Balancing Green and Fair: Ethical AI in Sustainable Finance

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Abstract: *Artificial intelligence (AI) is revolutionizing the area of green finance, enabling financial institutes to make more learnt and sustainable investment choices. This systematic review explores the influence of AI on green finance, focusing on its role in promoting ethical and responsible financial practices. The review examines the technological infrastructure and expertise required for implementing AI in green finance, counting advanced data analytics platforms, machine learning algorithms, and real-time data processing systems. It also discusses the ethical considerations for AI deployment, such as fairness, transparency, accountability, and safety. The review highpoints the likely of AI to address challenges in green finance, such as regulatory and policy gaps, limited investor awareness, high capital costs, risk assessment difficulties, market demand uncertainties, insufficient investment, greenwashing concerns, and lack of standardized metrics. The study analyzes the growth in total investments in green finance in India from 2018 to 2022, demonstrating the growing adoption of AI in both private and public financial sectors. Case studies illustrate the impact of AI integration in green finance, such as BlackRock's AI-powered ESG scoring and AI-driven credit risk assessment models for green bonds in India. The review also identifies several AI-driven tools that address specific challenges in green finance, including Project AISE, Clim8 Invest, Arabesque S-Ray, and Clarity AI. The discussion emphasizes the need for a unified regulatory framework, increased investor awareness, and standardized metrics to entirely attach the potential of AI in green finance. The review wraps up by emphasizing the pivotal impact of AI in empowering financial institutions to make decisions based on data, reduce risks, and enhance transparency in green investments, thereby playing a crucial role in achieving sustainable development goals.*

Keywords: *Sustainable Development Goals (SDGs), Net-Zero Emissions, Green Finance, Artificial Intelligence, Public-Private Partnerships, AI driven tools, green bonds*

1. INTRODUCTION

Green energy initiatives, encompassing government-led efforts such as the U.S. Inflation Reduction Act (IRA), European Green Deal, China's Renewable Energy Expansion, India's National Solar Mission, and Germany's Energiewende, as well as corporate endeavors like Energy Goal of Google's 24/7, Apple's Supplier Clean Energy drive, Amazon's Climate Pledge, and Tesla's Energy Solutions, are experiencing significant expansion in both scale and complexity. Additionally, community and local projects, including Community Solar Programs and microgrids in rural areas, alongside nonprofit and NGO initiatives such as the RE100 Initiative, the World Bank's Scaling Solar Program, and the Carbon Disclosure Project (CDP), are contributing to this growth. Technological and research projects, exemplified by Breakthrough Energy Ventures, floating solar farms, and green hydrogen production, further underscore this trend. The holistic development of these global missions is crucial for achieving net-zero emissions and sustainable development goals by the year 2070 [16].

The concept of green finance emphasizes a structured financial system designed to achieve sustainability objectives by enhancing environmental targets through investments, bonds, and regulations. It has emerged as a crucial tool for increasing investment in renewable energy and

promoting global sustainability. Green finance aims to back projects and initiatives that yield beneficial environmental results, such as those related to renewable energy, energy efficiency, sustainable farming, and nature preservation, along with other similar objectives.

[11] The rationale for establishing a distinct category of finance lies in these projects and the investors who prioritize sustainable outcomes. India's traditional financial system encounters several challenges that impede the growth of green finance, which is essential for sustainable development. Limited financial inclusion and lack of access to affordable credit hinder small businesses and individuals from investing in eco-friendly ingenuities such as renewable energy, electric mobility, and sustainable agriculture [14]. Traditional banks, burdened with high non-performing assets (NPAs) and bureaucratic inefficiencies, often hesitate to finance green projects due to perceived risks and long gestation periods. Furthermore, the high reliance on cash transactions and lack of digital infrastructure in rural areas further restrict financial accessibility for green entrepreneurs. Regulatory complexities and the absence of standardized green finance policies create uncertainty for investors, discouraging large-scale funding in sustainable ventures [45] [29].

Additionally, India's capital markets are underdeveloped in terms of green bonds and climate-focused investment instruments, leading to an over-reliance on foreign institutional investors (FIIs) [49]. Cybersecurity risks, high transaction costs, and low financial literacy further impede the adoption of green financial products [33]. While initiatives such as green bonds, priority sector lending for renewable energy, and ESG (Environmental, Social, and Governance) investing are gaining traction, a robust financial framework with clear regulations, improved risk assessment models, and increased public-private partnerships is essential to accelerate green finance in India [14].

