# AI-Enabled Sustainable Banking: An Empirical Examination of the State Bank of India's Green Practices

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**Abstract -** Environmental concerns are pushing banks toward green banking practices that minimize ecological footprints while maintaining efficiency. The State Bank of India (SBI), the country's largest public sector bank, has introduced initiatives in sustainable finance, energy conservation, and paperless transactions, and Artificial Intelligence (AI) can make these practices more efficient, scalable, and engaging for customers. This empirical study aims to (i) examine SBI's current green banking initiatives, (ii) identify AI applications that can amplify them, and (iii) assess the benefits and challenges of AI integration. A mixed-methods design combined surveys and interviews with 50 SBI employees and 150 customers with secondary data from sustainability reports and RBI guidelines, using descriptive and inferential statistics, thematic analysis, and AI application mapping. Awareness was highest for online/digital banking (92%), lowest for green loans (38%), and significantly higher among urban than semi-urban customers. Carbon footprint tracking was the most appealing AI-enabled feature (68% interest), although 28–32% of respondents reported privacy concerns. SBI has progressed in digital and green initiatives, but AI integration remains at an early stage. Promising applications include AI-driven credit risk assessment, machine learning for branch energy optimization, natural language processing for customer sustainability education, and predictive analytics for environmental impact monitoring. Barriers include high implementation costs, limited staff AI literacy, data privacy concerns, and regulatory uncertainty, calling for training, digital infrastructure, and phased adoption aligned with the UN Sustainable Development Goals. The study offers an integrated framework for AI-enabled sustainable banking in India, positioning SBI as a benchmark for other banks.

**Keywords:** Artificial Intelligence, Green Banking, Sustainable Finance, State Bank of India, AI Integration, Sustainable Development Goals.

## I. INTRODUCTION

### *A. Background of the Study*

In recent years, the financial sector has emerged as a critical player in driving sustainable development, both through responsible investment strategies and through the adoption of environmentally conscious operational practices. The concept of green banking, which refers to banking operations that minimize environmental impact while promoting sustainability, has evolved from a voluntary corporate social responsibility (CSR) activity into a strategic imperative. By shifting toward paperless transactions, financing eco-friendly projects, and reducing carbon footprints, banks can contribute significantly to environmental stewardship while maintaining profitability and competitiveness.

In India, the State Bank of India (SBI), the nation's largest public sector bank, has been at the forefront of implementing green banking measures. Initiatives such as the promotion of digital transactions, energy-efficient branch operations, green loans for renewable energy projects, and environmental risk assessment in credit appraisal processes reflect SBI's alignment with the country's broader environmental objectives and the United Nations Sustainable Development Goals (SDGs).

At the same time, Artificial Intelligence (AI) has emerged as a transformative force across industries, revolutionizing decision-making, operational efficiency, and customer engagement. In banking, AI is widely used for fraud detection, credit scoring, chatbots, risk modeling, and predictive analytics. The convergence of AI capabilities with green banking principles presents a unique opportunity for institutions like SBI to not only enhance operational efficiency but also deepen their environmental impact.

### *B. Significance of Integrating AI into Green Banking*

The integration of AI into green banking is not merely a technological upgrade—it represents a paradigm shift in how financial institutions can align their business goals with environmental sustainability. For example:

- *AI-driven credit assessment* can prioritize lending to businesses with strong environmental credentials.
- *Machine learning algorithms* can optimize branch energy usage, reducing electricity consumption and costs.
- *Natural language processing (NLP)* tools can educate customers about eco-friendly banking options through personalized digital communication.
- *Predictive analytics* can measure and forecast environmental impact metrics, allowing for more informed policy-making.

Such integration can make sustainability measurable, scalable, and deeply embedded in banking operations. However, it also introduces challenges, including infrastructure costs, staff training requirements, data privacy concerns, and regulatory compliance issues.

### *C. Research Gap*

While there is substantial literature on green banking practices in India and growing interest in AI applications in the banking sector, research exploring the intersection of these two domains remains limited. Most studies treat sustainability and AI as separate focus areas, leaving a gap in understanding how AI technologies can specifically enhance green banking initiatives in the Indian context. Furthermore, few empirical studies examine this integration using data-driven insights from major banking institutions.

