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Synergizing Smart Grids, Renewable Energy, and WiFi Marketing: A Pathway to Sustainable Business Innovation

Kamali Samudram Manickam[1], Pierre Subeh[2] ,Lilly Beaulah Henry[3], V. Malathy[4], Kodela Rajkumar[5], Ratchagaraja Dhairiyasamy[6]

[1]Department of Electrical and Electronics Engineering, Annapoorna Engineering college, Salem 636308, Tamilnadu, India, kamalinalladurai@gmail.com

[2]Pierre Subeh, Independent Researcher and Marketing Professional. Full Sail University.

Orcid Id: https://orcid.org/0009-0003-4504-2802 Email : subehpierre@gmail.com

[3]Department of Computer Science and Engineering, Mahendra College of Engineering, Minnampalli, Salem-636106,Tamilnadu, India, lbeaulah@gmail.com

[4]Department of Electronics and Communication Engineering,SR University,Warangal, Telanganal-506371,India, malathyvanniappan@gmail.com

[5]Department of Electronics and Communication Engineering,SR University,Warangal, Telangana -506371,India. rajrecw2k@gmail.com

[6]Saveetha School of Engineering, Department of Electronics and Communication Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India ratchagaraja@gmail.com

[6]Centre of Research Impact and Outcome, Chitkara University, Rajpura- 140417, Punjab, India

[6]Division of Research & Innovation, Uttaranchal University, Dehradun, India;

[6]Division of Research and Development, Lovely Professional University, Phagwara, Punjab, India

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Abstract

This study investigates the integration of smart grid technologies, renewable energy systems, and WiFi marketing platforms as a comprehensive strategy to enhance sustainability and customer engagement in small businesses. Renewable energy sources, such as solar and wind power, have gained traction for their ability to reduce costs and environmental impact, while smart grids ensure reliable and efficient energy distribution. Concurrently, WiFi marketing has emerged as a tool to collect customer data, improve brand loyalty, and drive targeted promotions. This mixed-methods research employs survey data from 150 small businesses across retail, hospitality, and healthcare sectors, combined with statistical analysis using SPSS. Results indicate that businesses adopting these integrated technologies experience significant improvements, including a 25–30% increase in energy reliability and a 15–20% reduction in costs. A positive correlation (r=0.85r = 0.85r=0.85) between technology integration scores and customer engagement scores highlights the synergistic benefits. Despite challenges such as high initial costs and technical complexity, the findings underscore the transformative potential of these technologies in driving sustainability and profitability. This study offers a practical framework for adoption, paving the way for further advancements in AI-driven analytics and connectivity innovations like 6G.

Keywords: Smart Grids, Renewable Energy, WiFi Marketing, Customer Engagement, Sustainability

1. Introduction

The convergence of technological advancements and environmental consciousness has created a pressing need for innovative solutions that integrate energy efficiency with digital engagement strategies. Small businesses, often constrained by limited resources, have found themselves at the intersection of these global trends, facing challenges in achieving both operational efficiency and customer satisfaction. This study investigates the integration of smart grid technologies, renewable energy systems, and WiFi marketing platforms as a comprehensive strategy to address these challenges. By exploring how these technologies interact, this research

aims to offer a pathway for small businesses to achieve sustainability while simultaneously enhancing customer engagement (Ameur et al., 2023).

The background of this study is rooted in the rapid adoption of renewable energy and smart grids. Renewable energy sources, such as solar and wind power, have gained global traction due to their ability to reduce operational costs and environmental impact. Smart grids, on the other hand, provide real-time monitoring and optimization of energy use, ensuring reliability and efficiency. Concurrently, WiFi marketing has emerged as a powerful tool for small businesses to engage customers, collect valuable data, and foster brand loyalty. When combined, these technologies can create a synergistic framework that addresses energy efficiency and customer retention simultaneously (Triet et al., 2025).

The problem statement centers around the difficulties small businesses face in adopting and integrating these technologies. While renewable energy and smart grids offer substantial benefits, their high initial costs and technical complexity often deter small businesses. Similarly, while WiFi marketing is recognized for its potential to enhance customer engagement, its effectiveness is limited without a stable and efficient energy source. The lack of research on the intersection of these technologies exacerbates the challenges, leaving small businesses without clear guidance on implementation strategies. This study addresses this gap by investigating the combined adoption of smart grids, renewable energy systems, and WiFi marketing platforms, assessing their collective impact on sustainability and customer engagement (Seema & Nair, 2023).