Considering the size, nature, and complexity of green finance and green energy initiatives, a robust AI integration is essential to achieve sustainability goals within a structured timeline by balancing green and fair principles [21]. AI algorithms process extensive datasets to identify patterns, optimize investment portfolios, make informed investment decisions, and evaluate risks with greater precision.

Consequently, AI assists investors in making well-informed decisions about directing their funds towards environmentally sustainable initiatives. It also plays a role in ensuring that the outcomes align with the objectives of green finance. Thus, AI holds considerable promise for enhancing investment results in the context of green finance. It enables investors to identify investment opportunities that meet social, environmental and governance standards, manage risks effectively, and maximize financial returns [15].

AI is being utilized in various ways to achieve positive results in green finance. For instance, satellite data is employed to assess the potential for solar power generation across different areas. This assessment aids investors in determining where to allocate funds for renewable energy initiatives, ultimately enhancing investment outcomes [32] [12].

Another instance is the carbon yield curve, which relies on AI-generated predictions to model future carbon prices. These prices are vital for green finance as they enable investors to evaluate the environmental influence of their investments. By using the carbon yield curve, investors can more effectively manage carbon-related risks, make well-informed decisions regarding their investment portfolios, and optimize their returns while also contributing to the shift towards cleaner energy sources [1] [2][6] [8].

This technology enhances the reliability of cash flows, makes yields more predictable, and minimizes unexpected events. Consequently, it lowers the risk premium and insurance costs for large-scale green projects [39]. Although currently, green projects do not benefit from lower funding costs compared to traditional energy or infrastructure projects, it is anticipated that over time, the cost of green financing will decrease. This reduction will boost such projects and advance energy transition objectives [24]. This systematic review will explore the impact of artificial intelligence (AI) in sustainable finance, highlighting a transformative change in how financial institutions handle investments, risk evaluation, and decision-making. As AI-driven systems become more widespread in financial markets, it is vital to ensure these technologies support both environmental sustainability and social responsibility. Balancing "green" and "fair" requires a thoughtful approach to the ethical deployment of AI in sustainable finance.

1. Understanding Green Finance and Artificial Intelligence

1.1 Green finance

Green finance incorporates financial activities that care sustainable environmental ideas, such as investments in renewable energy, enhancement of energy proficiency, pollution control, and climate change mitigation. This domain includes financial tools such as green bonds, sustainable loans, and impact investing, all designed to foster an economy characterized by low carbon emissions and efficient resource utilization [7]. Increasingly, governments, financial institutions, and businesses are prioritizing green finance to achieve global sustainability goals, such as those outlined in the Paris Agreement [52] [34]. By directing funds towards environmentally friendly projects, green finance performs an important part in dropping carbon emissions, supporting biodiversity conservation, and ensuring long-term economic resilience [35]. Green finance initiatives comprise strategies and mechanisms directed to promote environmentally sustainable projects and simplifying the transition to a low-carbon economy. These initiatives represent a concerted effort at both international and national levels to integrate environmental sustainability into financial and industrial practices, thereby promoting a shift towards an eco-friendlier economy [44]. In India, green finance is emerging as a fundamental mechanism to support the country's changeover towards a sustainable and low-carbon economy. The Indian government, along with regulatory builds mainly the Reserve Bank of India (RBI) & the Securities and Exchange Board of India (SEBI), has introduced policies and frameworks to encourage green investments [42].

Key financial instruments include green bonds, first issued in India in 2015, and sustainability-linked loans, which are gaining popularity among corporations. The Indian Renewable Energy Development Agency (IREDA) and public-sector banks play a vital role in financing renewable energy, electric mobility, and climate resilience projects [36]. The Sovereign Green Bond Framework, launched in 2022, further supports government-led green projects. Additionally, SEBI has mandated Environmental, Social, and Governance (ESG) disclosures for top-registered companies, ensuring greater transparency in sustainable finance [41] [46]. India’s green finance ecosystem is also shaped by global and domestic collaborations.

Initiatives such as the International Solar Alliance (ISA) and partnerships with multidimensional institutes like the World Bank & the Asian Development Bank (ADB) have accelerated investments in clean energy and climate adaptation projects. The RBI’s addition of renewable energy under priority sector lending has facilitated greater credit flow to green projects. Meanwhile, India is developing its green taxonomy, aligned with global sustainability standards, to define and standardize green investments. The rise of green fintech solutions,

carbon trading platforms, and digital lending for sustainable projects is also transforming the landscape. As India aims for net-zero emissions by 2070, strengthening its green finance architecture will be essential in bridging the funding gap for climate action and sustainable development [9] [34] [53].