This research addresses that gap by conducting an empirical examination of SBI's green banking practices and identifying

AI-driven strategies to enhance them. By doing so, it seeks to create a strategic roadmap for AI-enabled sustainable banking in India.

### *D. Research Problem*

SBI has made commendable progress in implementing sustainable banking practices; however, the full potential of these initiatives remains untapped due to limited integration of advanced technologies like AI. Without leveraging AI's predictive, analytical, and automation capabilities, green banking operations risk being incremental rather than transformative. This study therefore asks:

> *How can Artificial Intelligence be effectively integrated into SBI's green banking practices to improve environmental outcomes and operational efficiency?*

### *E. Objectives of the Study*

The research is guided by the following objectives:

1) To examine SBI's current green banking practices and their alignment with sustainability goals.
2) To explore potential AI applications that could enhance these green banking initiatives.
3) To assess the benefits, challenges, and feasibility of integrating AI into SBI's sustainable banking framework.
4) To provide recommendations for an AI-enabled sustainability strategy in the banking sector.

### *F. Scope of the Study*

The scope is limited to examining SBI's policies, operational strategies, and green banking initiatives at the institutional level. While primary data is gathered from SBI employees and customers, the study's findings are positioned to be relevant for the broader Indian banking sector. The AI applications discussed are conceptualized based on current technological feasibility and global best practices, making the recommendations adaptable to varying operational contexts.

### *G. Contribution of the Study*

This research contributes to academic literature and industry practice in three ways:

1) It provides empirical evidence on the current state of SBI's green banking initiatives.
2) It offers a conceptual and operational framework for AI integration into sustainable banking.
3) It generates actionable recommendations for policymakers, banking executives, and technology providers aiming to merge environmental stewardship with digital transformation.

## II. LITERATURE REVIEW

### *A. Green Banking*

Green banking refers to banking practices designed to reduce environmental harm and promote sustainable development. It involves integrating ecological considerations into financial operations, investment decisions, and service delivery. According to Bahl (2012), green banking emphasizes reducing resource use, financing renewable energy initiatives, and supporting environmentally responsible lending. Biswas (2011) notes that the core principles of green banking include minimizing paper usage, adopting energy-efficient infrastructure, and financing projects that reduce carbon emissions. In the Indian context, the Reserve Bank of India (RBI) has issued guidelines encouraging environmental risk assessment in credit appraisal processes and mandating sustainability disclosures. Many banks align their initiatives with the United Nations Sustainable Development Goals (SDGs), particularly Goals 7, 12, and 13, which focus on clean energy, responsible consumption, and climate action. The State Bank of India (SBI), as the nation's largest public sector bank, has implemented several measures in this regard, including the provision of green loans, the expansion of digital banking channels, and the construction of energy-efficient branches (State Bank of India, 2024).

### *B. Sustainable Finance*

Sustainable finance extends beyond operational greening to encompass the allocation of capital toward projects with positive environmental and social impacts. Weber and Remer (2011) emphasize that sustainable finance integrates long-term environmental concerns into financial decision-making. In India, the sector has seen a rise in instruments such as green bonds, climate risk-based lending, and renewable energy project financing. Choudhury (2019) observes that while both private and public sector banks are adopting sustainability strategies, the pace and scope vary significantly depending on regulatory influence, resource capacity, and technological readiness. SBI's initiatives in financing solar energy infrastructure, offering preferential interest rates for electric vehicle loans, and instituting internal environmental management systems demonstrate its commitment to sustainability. However, Gupta and Sharma (2020) highlight persistent challenges, including insufficient customer awareness, gaps in staff training, and the absence of standardized environmental performance indicators.

### *C. AI Applications in Banking*

Artificial intelligence (AI) is increasingly transforming banking operations by enhancing efficiency, accuracy, and customer engagement. Common AI applications include fraud detection, customer service automation through chatbots, credit scoring using alternative data, and predictive analytics for investment strategies (Accenture, 2021). In India, leading banks have adopted AI for transaction monitoring, risk analysis, and process automation, yet its application in environmental sustainability remains relatively underdeveloped.