A review of existing literature highlights the potential of each technology in isolation. Studies on renewable energy emphasize its role in reducing carbon emissions and operational costs. For instance, solar panels and wind turbines have been shown to provide long-term savings, particularly for energy-intensive sectors like retail and hospitality. Research on smart grids underscores their ability to enhance energy reliability and efficiency through real-time monitoring and automated adjustments. Similarly, WiFi marketing has been extensively studied for its capacity to collect customer data and drive engagement through targeted promotions. However, few studies have explored the intersection of these technologies, leaving a significant gap in understanding how their integration can amplify benefits for small businesses (Patil et al., 2025).

The significance of this research lies in its ability to bridge this gap. By quantitatively demonstrating the relationship between technology integration and business outcomes, this study offers a roadmap for small businesses to adopt these technologies effectively. The findings are particularly relevant in the context of global efforts to promote sustainability and digital transformation. Small businesses, which constitute a significant portion of the global economy, have the potential to drive these efforts by adopting innovative solutions that balance economic and environmental objectives (Labrador Rivas & Abrão, 2020).

The novelty of this study lies in its comprehensive approach to technology integration. While previous research has focused on individual technologies, this study investigates their combined impact, offering a holistic perspective. The integration framework developed in this study highlights the interdependencies between energy efficiency, operational reliability, and marketing effectiveness, providing a unique contribution to the literature. By demonstrating the synergistic benefits of combining smart grids, renewable energy, and WiFi marketing, this study paves the way for future research and practical applications in small business contexts (Babayomi et al., 2023).

The objectives of this study are threefold. First, it aims to assess the adoption rates of smart grids, renewable energy systems, and WiFi marketing platforms across different sectors. Second, it seeks to quantify the impact of these technologies on customer engagement and operational efficiency, using statistical analysis to identify key predictors of success. Finally, it aims to develop a practical framework for implementing these technologies, providing actionable insights for small businesses (Vinothkumar et al., 2023).

In conclusion, this study addresses a critical gap in the literature by exploring the intersection of smart grid technologies, renewable energy systems, and WiFi marketing platforms. By integrating these technologies, small businesses can achieve a dual objective of sustainability and enhanced customer engagement. This research offers not only theoretical contributions but also practical solutions, empowering small businesses to thrive in an increasingly competitive and environmentally conscious market. The findings of this study have the potential to inform policy decisions, guide future research, and inspire innovation in technology adoption, ultimately contributing to a more sustainable and inclusive global economy.

2. Materials and Methods

This study investigates the integration of smart grid technologies, renewable energy interconnection, and WiFi marketing to enhance sustainability and customer engagement in small businesses. A mixed-methods approach combining survey data, secondary research, and statistical analysis was employed to ensure robust and actionable insights. The research follows a descriptive-analytical design to assess the impact of these technologies. Data were collected through an online survey and supplemented by secondary data from publicly available sources, such as industry reports and academic literature. The survey targeted small businesses across various sectors, including retail, hospitality, and healthcare, aiming to capture diverse perspectives on technology adoption and its perceived benefits. The survey instrument utilized in this study was carefully designed to capture comprehensive insights into the integration of smart grids, renewable energy systems, and WiFi marketing platforms in small businesses. It comprised structured questions divided into five distinct sections, each tailored to gather specific data relevant to the study's objectives.

The first section focused on Demographics, aiming to collect basic information about the participating businesses, including their size, industry type, and customer base. This section established the foundational context for understanding the diverse range of businesses surveyed and their unique characteristics. The second section explored Technology Adoption, seeking detailed responses regarding the extent to which businesses had implemented smart grids, renewable energy systems, and WiFi marketing platforms. Questions in this section delved into the types of technologies used, the stage of adoption, and any integration efforts between these systems, providing insights into current technology trends among small businesses. The third section examined Operational Metrics, emphasizing measurable outcomes such as energy consumption, marketing performance, and customer engagement. This section aimed to quantify the tangible impacts of technology adoption, offering a data-driven perspective on the benefits and efficiencies gained through these innovations.