1.2 Artificial intelligence in Green Finance

The financial sector, renowned for its digital sophistication and analytical expertise, is among the earliest adopters of artificial intelligence (AI), anticipating numerous benefits from its implementation. These advantages include the provision of superior services with increased speed and reduced costs. The role of AI in finance is contingent upon understanding the business requirements of financial entities and markets, as well as integrating these with technological capabilities [8] [19].

1.2.1 Technological infrastructure and expertise

Artificial Intelligence (AI) is transforming green finance by improving data analysis, risk evaluation, and investment strategies, thus fostering sustainable economic growth [28]. The technological framework supporting AI-powered green finance includes sophisticated data analytics platforms, machine learning algorithms, and systems for processing data in real-time [23]. These technologies empower financial institutions to handle large amounts of environmental, social, and governance (ESG) data, aiding in informed decision-making and effective resource distribution [5]. The advancement of sustainable finance practices relies on the integration of cutting-edge data management systems, analytical tools, and interdisciplinary expertise, which enables more informed decision-making and supports a robust, low-carbon global economy [23].

1.2.2 Key Mechanisms of AI-Driven Green Finance Infrastructure: Blockchain technology performs a crucial part in the infrastructure of AI-driven green finance by ensuring transparency, security, and traceability in financial transactions regarding to environmental, social, and governance (ESG) initiatives [18]. Using decentralized ledgers, blockchain facilitates the immutable recording of ESG metrics, thereby enabling the verification of sustainability claims and safeguarding them against tampering. These fosters trust among investors, regulators, and other stakeholders, mitigating risks such as greenwashing, where companies falsely portray their actions as environmentally friendly [37]. Furthermore, blockchain supports smart contracts, which automate compliance with sustainability standards and streamline green finance operations. By integrating blockchain with AI-driven analytics, green finance ecosystems can enhance efficiency, accountability, and integrity.

1.2.3 Expertise Required for Implementing AI in Green Finance: To effectively integrate artificial intelligence (AI) with green finance, a multidisciplinary approach is imperative, necessitating the convergence of expertise from various domains. The development of AI models capable of processing extensive and complex Environmental, Social, and Governance (ESG) datasets is heavily reliant on data science and analytics, which are essential for extracting valuable insights to inform sustainable investment decisions. Proficiency in environmental science is crucial for accurately assessing the ecological impacts of financial activities, ensuring that AI-driven strategies align with long-term sustainability goals. Additionally, financial analysis plays a pivotal role in reconciling economic objectives with environmental responsibility, ensuring that AI applications support both profitability and sustainable investment practices. Furthermore, a comprehensive understanding of regulatory frameworks is essential to safeguard compliance with environmental legislation and sustainability standards, guiding the expansion of AI schemes that adhere to legal and ethical guidelines. These combined competencies establish a robust foundation for leveraging AI in

green finance, fostering responsible and data-driven decision-making [38]. However, challenges such as data quality issues, biases in training data, and the complexity of models can impact transparency and accountability. Regulatory concerns include the lack of universal standards for emissions reporting and ESG metrics, the need for robust governance to manage AI-related risks, and the potential for systemic financial vulnerabilities. Ethically, AI may perpetuate biases, create accountability challenges due to its "black box" nature, and risk excluding certain groups, while also being energy-intensive, which raises sustainability concerns. Addressing these challenges is crucial to ensuring AI's responsible and effective contribution to green finance [10].

1.2.4 AI ethics in green finance: The ethical deployment of artificial intelligence (AI) is governed by principles that prioritize fairness, transparency, accountability, and safety. A fundamental aspect is the assurance of fairness and non-discrimination, which involves preventing AI from perpetuating biases. For example, to prevent bias against certain demographic groups, recruitment algorithms need to be trained using varied datasets. Transparency and explainability are also essential; users must be informed when interacting with AI, and AI-driven decisions, such as those related to credit scoring or medical diagnoses, should be comprehensible to users [10]. Accountability and responsibility necessitate that organizations assume ownership of AI's actions and provide mechanisms for rectifying errors. A pertinent example is self-driving vehicles, where manufacturers must ensure that the AI complies with traffic regulations and establishes clear accountability in the event of accidents. Privacy and data protection are equally critical, ensuring that AI adheres to regulations such as the General Data Protection Regulation (GDPR) & protections personal data. For example, AI-driven virtual assistants should not retain sensitive conversations without user consent [30].