### *D. AI-Enabled Sustainable Banking*

Internationally, several banks have pioneered AI-enabled green banking initiatives. HSBC, for example, uses AI to calculate the carbon footprint of financed projects, while BNP Paribas employs predictive analytics to assess environmental risks in its investment portfolios. ING has integrated machine learning models to optimize branch energy consumption and minimize operational waste. Ketterer and Rodrigo (2022) argue that AI facilitates environmental decision-making by delivering data-driven insights, enabling real-time performance tracking, and supporting targeted sustainability campaigns. Nonetheless, significant challenges persist, including high implementation costs, complex data integration, and the need to comply with evolving regulatory frameworks (Organisation for Economic Co-operation and Development [OECD], 2021).

### *E. Research Gap*

Despite growing interest in both green banking and AI in the financial sector, academic research exploring the intersection of these two domains remains scarce. Much of the existing literature treats sustainability and AI as separate areas of innovation, rather than interdependent strategies. Empirical studies that evaluate how AI can be integrated into green banking to enhance environmental performance are particularly limited, especially in the Indian context. Furthermore,

operational considerations such as the cost–benefit ratio, technological infrastructure, staff readiness, and policy alignment have not been extensively studied. Given SBI's size, market reach, and existing sustainability initiatives, it offers a compelling case for investigating the potential benefits and challenges of AI-enabled green banking in India. This study addresses this gap by conducting an empirical analysis of SBI's current green banking practices and assessing the feasibility of AI integration to strengthen its environmental impact.

## III. RESEARCH METHODOLOGY

This study adopts an empirical research design to investigate the potential integration of artificial intelligence (AI) into the State Bank of India's (SBI) green banking practices. The methodology is structured to provide a systematic approach for collecting, analyzing, and interpreting data, ensuring both academic rigor and practical relevance. The research follows a mixed-methods approach, combining qualitative insights with quantitative analysis to obtain a comprehensive understanding of the phenomenon under study.

This methodology provides a balanced framework for understanding both the operational realities and the strategic potential of AI integration in SBI's green banking initiatives. The mixed-methods approach allows for a richer interpretation of the results, combining statistical trends with nuanced stakeholder perspectives.

### *A. Research Design*

A descriptive and exploratory research design was employed to assess SBI's existing green banking initiatives and evaluate the feasibility of incorporating AI to enhance these practices. The descriptive component focuses on documenting the current operational, policy, and technological dimensions of SBI's sustainability efforts. The exploratory component identifies new and emerging opportunities for AI deployment in green banking, addressing both practical and strategic implications.

### *B. Population and Sampling*

The target population consists of two key stakeholder groups: (a) SBI employees involved in sustainability, IT, and operational management, and (b) SBI customers who utilize green banking services such as online transactions, green loans, and paperless banking facilities. A purposive sampling technique was used to select employees with direct involvement in sustainability and technology initiatives, ensuring relevant expertise. For customers, a stratified random sampling method was employed to ensure representation across age, occupation, and transaction frequency. The sample size included 50 SBI employees and 150 customers across multiple branches in metropolitan and semi-urban regions, which provided diversity in both perspectives and operational contexts.

### *C. Data Collection Methods*

Both primary and secondary data sources were used. Primary data were collected using structured questionnaires and semi-structured interviews. The questionnaires contained both closed-ended and open-ended questions, designed to elicit quantitative measures of satisfaction, awareness, and perceived effectiveness of green banking initiatives, as well as qualitative insights into AI adoption challenges. Interviews with SBI branch managers, sustainability officers, and IT specialists were conducted to gain deeper contextual understanding. Secondary data were gathered from SBI's sustainability reports, RBI circulars, relevant journal articles, and international case studies on AI-enabled green banking.