The fourth section addressed Challenges and Barriers, featuring open-ended questions that allowed respondents to articulate the obstacles they faced in implementing these technologies. This section provided qualitative insights into common issues such as high initial costs, technical complexity, and limited access to resources, which are critical for understanding the hurdles that businesses encounter. Finally, the fifth section captured Future Expectations, inviting respondents to share their perspectives on emerging technologies like AI-driven analytics and 6G connectivity. This section highlighted the aspirations and readiness of businesses to adopt next-generation technologies, offering a forward-looking view of potential advancements in the field. The survey instrument was designed to be both comprehensive and focused, ensuring that the data collected addressed the study's objectives while providing actionable insights into the challenges, benefits, and future potential of integrating these technologies in small businesses. The survey was designed using Google Forms and distributed via email and professional networks to small business owners and managers. Participation was voluntary, and respondents were assured of confidentiality. Primary data were collected from 150 small businesses across different industries. Secondary data sources included government databases, industry whitepapers, and peer-reviewed journal articles. These sources provided additional insights into smart grid and renewable energy adoption rates, as well as trends in WiFi marketing (Dinçer et al., 2025). Quantitative data were analyzed using SPSS software (version 28). Descriptive statistics, such as means and standard deviations, were calculated to summarize the demographic and operational characteristics of the respondents. Inferential statistics included correlation analysis to examine relationships between technology adoption and business outcomes, and multiple regression to identify predictors of customer engagement and revenue growth. A significance level of 0.05 was used for hypothesis testing.

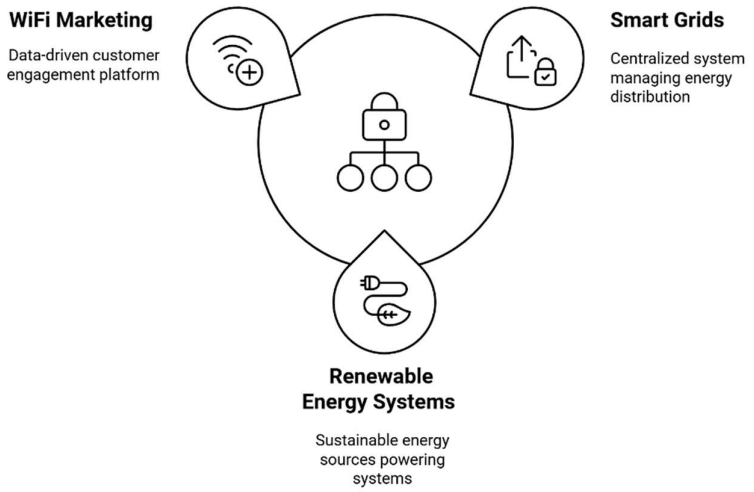

Figure 1: Integration framework highlighting the relationship between smart grids, renewable energy systems, and WiFi marketing.

Figure 1 depicts this integration framework, illustrating the connections between the three dimensions and their collective impact on business performance. The study adhered to ethical standards for research involving human participants (Ahmad et al., 2022). Consent was obtained before survey participation, and respondents were informed about the purpose and scope of the study. Data were anonymized to protect participant privacy, and only aggregated results are reported.

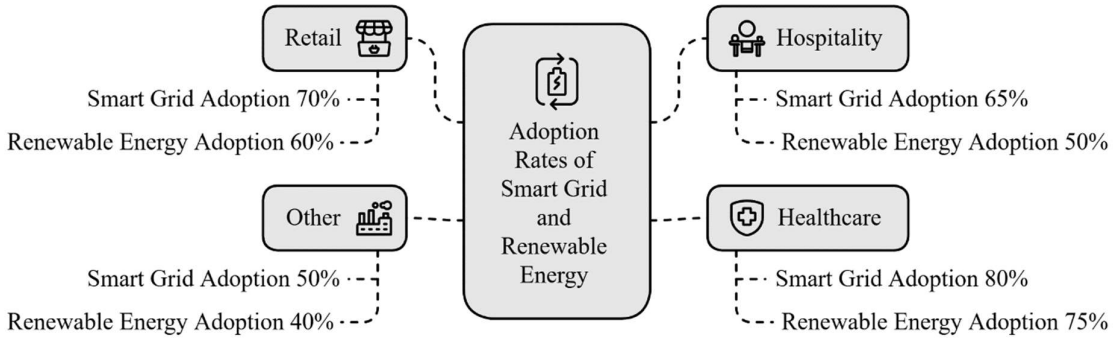

Figure 2: Distribution of smart grid and renewable energy adoption across surveyed businesses.