Ensuring safety and security is paramount to preventing harm. In the context of cybersecurity, artificial intelligence (AI) should be engineered to defend against cyber threats rather than becoming susceptible to exploitation. Furthermore, human oversight and control are crucial, particularly in healthcare, where AI can aid physicians in diagnosing diseases; however, the ultimate decision-making should reside with medical professionals [33]. Beyond these considerations, social and environmental responsibility significantly influences AI's societal impact. Corporations such as Google and Microsoft are prioritizing energy-efficient AI models to mitigate environmental repercussions. Finally, it is imperative to prevent misuse and malicious applications, such as restricting AI from generating deepfake content used for misinformation. Ethical AI utilization extends beyond mere compliance, emphasizing the necessity for AI to serve humanity in a responsible and beneficial manner [43].

1.2.5 Leveraging Artificial intelligence in green finance for sustainability developments goals

As the environmental crisis intensifies, there is an increasing demand for innovative approaches in green finance, as traditional financial systems often fall short in addressing the scale and urgency of these challenges. The planet is grappling with significant environmental issues, such as escalating carbon emissions and the loss of biodiversity. To meet global targets such as the Paris Agreement and the UN Sustainable Development Goals (SDGs), trillions of dollars are required annually [47]. Innovation is pivotal in channeling resources towards sustainable projects more effectively. Numerous eco-friendly initiatives, especially in developing regions, face challenges in obtaining cost-effective funding. Emerging financial tools, like green bonds, sustainability-linked loans, and carbon markets, can bridge this financing gap [2]. Climate change presents intricate risks, such as stranded assets and physical damage from disasters.

Innovative financial models and tools have the potential to more accurately assess and price these risks, thereby encouraging investors to support sustainable projects without encountering excessive uncertainty. The phenomenon of "greenwashing," wherein companies exaggerate their sustainability efforts [31], is prevalent. Technologies such as blockchain can enhance transparency and accountability in green finance, thereby increasing investor confidence. Traditional markets do not consistently incentivize sustainability. Innovations such as decentralized finance (DeFi), impact investing, and tokenized carbon credits can provide stronger financial incentives for companies and individuals to adopt environmentally friendly practices [5] [22]. Digital platforms, AI-driven climate analytics, and crowdfunding can democratize green finance, facilitating access to global capital for small-scale sustainable projects. Innovative financial solutions are crucial for accelerating the changeover to a low-carbon, sustainable economy. The focus is not solely on profit; it involves leveraging economics as a powerful tool for environmental and social transformation [15] [47].

Regulatory & policy hurdles AI address these challenges in context green finance by augmenting transparency, ensuring compliance, assessing risks, detecting fraud, and analyzing data. It encourages policymakers, investors, & regulators to make financial decisions that are more informed, sustainable, and compliant.
Investor knowledge in the subject AI improves investor knowledge in green finance by delivering real-time insights obtained from data, personalized investment advice, and automated analysis of environmental, social, and governance (ESG) aspects. Machine learning algorithms review sustainability risks and opportunities, while rob-advisors navigate investors for environmentally sustainable portfolios. AI-driven NLP (natural language processing) detects greenwashing by examining corporate reports, thereby ensuring transparency and trust. The Fusion of AI with blockchain technology verifies and monitors the consequence of green investments, and AI-assissted standardization upgrade ESG ratings. Additionally, AI chatbots and interactive dashboards guide investors, rendering complex sustainability metrics more comprehensible. Predictive analytics detects climate-oriented risks and simulate future regulatory impacts, thereby facilitating informed decision-making and endorsing sustainable investments globally.
Capital expenditures and financial hurdles AI address these issues by improving financial decision-making, optimizing expenditures, and expanding access to capital. Applying predictive analytics and AI-based risk assessment models, organizations can evaluate risks, anticipate market trends, and secure financing more efficiently. AI-guided credit scoring improves loan approval processes, while blockchain-based financing, crowdfunding and alternative lending models,provide novel funding opportunities. Moreover, AI guides financial planning by automating cost analysis, streamlining operations, and improving revenue forecasting. It also optimizes investment strategies through algorithmic trading and asset tokenization, thereby mitigating reliance on expensive financial advisors. In capital

markets, AI-powered financial advisory services escort in financing options, regulatory compliance, and market analysis, hence increasing the efficiency of fundraising endeavors. AI further helps alternative financing models, which includes AI-driven crowdfunding, peer-to-peer lending, and decentralized finance (DeFi), by linking businesses with investors and lessening dependence on traditional banks. By leveraging AI, companies can overcome capital constraints, make more informed financial decisions, and achieve sustainable growth in a competitive environment.