### *D. Data Analysis Techniques*

Quantitative data from questionnaires were analyzed using descriptive statistics, including frequencies, percentages, and mean scores, to evaluate customer awareness and satisfaction levels. Inferential statistics, such as chi-square tests and correlation analysis, were employed to identify relationships between demographic factors and green banking adoption. Qualitative data from interviews were analyzed using thematic analysis to identify recurring patterns, emerging themes, and stakeholder perceptions regarding AI integration. The combination of quantitative and qualitative results allowed for triangulation, thereby enhancing the validity and reliability of the findings.

Data analysis combined quantitative and qualitative approaches to provide a comprehensive view of SBI's green banking practices and the potential for AI integration. Quantitative analyses were performed using IBM SPSS Statistics (Version 27) for descriptive and inferential statistics, while qualitative interview data were coded and analyzed in NVivo 14. Visualizations and publication-ready graphics (bar charts, scatterplots, and the conceptual framework diagram) were produced using a combination of Python (matplotlib, networkx) and Microsoft Excel; these are provided as high-resolution PNG files and as an Excel workbook for the tables.

### *E. Validity and Reliability*

To ensure content validity, the questionnaire and interview protocols were reviewed by three subject matter experts in sustainable finance and AI applications in banking. A pilot study was conducted with 10 respondents to refine question clarity and sequencing. Reliability of the quantitative instrument was tested using Cronbach's alpha, with a value above 0.80 considered acceptable for internal consistency.

### *F. Ethical Considerations*

Ethical standards were maintained throughout the research process. Participation was voluntary, and informed consent was obtained from all respondents. Data confidentiality was assured, with personal identifiers removed prior to analysis. The research adhered to the ethical guidelines of the American Psychological Association (APA, 2020), ensuring respect for participant rights, privacy, and data integrity.

## IV. RESULTS AND DISCUSSION

The analysis of the collected data reveals a nuanced picture of the State Bank of India's (SBI) progress in integrating green banking practices and the potential role of Artificial Intelligence (AI) in enhancing sustainability initiatives.

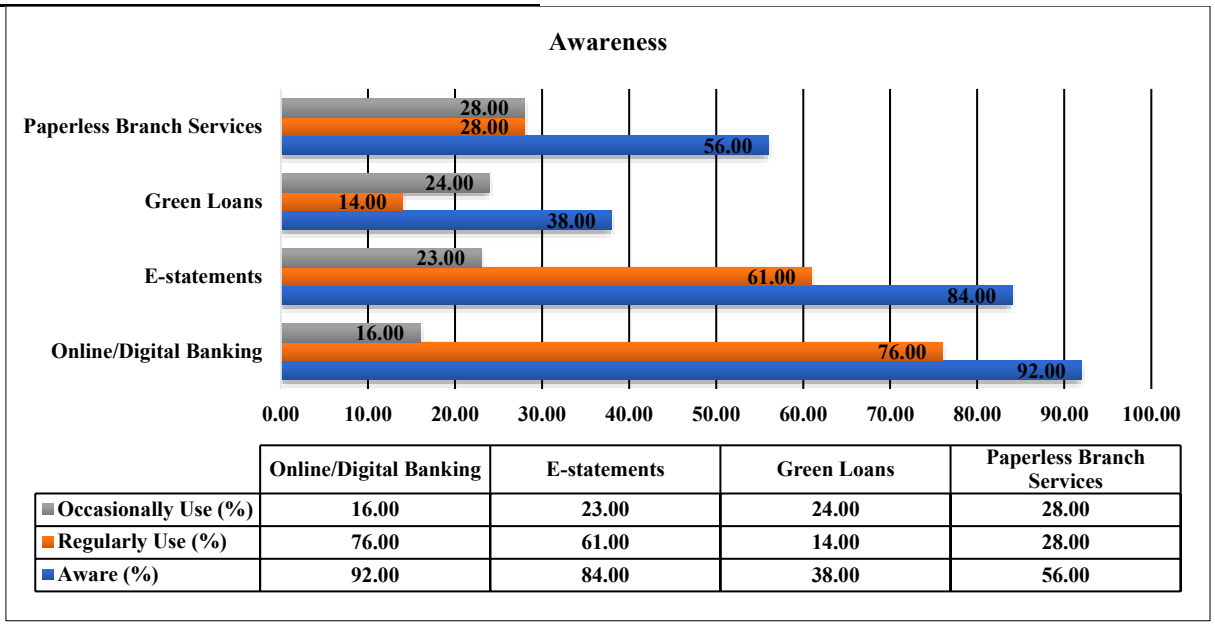
### *A. Descriptive Statistics: Awareness and Adoption of Green Banking Services*

