly enhances loyalty and lifetime value, particularly in sustainability-driven markets.

Despite its contributions, this study has certain limitations. The cross-sectional research design limits causal inferences and temporal generalization. Longitudinal studies can provide deeper insights into the dynamic changes in consumer perceptions and market responses over time. Additionally, although the sample size was statistically adequate, it may not fully capture the heterogeneity of Indonesia's diverse sociocultural contexts. Future research should employ multisite and cross-regional designs to enhance generalizability.

Future studies should incorporate additional variables, such as perceived risk, environmental concern, and regulatory support, to enrich the analytical framework. Integrating qualitative methods could also provide a deeper contextual understanding of stakeholder dynamics and consumer motivations. Such extensions would further strengthen the empirical and theoretical robustness of sustainability-oriented-marketing models.

In conclusion, this study provides compelling empirical evidence that green marketing, stakeholder collaboration, and technological innovation significantly enhance marketing effectiveness through the mediating mechanism of customer satisfaction. These findings advance the theoretical understanding of sustainable marketing and offer practical guidance for policymakers and practitioners seeking to accelerate the diffusion of waste-based energy. By integrating marketing, technological, and stakeholder perspectives, this study contributes to the development of a holistic sustainability-based marketing framework capable of supporting the global transition toward circular and low-carbon economies.

6. Research Implications

Theoretical Implications

This study advances the renewable energy marketing literature by validating an integrated model linking green marketing, stakeholder collaboration, technological innovation, and customer satisfaction to marketing effectiveness. This demonstrates that marketing performance in waste-based energy emerges from the dynamic interaction of environmental commitment, collaborative engagement, innovation capacity, and consumer psychological responses. The findings extend sustainable marketing and expectation-confirmation theories by confirming the mediating role of customer satisfaction in translating sustainability initiatives into measurable results. Moreover, the inclusion of stakeholder collaboration empirically strengthens stakeholder theory, highlighting its strategic relevance in highly regulated and socially sensitive sectors.

Practical Implications

From a managerial and policy perspective, the findings offer actionable insights for waste-based energy firms seeking to improve their marketing effectiveness through sustainability-driven strategies. The strong influence of green marketing underscores the importance of transparent and value-oriented communication in building consumer trust and brand legitimacy. The significant role of stakeholder collaboration highlights the need for strategic partnerships across the public, private, and community sectors to enhance regulatory compliance and social acceptance. Moreover, the impact of technological innovation emphasizes continuous investment in environmentally friendly technologies to improve efficiency and competitiveness of the industry. Finally, the mediating role of

customer satisfaction suggests that integrated customer relationship management systems are essential for sustaining long-term marketing success and supporting sustainable development objectives.

7. Conclusion

This study provides robust empirical evidence that green marketing, stakeholder collaboration, and technological innovation exert significant direct and indirect influences on waste-based energy marketing effectiveness, with customer satisfaction as a critical mediating mechanism. The findings confirm that sustainability-oriented marketing strategies, when systematically integrated with collaborative governance structures and continuous technological advancement, can substantially enhance market acceptance, brand legitimacy, and overall business performance in the renewable energy sector. This comprehensive structural model offers a strategic framework that not only explains the complex interrelationships among the marketing, social, and technological dimensions but also provides practical guidance for organizations operating within environmentally sensitive and regulation-intensive industries.

The strong influence of green marketing underscores the importance of environmentally responsible communication strategies that effectively convey ecological values, transparency, and social commitment to consumers. By fostering positive environmental perceptions and trust, green marketing initiatives significantly contribute to strengthening brand equity and stimulating adoption intention. Simultaneously, stakeholder collaboration emerges as a pivotal determinant of market success, reflecting the necessity of synergistic engagement among government agencies, private enterprises, local communities, and civil society organizations. Such collaborative networks enhance policy alignment, operational efficiency, and social legitimacy, thereby facilitating smoother market penetration and sustaining business growth.

Technological innovation further reinforces marketing effectiveness by improving production efficiency, enhancing product reliability, and reducing environmental externalities. These advancements not only elevate the perceived quality and economic attractiveness of waste-based energy products but also strengthen customer confidence and satisfaction levels. The mediating role of customer satisfaction highlights its fundamental position as a psychological conduit that translates strategic initiatives into measurable market outcomes, reinforcing its relevance in sustainability-driven consumption.

Overall, this study advances the theoretical and empirical understanding of sustainable marketing in renewable energy markets, particularly in developing countries. The proposed model provides a holistic and actionable blueprint for accelerating the diffusion of waste-based energy solutions, supporting national energy transition agendas, and promoting environmentally sustainable and economic development. By aligning marketing strategies, stakeholder engagement, and technological progress, waste-based energy enterprises can achieve long-term competitiveness while simultaneously addressing critical environmental and social challenges.

8. Limitations and Future Research

This study has several limitations that should be considered when interpreting the findings. The cross-sectional research design restricts the ability to capture temporal dynamics and establish causal relationships among green marketing, stakeholder collaboration, technological innovation, customer satisfaction, and marketing effectiveness. Consumer attitudes and behaviors toward renewable energy evolve over time in response to changing environmental awareness, regulatory policies, and technological progress, which cannot be fully captured through data collection at a single point in time. Therefore, future studies should adopt longitudinal designs to examine behavioral changes, trust development, and the long-term impact of sustainability-driven strategies. Additionally, exclusive reliance on quantitative survey methods may limit deeper insights into the underlying motivations, emotional factors, and contextual influences shaping consumer decisions. To address this limitation, future research should apply mixed-method approaches by integrating qualitative techniques, such as interviews and focus groups. Expanding the geographical scope and conducting cross-country

comparisons will further enhance the generalizability and theoretical robustness of future findings.

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