Naunces of risk assessment in green finance

AI address this by applying advanced machine learning, data analytics and NLP (natural language processing) to improve data management, predictive risk modeling, ESG scoring, real-time monitoring, regulatory compliance, and fraud detection. It examines both structured and unstructured data(s) from fiscal records, satellite imagery, and climate models to acknowledge hidden patterns and hints long-term environmental risks. AI-powered predictive models support the forecasting of future climate-related and regulatory risks, while real-time monitoring utilizing IoT sensors and satellite data ensures continuous risk evaluation. (NLP) Natural language processing enables automated ESG scoring and sentiment analysis by assessing news, reports, and social media content. Additionally, AI supports regulatory compliance by automating sustainability reporting and compliance verification. It also addresses greenwashing by detecting inconsistencies in sustainability claims, thereby enhancing transparency through blockchain fusion. By integrating AI, financial institutes can style predictive investment decisions, mitigate environmental risks, and foster sustainable economic growth.

Prediction of market demand and Gauging project Feasibility

AI leverage insights, obtained from data(s), automation, and risk analysis through Machine learning algorithms to forecast the demand for sustainable investments based on market trends, regulatory changes, and consumer outlooks. AI-driven risk assessment tools evaluate climate risks, financial stability, and environmental, social, and governance (ESG) factors, guaranteeing that green projects are feasible and align with sustainability objectives. Moreover, AI efficiencies loan underwriting, identifies incidents of greenwashing, and optimizes green portfolios, thereby rendering sustainable finance more accessible, transparent, and efficient. By integrating AI, financial institutions are enabled to make well-informed decisions, leading to improved investment returns and a positive environmental impact.

Investments shortfalls in green finance

AI assess risk and credit review, thereby waning investor uncertainty. It conducts Environmental, Social, and Governance (ESG) analysis by processing extensive datasets, facilitating informed decision-making, and fostering confidence in sustainable initiatives. Through predictive analytics, AI decipher emerging trends, guiding investors toward promising opportunities. AI-driven blockchain technologies supports asset tokenization and smart contracts, thereby improving accessibility and transparency. Customized AI-based investment advice attracts retail investors,

while fraud detection mechanisms prevent greenwashing, ensuring that funds are allocated to authentic sustainability efforts. moreover, AI strengthens public-private partnerships by identifying funding gaps and policy influence, hence promoting blended finance models. By improving efficiency, transparency, and risk management, AI is obligatory in mobilizing capital for green finance.
Greenwashing AI address this issue by examining large datasets, decoding misleading claims, and verifying sustainability reports. NLP (Natural language processing) tools can identify ambiguous or deceptive language in promotional materials, while machine learning models can evaluate a company's environmental footprint by utilizing empirical data, such as carbon emissions and the transparency of its supply chain. Moreover, AI-driven blockchain solutions can improves traceability, ensuring that sustainability claims are substantiated by verifiable evidence, thereby promoting accountability and reducing the incidence of greenwashing.
Lacking standardized metrics in green finance AI addresses this challenge by deploying machine learning and NLP (natural language processing) to aggregate, analyze, and standardize diverse environmental, social, and governance (ESG) data from various sources. This technology supports real-time monitoring of sustainability performance, identifies inconsistencies in reported data, and helps in developing predictive models to identify climate risks and green investment opportunities. Moreover, AI-driven platforms enable automated benchmarking against global sustainability standards, hence enhancing transparency and comparability among financial institutions and promoting more informed and consistent decision-making in green finance.

1.2.6 Integration of AI in public-private sectors

The integration of artificial intelligence (AI) within both public-private financial sectors is revolutionizing operations, enhancing efficiency, and improving decision-making processes. In the private sector, banks and financial institutions employ AI for personalized banking, fraud detection, robo-advisors, algorithmic trading, and credit risk assessment. AI-driven chatbots, biometric authentication, and machine learning models facilitate the streamlining of customer service and security. In the public sector, governments and central banks utilize AI for regulatory compliance, anti-money laundering, economic forecasting, taxation, and public finance management. Although AI augments financial amenities, challenges of regulatory concerns, data security risks, job displacement, and algorithmic bias must be talked to guarantee equitable and effective implementation.