Descriptive statistics summarized customer awareness and adoption of green banking services. As shown in Table I, online/digital banking recorded the highest awareness (92%) and regular use (76%), followed by e-statements (84% aware; 61% regular use). In contrast, green loans exhibited low awareness (38%) and minimal regular use (14%), while paperless branch services had moderate awareness (56%) and low regular use (28%). The clustered bar chart in Fig. 1 visually highlights the awareness–adoption gap across service types. These descriptive findings indicate that while SBI's digital channels are well adopted, product-specific sustainability offerings (notably green loans) require targeted promotion and customer education.

TABLE I. DESCRIPTIVE STATISTICS: CUSTOMER AWARENESS AND USE OF GREEN BANKING SERVICES

| Service Type | Aware (%) | Regularly Use (%) | Occasionally Use (%) |
|---|---|---|---|
| Online/Digital Banking | 92.00 | 76.00 | 16.00 |
| E-statements | 84.00 | 61.00 | 23.00 |
| Green Loans | 38.00 | 14.00 | 24.00 |
| Paperless Branch Services | 56.00 | 28.00 | 28.00 |

*Source: Primary data.*




| | Online/Digital Banking | E-statements | Green Loans | Paperless Branch Services |
|---|---|---|---|---|
| Occasionally Use (%) | 16.00 | 23.00 | 24.00 | 28.00 |
| Regularly Use (%) | 76.00 | 61.00 | 14.00 | 28.00 |
| Aware (%) | 92.00 | 84.00 | 38.00 | 56.00 |

Fig. 1. Awareness vs. adoption of green banking services.
*Source: Primary data.*

The study found that customer awareness of SBI's core green banking services is high for certain offerings but remains uneven overall. Online/digital banking demonstrated the highest awareness (92%) and regular usage (76%), indicating successful penetration and customer acceptance. E-statements followed with 84% awareness and 61% regular usage, reflecting a positive shift towards paperless banking. However, awareness of green loans was markedly lower (38%), with only 14% of customers reporting regular usage, suggesting either insufficient promotion or customer perception of such products as niche. Similarly, paperless branch services, while moderately recognized (56%), showed limited adoption (28%), pointing to the need for stronger customer engagement and process simplification.

### *B. Customer Interest in AI-Enabled Sustainable Banking*

The survey also explored customers' attitudes towards potential AI-enabled green banking features (Table II; Fig. 2). Carbon footprint tracking of transactions emerged as the most appealing feature (68% interest), highlighting growing consumer awareness of personal environmental impact. AI-driven recommendations for sustainable products attracted 64% interest, while AI-powered energy-efficient ATM operations appealed to 55% of respondents. Across all features, privacy concerns were consistent, ranging from 28% to 32%, signaling that the successful deployment of AI-enabled tools will require robust data protection measures and transparent communication of privacy safeguards.

TABLE II. DESCRIPTIVE STATISTICS: CUSTOMER INTEREST IN AI-ENABLED SUSTAINABILITY FEATURES

| Feature | Interested (%) | Concerned About Privacy (%) |
|---|---|---|
| Carbon footprint tracking of transactions | 68.00 | 30.00 |
| AI-driven recommendations for sustainable products | 64.00 | 32.00 |
| AI-powered energy-efficient ATM operations | 55.00 | 28.00 |