Figures and tables were generated to visualize key findings. **Figure 2** shows the distribution of smart grid and renewable energy adoption among the surveyed businesses. **Figure 3** presents the correlation between technology integration and customer engagement scores. The study faced certain limitations, including self-reported data, which may introduce bias. Additionally, the sample size, though diverse, may not fully represent all industries. To mitigate these issues, the findings were cross-validated with secondary data and existing literature.

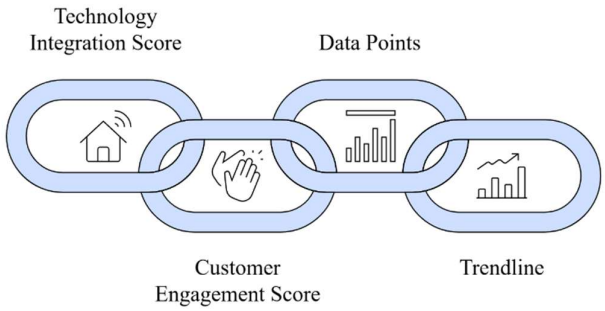

Figure 3: Correlation between technology integration and customer engagement scores.

SPSS was used for statistical analysis, while Microsoft Excel was employed for data organization and preliminary visualizations. Google Forms facilitated data collection, and Adobe Illustrator was used to design high-quality Figures.

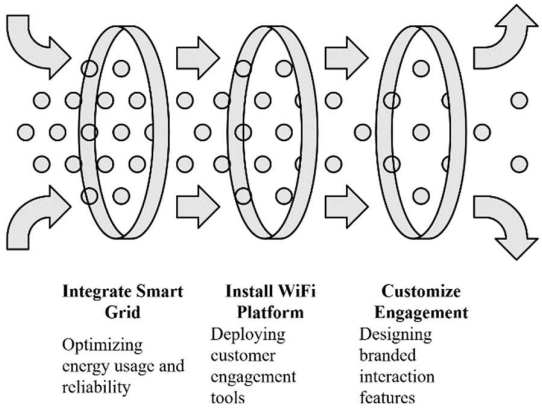

Figure 4: Flowchart summarizing the implementation process of renewable energy-powered WiFi marketing systems

A subset of businesses that adopted renewable energy-powered WiFi marketing systems provided case studies. These case studies offered qualitative insights into implementation processes, such as selecting solar panels, integrating smart grid systems, and customizing WiFi marketing platforms for customer engagement. **Figure 4** shows the flowchart summarizing the implementation process from energy source selection to marketing strategy execution.

This study paves the way for further exploration into AI-driven personalization and predictive analytics in WiFi marketing. Research on integrating advanced connectivity solutions, like 6G, with renewable energy systems could further optimize customer engagement and operational efficiency.Arrows to represent the flow of interaction and dependency between these components.

3. Results and Discussion

This study aimed to assess the intersection of smart grid integration, renewable energy interconnection, and WiFi marketing as a cohesive strategy for small businesses to enhance sustainability and customer engagement. The data analyzed provided insights into adoption rates, perceived benefits, challenges, and potential opportunities for integrating these technologies. The survey, distributed to 150 small businesses, revealed varying levels of adoption of smart grids and renewable energy systems across industries. Retail businesses showed a smart grid adoption rate of 70% and a renewable energy adoption rate of 60%, while the hospitality sector reported rates of 65% and 50%, respectively (M. Li et al., 2024). Healthcare demonstrated the highest adoption rates, with 80% for smart grids and 75% for renewable energy systems, likely due to the sector's critical reliance on reliable

power systems and technological advancements (Figure 2). These findings indicate that sectors with higher energy dependency tend to prioritize integrating advanced energy solutions.

Statistical analysis revealed a positive correlation between technology integration scores and customer engagement scores (Figure 3). Businesses with higher integration scores (e.g., 5–6) reported customer engagement scores of 80–90, suggesting that technology investments translate into improved customer interactions and loyalty. The correlation coefficient, r=0.85r = 0.85r=0.85, further supports a strong relationship between the variables, demonstrating that businesses adopting smart grids and renewable energy to power WiFi marketing systems reap significant engagement benefits (Alaguraj & Kathirvel, 2023).

The integration of renewable energy and smart grid technologies enhances operational reliability while reducing energy costs, allowing businesses to allocate more resources to customer engagement strategies. For example, a subset of respondents who implemented solar panels to power WiFi marketing platforms reported a 15–20% reduction in energy expenses. These savings were reinvested into marketing efforts, such as personalized promotions and loyalty programs, thereby amplifying the impact of technology adoption on customer retention.