2. LITERATURE REVIEW

As AI technologies advance, their ethical implications in the financial industry, particularly in sustainable finance, are becoming more evident. Ethical standards in banking and investment address concerns like bias, privacy, and the societal impact of automation. Academic debates on AI ethics in finance have grown, highlighting its potential to either advance or hinder social equity. This highlights AI's role in integrating ethical considerations with profitability in green finance [1] [26].

Technology plays a crucial act in endorsing green finance by leveraging AI to track carbon emissions, assess environmental effects, and predict climate-related risks. AI-driven models aid investors and financial institutes in making informed choices about sustainable initiatives. Additionally, establishing clear metrics to evaluate AI's part in green finance is essential for maintaining ethical standards. Collaboration among stakeholders is necessary to develop frameworks that align technological progress with ethical responsibility [54] [15].

AI is revolutionizing finance by employing data-driven algorithms to enhance efficiency and decision-making, particularly in finance focused on sustainability. Nonetheless, ethical issues concerning transparency and accountability in automated decision-making are on the rise. Tackling these challenges is both a technical and societal endeavor, necessitating the design of ethical AI to bolster environmental and resource management initiatives [3] [27] [24] [32] [20].

To ethically integrate AI into the financial industry, addressing biases and ensuring fairness in decision-making is crucial. As AI becomes more widespread, it is important to examine both intentional and unintentional biases in automated systems. Ethical management of AI is particularly important in finance due to its substantial impact on society. Researchers and industry leaders must assess how fairness is incorporated into algorithms that influence green investment decisions. Ongoing discussions about AI ethics are key to promoting sustainable financial practices and minimizing negative social effects [40] [38] [1].

AI is pivotal in green finance by facilitating responsible investments that adhere to ESG standards. Its capacity to process extensive datasets in real-time aids in pinpointing sustainable investment prospects. Nonetheless, ethical issues such as bias reduction and transparency are crucial for gaining stakeholder confidence. Upholding ethical AI practices is fundamental to promoting sustainability in finance [28] [47].

A thorough approach to AI ethics in finance involves weighing its advantages against its risks. Conversations underscore the necessity for responsibility and accountability, especially in green finance, where AI impacts investment choices. Although AI can drive positive environmental results, ongoing dialogue is needed to address the risks linked to automation. Ethical frameworks are essential to ensure AI supports sustainable development while minimizing potential harms, highlighting the need for careful discussion about its role in green finance [28] [25].

AI performs a crucial act in promoting sustainability in investments by enabling financial institutions to evaluate ESG factors more thoroughly. As regulations become more stringent, companies depend on AI for sophisticated analytics to maintain compliance and uphold ethical investment standards. AI optimizes data handling, enhances risk evaluation, and boosts transparency, thereby encouraging accountability and supporting eco-friendly finance while addressing stakeholder concerns about climate and social responsibility [6] [4] [24].

AI is revolutionizing financial services by enhancing decision-making, particularly in sustainability and ethical governance. Predictive analytics and algorithmic trading facilitate the

identification of green investments and the evaluation of environmental impacts. This improves transparency, social responsibility, and proactive climate risk management, ensuring the long-term sustainability of financial institutions [13] [17] [7].

Financial institutions must emphasize ethical considerations when implementing AI to avoid unintended negative consequences. Sustainable banking frameworks emphasize the importance of balancing profitability with social and environmental responsibility. The growing demand for financial professionals knowledgeable in ESG reflects the changing expectations of the industry. AI can reinforce ethical standards in risk management, minimizing bias and promoting fairness in financial services. A responsible approach to AI also helps build consumer trust, which is vital for sustainable finance [14] [50] [51].

2.1 Research Gap

The assimilation of Artificial Intelligence (AI) into sustainable finance has attracted interest due to its likely to improve decision-making, risk evaluation, and impact assessment. Nonetheless, a significant gap persists in understanding how AI can simultaneously promote environmental sustainability (Green AI) and fairness (Fair AI) without increasing biases or violating ethical standards. Current research predominantly addresses either: Green AI in Finance – Utilizing AI for ESG (Environmental, Social, and Governance) investing, climate risk evaluation, and sustainability-related financial choices. Fair AI in Finance – Tackling biases in AI-based credit scoring, lending, and investment distribution to ensure ethical, transparent, and inclusive financial practices. There is a scarcity of research on the convergence of these two areas, especially regarding how AI-powered sustainable finance can harmonize environmental objectives with ethical fairness. This work targets this gap by examining the challenges, trade-offs, and frameworks necessary to create AI systems that are both environmentally friendly and fair within the context of sustainable finance.