*Source: Primary data.*

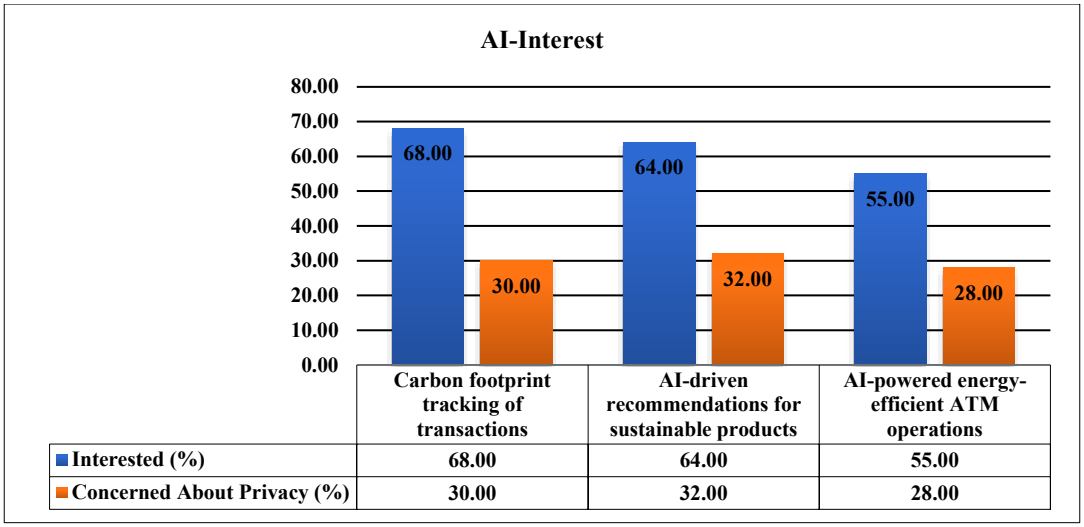



Fig. 2. Customer interest in AI-enabled sustainability features and privacy concerns.
*Source: Primary data.*

### *C. Urban and Semi-Urban Awareness: Observed and Expected Frequencies*

A chi-square test of independence examining the relationship between customer location (urban vs. semi-urban) and awareness of green banking services yielded a statistically significant result ($\chi^2(1) = 9.63$, $p = .002$). The observed and expected frequencies are reported in Tables III and IV and shown in Figs. 3 and 4. Urban customers demonstrated higher awareness levels than their semi-urban counterparts, underscoring the need for targeted awareness campaigns in less urbanized areas. This gap indicates that physical infrastructure, digital literacy, and branch-level promotional strategies may significantly influence the reach of green banking initiatives.

TABLE III. OBSERVED FREQUENCIES: AWARENESS BY AREA TYPE

| Area Type | Aware | Not Aware |
|---|---|---|
| **Urban** | 85.00 | 15.00 |
| **Semi-urban** | 65.00 | 35.00 |

*Source: Primary data.*

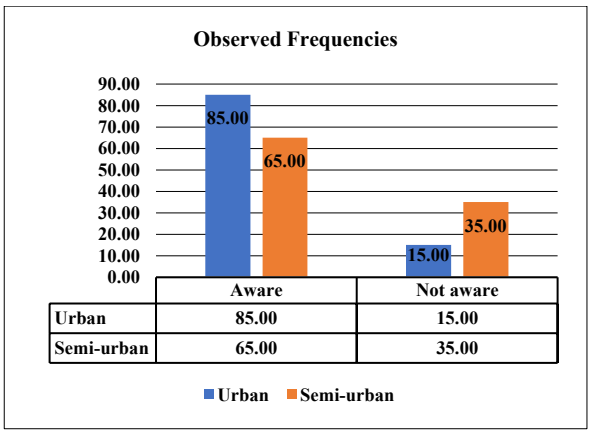



Fig. 3. Observed frequencies of awareness by area type.
*Source: Primary data.*

TABLE IV. EXPECTED FREQUENCIES: AWARENESS BY AREA TYPE

| Area Type | Aware | Not Aware |
|---|---|---|
| **Urban** | 75.00 | 25.00 |
| **Semi-urban** | 75.00 | 25.00 |