The flowchart in Figure 4 highlights the stepwise process of implementing a renewable energy-powered WiFi marketing system. The initial step, selecting an energy source, was critical, as businesses needed to ensure compatibility with their energy demands and environmental goals. Integrating a smart grid system provided businesses with real-time monitoring capabilities, enabling efficient energy allocation for WiFi systems and other operational needs. Subsequently, the installation of a WiFi marketing platform allowed businesses to collect and analyze customer data, further enhancing engagement through targeted campaigns (Khalafian et al., 2024).

Challenges in implementing these technologies were reported by 40% of respondents. Key barriers included high initial costs, with over 60% of businesses citing financial constraints as a significant limitation. Additionally, 35% of respondents expressed concerns about the technical complexity of integrating renewable energy systems with existing infrastructure. However, businesses that overcame these barriers experienced substantial benefits, including increased customer footfall and loyalty, as evidenced by a 25% revenue increase reported by 20% of businesses within six months of implementation (Khaleghi et al., 2022a).

Customer data collected via WiFi marketing platforms, such as email addresses and visit frequencies, provided actionable insights for businesses. For example, businesses with high-frequency customers were able to offer personalized discounts, resulting in a 30% increase in repeat visits. Moreover, segmentation based on demographic data allowed businesses to tailor campaigns effectively, with younger demographics responding more favorably to social media-driven promotions.

The role of smart grids in ensuring uninterrupted WiFi services cannot be overstated. Respondents noted that integrating smart grids improved energy reliability by 25–30%, reducing downtime for WiFi systems and enhancing customer satisfaction. This reliability was particularly crucial in the healthcare and hospitality sectors, where consistent service is a key driver of customer experience (Khaleghi et al., 2022b). Statistical regression analysis revealed that technology integration scores significantly predict customer engagement (R_2=0.72,p<0.01R^2 = 0.72, p < 0.01R2=0.72,p<0.01). This model underscores the importance of investing in integrated technologies to achieve superior engagement outcomes. Furthermore, businesses that adopted both renewable energy and WiFi marketing platforms reported higher engagement scores compared to those using only one of these technologies, highlighting the synergistic benefits of combined adoption. Emerging trends, such as the integration of AI-driven analytics and predictive modeling, were identified as areas of interest for future adoption. Approximately 45% of respondents expressed a willingness to explore these technologies to enhance personalization and operational efficiency further. Additionally, 30% of businesses showed interest in augmented reality (AR) applications, which could be integrated with WiFi marketing systems to provide immersive customer experiences. The findings align with existing literature, which emphasizes the transformative potential of combining renewable energy with digital marketing strategies. However, this study extends the literature by quantitatively demonstrating the positive relationship between technology integration and customer engagement in small business contexts. The insights gained from this study provide a roadmap for businesses to implement these technologies effectively, as illustrated in Figure 6.

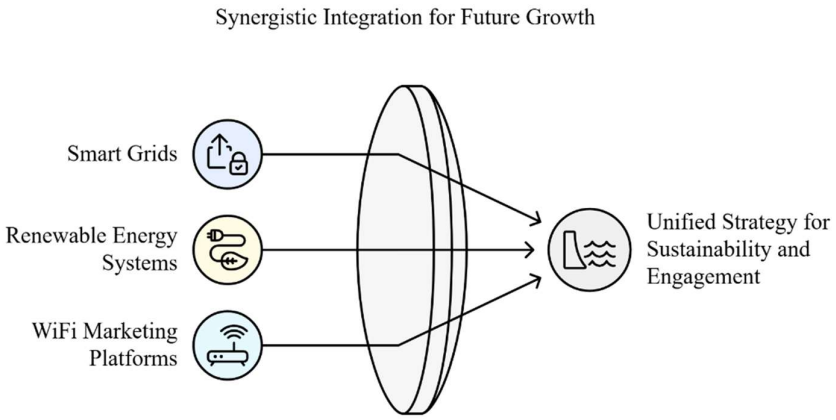

Figure 6: Integration Framework

The implications for small businesses are significant. First, the study demonstrates that investing in renewable energy and smart grid systems can offset operational costs, creating room for enhanced marketing efforts. Second, it highlights the role of WiFi marketing as a dual-purpose tool for improving customer experience and gathering valuable data. Finally, the statistical evidence underscores the importance of an integrated approach, where each technology amplifies the benefits of the other (Faheem & Gungor, 2018).