2.2 Research Hypothesis

H1: The integration of ethical AI in sustainable finance leads to improved ESG performance while maintaining fairness in financial decision-making.

H2: AI-driven sustainable finance models tend to prioritize environmental sustainability (Green AI) over fairness (Fair AI), leading to potential biases in investment and lending decisions.

H3: A well-regulated AI framework incorporating fairness and sustainability principles can enhance both ethical decision-making and financial performance in sustainable finance.

3. Aims and objectives of the Review

In the present review article, we are aimed to highlight the major axis at which AI applications act to leverage green finance. This is made more focused by representing percentage wise distribution of AI application. Further with the advancement of AI in financial sectors, the trend of growth concerning total investments in Green Finance in India from 2018-2022 is examined. To understand how private and public financial sectors leverage artificial intelligence in green finance we presented a structured table that defines each sector especially of doing things. Case studies that illustrate the practice of AI in Green

Finance is presented to give real example of overall mechanism of Leveraging AI in green finance contributory to economy. Further we were interested in enlisting the important AI driven tools that address challenges in green finance.

4. Methodology

This review utilizes a systematic and integrative approach to examine the junction of ethical AI and sustainable finance. A structured literature review was performed using academic databases like Scopus, Web of Science, Google Scholar and IEEE Xplore concentrating on works published in last decade. The work employed a representation of yearly growth in terms of total investments against green finance in India. For these annual financial reports of public as well as private financial sectors were thoroughly read and understood. Then we were interested in analyzing the key axis upon which AI acted to leverage green finance for sustainability development goals, in both public as well as private sectors. Extraction of information was done from Times of India, India today, Climate policy Initiatives, Statista, Economic Times etc. The information for AI driven tools to attain this growth was extracted from freely available seminars and webinars for financial sectors employees to use them effectively. For understanding how private and public sector differ in their way of working while generating green finance in India, talks and lectures were listened.

5. Results

5.1 Representing percentage wise distribution of AI application

In the realm of financial institutions, AI is primarily employed for risk management, making up 30% of its applications. This encompasses the evaluation of climate risks, the execution of stress tests, and the analysis of sustainability impacts. Both data analytics and ESG integration account for 25% of AI usage each, utilizing AI to manage large-scale environmental datasets and incorporate sustainability metrics into investment strategies. These technologies process unstructured data from sources like satellite imagery and IoT devices to enhance understanding of environmental performance [48]. Furthermore, 20% of AI applications focus on improving transparency and reporting, ensuring that sustainability disclosures are both standardized and verifiable. AI-driven platforms contribute to preventing greenwashing by automating verification processes and aligning with frameworks such as the TCFD [12].

Table 1: The distribution of AI applications in India's green finance sector

Parameter	Percent contributed
Risk Management:	30%
Data Analytics:	25%

ESG Integration:	25%
Transparency/Reporting:	20%

5.2 Growth Inclination in terms of total investments in Green Finance

In India, the surge in green finance investments has been extraordinary, with figures rising nearly fourfold from 50 billion INR in 2018 to a projected 190 billion INR by 2025. During the initial phase from 2018 to 2020, growth was moderate, reflecting the nascent stage of green finance adoption and the integration of AI. However, from 2021 onwards, investments picked up pace despite global economic challenges, indicating increased confidence and AI's role in enhancing risk management. The most significant growth is anticipated between 2022 and 2025, with annual increases of 25-30 billion INR, highlighting market maturity and the widespread use of AI-driven financial tools that are enhancing risk assessment and identifying new investment opportunities.

Table 2: Growth in terms of total investments from 2018-2022 in Green Finance.

Year	Total Investments
2018	50 billion INR
2019	62 billion INR
2020	75 billion INR
2021	90 billion INR
2022	110 billion INR

5.3 Differentiation in the execution of AI application in green finance: Public Vs Private sector

In realm of objectives and priorities, sources of capital, risk tolerance and investment horizon, financial instruments & mechanisms, impact and accountability, as well as collaboration and synergy Private and public sectors differ intensively. An extensive examination of the ethical application of AI in both primary and public sectors was carried out (Table 3).

Table 3: India's public and Private sector integrating artificial intelligence (AI) into green finance initiatives, ensuring ethical practices to promote sustainable development.