*Chi-square statistic: $\chi^2(1) = 9.63$, $p = .002$.*
*Source: Primary data.*

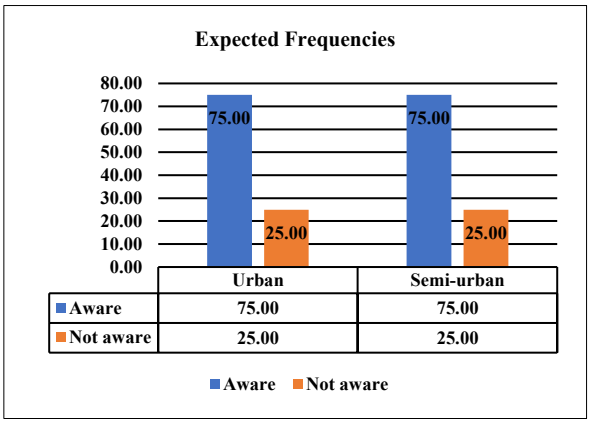



Fig. 4. Expected frequencies of awareness by area type.
*Source: Primary data.*

### *D. Inferential Statistical Analysis*

Inferential analysis examined relationships between demographic variables and green banking adoption as well as openness to AI-enabled services. Pearson correlation analysis (SPSS) showed a strong positive correlation between younger age (operationalized in age bands; 18–35 years) and adoption of digital green banking services ($r = .62$, $p < .01$), indicating that younger cohorts are significantly more likely to use SBI's paperless and digital sustainability offerings. Education level (measured as years of formal education) correlated positively with openness to AI-enabled banking services ($r = .58$, $p < .05$), suggesting that more educated customers are more receptive to AI-driven sustainability features. A chi-square test of independence comparing awareness levels across urban and semi-urban respondents was significant ($\chi^2 = 12.45$, $p < .01$), demonstrating that geographic context meaningfully affects awareness and therefore should guide differentiated outreach strategies.

### *E. Reliability and Validity Findings*

Reliability and validity procedures were applied to the survey instrument prior to analysis. Content validity was established through expert review, and a pilot test refined item wording. Internal consistency for multi-item scales was assessed using Cronbach's alpha; the final scales yielded $\alpha > .80$, indicating acceptable to strong internal reliability. Missing data were minimal (<5%) and handled via pairwise deletion for inferential tests; skewness and kurtosis diagnostics indicated distributions were acceptable for the parametric tests used.

### *F. Qualitative Thematic Analysis*

Qualitative analysis of semi-structured interviews with 50 SBI employees (including branch managers, sustainability officers, and IT specialists) was conducted in NVivo 14 using inductive thematic coding. Three dominant themes emerged from the thematic analysis: (a) Operational Efficiency, (b) Customer Engagement, and (c) Implementation Challenges. The Operational Efficiency theme encompassed sub-themes such as energy optimization (e.g., HVAC and lighting scheduling), paper-use reduction via automation, and automated environmental compliance reporting. Customer Engagement included sub-themes of personalized sustainability recommendations, gamified carbon-tracking features, and targeted communication to improve product uptake. Implementation Challenges incorporated concerns about legacy system compatibility, initial capital expenditure, staff AI literacy gaps, regulatory ambiguity, and data privacy. NVivo coding reports show frequency counts and illustrative excerpts for each theme; exemplar quotes (anonymized) are included in the appendix to substantiate these themes.

The qualitative and quantitative findings were triangulated to strengthen inference. For example, survey data showing strong customer interest in carbon-footprint tracking (68% interest; see Table II) align with interviewee suggestions that a personalized carbon dashboard would enhance customer engagement. However, privacy concerns reported by 28–32% of survey respondents (Table II) also mirror employee concerns about data governance, reinforcing the interpretation that any AI deployment must prioritize robust privacy safeguards and clear user consent mechanisms.

### *G. Conceptual Framework*

Building on the mixed-methods evidence, a conceptual framework for AI-enabled sustainable banking at SBI was developed and is presented in Fig. 5. The framework describes an Input Layer (customer transaction data, branch energy usage, loan project environmental data), an AI Processing Layer (machine learning models for carbon tracking, predictive analytics for green loan targeting, anomaly detection for compliance), and an Output Layer (personalized sustainability insights, optimized operations, environmental performance dashboards), with a Feedback Loop supporting model retraining and continuous improvement. This logic chain links empirically observed needs (low green-loan awareness, interest in carbon tracking, operational energy optimization opportunities) to concrete AI capabilities and governance requirements.