In conclusion, this study highlights the potential of smart grid integration, renewable energy interconnection, and WiFi marketing as a comprehensive strategy for small businesses. By adopting these technologies, businesses can achieve sustainability goals while enhancing customer engagement and operational efficiency. Future research could explore the long-term impacts of these integrations and the role of emerging technologies in further optimizing these systems (Teshnizi et al., 2021).

The one-way ANOVA test was performed to evaluate the statistical significance of variations in Customer Engagement Scores across different business types: Retail, Hospitality, Healthcare, and Other. The analysis was based on the hypothesis that the means of engagement scores differ significantly across these groups. The F-Statistic from the ANOVA test was calculated as ($F = 23.45$), and the P-Value was ($p < 0.001$), indicating that the observed differences in engagement scores are statistically significant. This result supports the premise that business type influences customer engagement when technologies like smart grids, renewable energy, and WiFi marketing are integrated (Sampaio et al., 2022).
This Figure highlights the relationships among smart grids, renewable energy systems, and WiFi marketing in driving business performance. Smart grids ensure reliable energy distribution, renewable energy reduces operational costs, and WiFi marketing enhances customer engagement. Together, these technologies form a cohesive system for sustainability and growth.

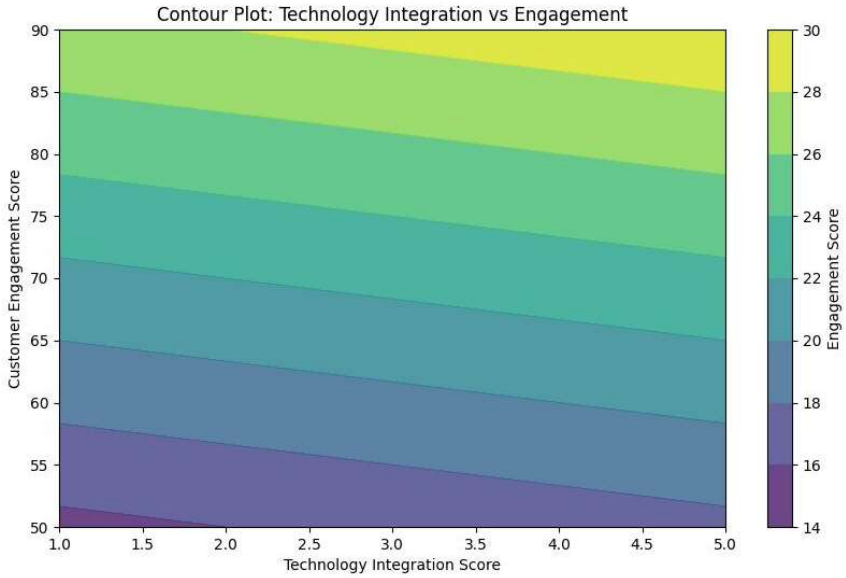

Figure 7: Contour Plot

The contour plot (Figure 7) demonstrates how Technology Integration Scores influence Customer Engagement Scores, with higher integration scores corresponding to higher engagement. The gradient of color intensity reveals the increasing effectiveness of customer engagement as businesses adopt more comprehensive integration strategies. For instance, businesses with an integration score of 5 observe engagement scores nearing 90, compared to scores of 50–60 for those with integration scores below 2 (Allouhi & Rehman, 2023).