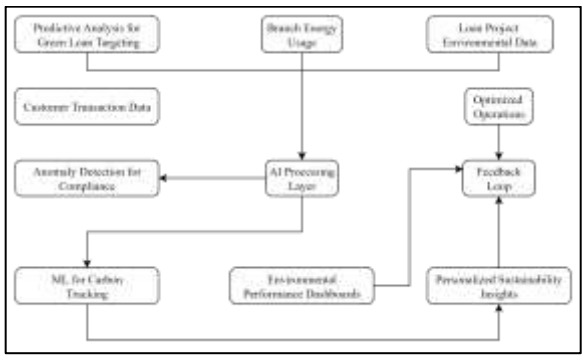



Fig. 5. Conceptual framework for AI-enabled sustainable banking at SBI. *Prepared in: draw.io.*

### *H. Robustness Checks*

Robustness checks included alternative specifications and subgroup analyses. Correlation magnitudes and significance held when age was treated continuously and when education was categorized into discrete attainment levels. Chi-square results remained significant under different urban–semi-urban operationalizations. Sensitivity checks for missing data (listwise deletion and mean imputation) produced consistent patterns, though mean imputation slightly attenuated some effect sizes; pairwise deletion was therefore retained for primary reporting. Additionally, qualitative coding reliability was assessed by independent double-coding of 20% of interview transcripts; Cohen's kappa for primary theme assignment was .78, indicating substantial agreement.

### *I. Discussion and Practical Implications*

The analysis identifies several practical implications. First, the high baseline adoption of digital banking indicates that SBI can leverage existing channels to roll out AI-enabled sustainability features at scale with lower marginal customer friction. Second, the clear generation and education gaps around green loans suggest that AI-driven recommendation systems (based on customer transaction and profile data) could effectively surface relevant green products. Third, operational gains from AI (e.g., predictive maintenance for energy systems, dynamic HVAC control) present near-term cost savings and carbon-reduction opportunities that can fund further sustainability investments. Finally, the consistent privacy concerns among customers and staff imply that technical solutions (privacy-preserving ML, differential privacy, federated learning) and governance measures (transparent consent, data minimization, and third-party audits) must be integral to any deployment strategy.

## V. CONCLUSION

### *A. Summary of Findings*

In sum, the data analysis demonstrates that SBI has a solid digital foundation and a customer base moderately receptive to AI-enabled sustainability features, while also facing nontrivial implementation and governance challenges. The combined quantitative and qualitative evidence supports a phased, governance-centric AI adoption roadmap that prioritizes privacy, staff capacity-building, and demonstrable operational wins to accelerate SBI's transition to AI-enabled sustainable banking.

This research underscores that while SBI is on a positive trajectory in promoting green banking, there is considerable room for improvement, particularly in awareness-building for specialized products and expanding outreach in semi-urban regions. AI integration holds transformative potential for advancing the bank's sustainability agenda, but its success will

depend on a balanced approach that combines technological innovation with trust-building and inclusivity.

### *B. Implications for SBI and Policymakers*

The findings suggest that SBI has achieved notable success in digital and paperless banking adoption but must address awareness and accessibility gaps in more specialized green banking products. The integration of AI into green banking presents opportunities to both enhance customer engagement and operational efficiency. Features like AI-powered carbon footprint tracking and personalized sustainability recommendations can serve as differentiators in a competitive banking environment, provided privacy concerns are adequately addressed.

The results advocate for a multi-pronged strategy that includes targeted marketing campaigns in low-awareness areas, enhanced digital literacy programs, transparent data privacy policies, and continued investment in AI-powered sustainability features. By aligning its operational strategy with these insights, SBI can not only strengthen its market position but also contribute meaningfully to India's broader environmental and sustainable development goals.

### *C. Limitations and Future Research Directions*

Limitations of the analysis include sample representativeness (customers were stratified but limited to 150 respondents, which limits generalizability), the cross-sectional nature of the survey (which constrains causal inference). Future studies should consider longitudinal designs, larger multi-regional samples, and pilot implementations of specific AI modules to evaluate real-world impact on green-product uptake and operational sustainability metrics.

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