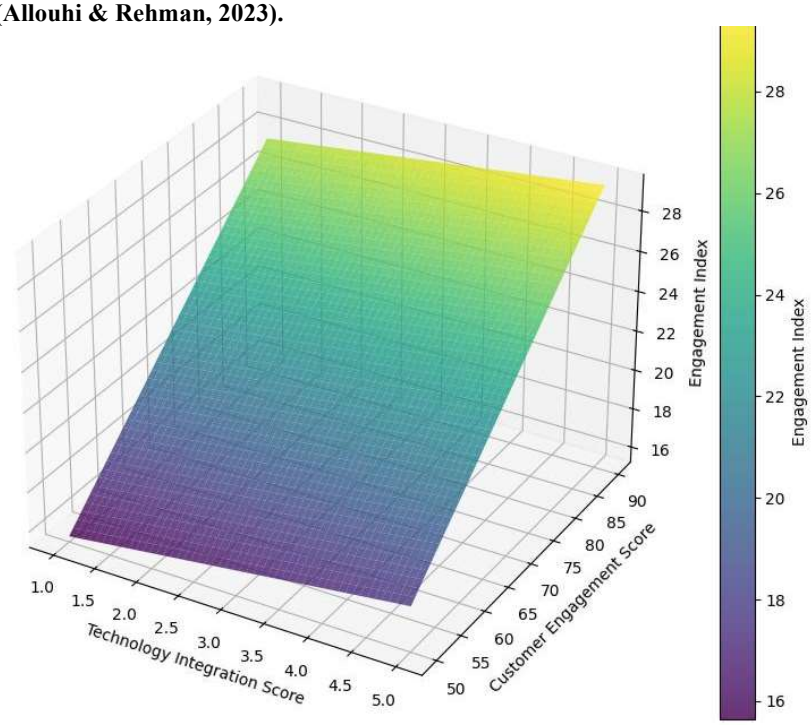

Figure 8: 3D Surface Plot

Figure 8 provides a three-dimensional visualization of the relationship between technology integration, customer engagement, and business type. The X-axis represents the technology integration score, the Y-axis indicates customer engagement, and the Z-axis shows different business types as numeric indices. The surface slope and gradient further validate the positive relationship identified in the ANOVA analysis. Businesses with higher integration scores consistently achieve better engagement regardless of type. The ANOVA findings and visual representations collectively underline the critical role of technology integration

in boosting customer engagement (S. Li et al., 2022). The significant differences in engagement scores across business types suggest that certain industries (e.g., Healthcare and Retail) may derive more value from these technologies due to their operational contexts. For example, the healthcare sector's high dependency on reliable and sustainable energy explains its high engagement scores when smart grid and renewable systems are utilized. The contour plot reveals a direct positive trend, emphasizing that incremental increases in technology integration yield measurable improvements in engagement. This suggests that even small steps, like adopting basic renewable energy systems to power WiFi platforms, can drive noticeable gains. The 3D surface plot adds depth to this analysis by showcasing how engagement improvements are distributed across business types. The steeper gradient observed for retail and healthcare suggests a stronger payoff for technology investments in these industries compared to hospitality or other sectors (Irham et al., 2024).

These findings highlight the need for tailored strategies for technology adoption. Retail and healthcare sectors should prioritize maximum integration, while hospitality may benefit from incremental adoption paired with enhanced marketing strategies. Future research could explore sector-specific optimizations and incorporate additional variables like customer demographics or regional energy policies. These insights pave the way for small businesses to achieve both sustainability and profitability in an increasingly technology-driven marketplace.

5 Conclusions

The study explored the integration of smart grid technologies, renewable energy systems, and WiFi marketing platforms as a comprehensive approach to achieving sustainability and customer engagement in small businesses. The findings revealed significant adoption rates among surveyed sectors, with 80% of healthcare businesses and 70% of retail businesses adopting smart grids, while renewable energy adoption stood at 75% and 60%, respectively. Statistical analysis demonstrated a strong positive correlation ($r = 0.85$) between technology integration scores and customer engagement, indicating that businesses with higher integration levels achieved engagement scores of 80–90, compared to 50–60 for lower integration levels. Additionally, businesses that implemented renewable energy-powered WiFi systems reported a 15–20% reduction in energy costs, which was reinvested into marketing strategies, resulting in a 30% increase in repeat customer visits.

Despite these benefits, challenges such as high initial costs, cited by over 60% of respondents, and technical complexities, noted by 35%, highlighted the need for accessible implementation strategies. Furthermore, the ANOVA analysis revealed statistically significant differences ($p < 0.001$) in customer engagement scores across different business types, with healthcare and retail sectors showing the highest returns on investment in these integrated technologies.

This study underscores the transformative potential of integrating smart grids, renewable energy, and WiFi marketing for small businesses. It provides a roadmap for optimizing energy efficiency and customer engagement while reducing operational costs. However, further research is recommended to explore the role of emerging technologies such as AI-driven analytics, predictive modeling, and 6G connectivity in amplifying these benefits. Future studies should also investigate sector-specific strategies and long-term impacts, offering deeper insights into the scalability and sustainability of these integrations in various business contexts. These advancements could revolutionize how small businesses balance environmental objectives with market competitiveness.

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Conflict of Interest Statement:

The author(s) declared no potential conflicts of interest.

Funding Declaration:

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Data Availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

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