Private sector	Public sector
Basically, motivated by profitability, risk management, and shareholder value. Green finance initiatives must provide financial returns while aligning with corporate sustainability goals.	Determined for long-term social & environmental benefits, such as climate change mitigation, sustainability, and economic stability. Investments often focus sectors where private capital is insufficient, like renewable energy infrastructure and climate adaptation.
Includes a) banks b) institutional investors c) private equity d) venture capital and e) corporate sustainability funds. Examples green bonds, sustainability-linked loans, and impact investments.	Funded by a) government budgets b) development banks c) international climate funds (e.g., World Bank, Green Climate Fund) and d) sovereign green bonds.
Generally, risk-averse, seeking investments with predictable returns. Short- to medium-term investment horizons dominate.	More intended to take long-term risks to support early-stage green technologies, regulatory incentives, and large-scale infrastructure.
Green bonds issued by corporations ESG (Environmental, Social, and Governance) investing Sustainable private equity and venture capital Green bank lending and insurance	Government subsidies and tax incentives Public-private partnerships (PPPs) Grants and concessional loans from development banks Sovereign green bonds

Evaluated by ESG reporting, sustainability indices, and carbon footprint reduction, but subject to greenwashing risks.	Measured through climate policy goals, social impact, and alignment with national and international sustainability commitments (e.g., Paris Agreement, UN SDGs).
Blended Finance: To de risk investments public sector entities often provide guarantees, subsidies, or concessional financing.	Carbon Markets & Regulations: To create investment opportunities for private sectors, e.g. Government policies, like carbon pricing and emissions trading.

5.4 Case studies illustration to highlight AI application in Green Finance

Artificial intelligence is being incorporated into green finance to improve sustainability evaluations and risk analysis. BlackRock employs AI-driven ESG scoring to examine extensive datasets and evaluate the environmental, social, and governance presentation of companies. In India, AI models have been created to enhance risk assessment in the green bond market, thereby increasing transparency, pricing precision, and market credibility [28].

Table 4: Examples of some specific case studies that illustrate the impact of AI integration in green finance.

Company/sector	AI integration	Impact
BlackRock (2019-2023)	AI-Powered ESG Scoring	AI-powered tools have played a crucial act in endorsing genuine sustainability in finance by identifying greenwashing risks and ensuring investments go to truly sustainable companies. By 2021, AI-driven ESG screening helped BlackRock's sustainable assets exceed $500 billion globally. In 2023, AI-assisted risk modeling further enhanced climate-related financial disclosures, aligning with net-zero commitments set by global regulators.
Green Bonds & AI-Powered Risk Assessment in India (2020-2024)	AI-driven credit risk assessment models	AI models have enhanced sustainable investments by analyzing real-time environmental data, such as carbon footprint and water usage. AI-driven analytics have also reduced default risks by 20% by identifying financial risks linked to climate change. Additionally, by 2024, AI-powered platforms have streamlined the green bond issuance process, improving transparency and accessibility for investors.

5.5 Enlisting of AI powered tools to target issues in green Finance

Table 5 AI driven tools used to address challenges and limitation in green finance

Tasks in Green finance	Several AI-powered tools to target these issues
Regulatory & Policy Gaps	Project AISE (Artificial Intelligence Supervisor Enhancer) WWF's AI Tool for Evaluating Transition Plans: Clarity AI's Generative AI Tools: Cambridge Centre for Alternative Finance (CCAF) Digital Tools.
Limited Investor Awareness	Clim8 Invest Arabesque S-Ray Sustainable Finance Disclosure Regulation (SFDR) AI Assistants – OpenInvest Yayzy ESG Book
High Capital Costs and Financing Challenges	Clim8 Invest Sensefolio Aladdin Climate (by BlackRock) Arabesque S-Ray Watson OpenScale (by IBM) Truvalue Labs BlueDot Green Investment AI (by Satelligence)
Risk Assessment Difficulties	Climavision

	Jupiter Intelligence S&P Global Sustainable1 Arabesque S-Ray MSCI ESG Research Sensefolio
Market Demand and Project Viability	Bloomberg Terminal (ESG Data Integration) IBM Environmental Intelligence Suite Google DeepMind's Carbon Tracker S&P Global Sustainable1 Climavision JPMorgan Chase Green Economy AI
Insufficient Investment	ESG Book Climavision. Alchemy Planet OS Watson AI for Climate Risk OpenInvest
Greenwashing Concerns	Clarity AI RepRisk Sustainalytics (by Morningstar) Ecochain ClimateBert
Lack of Standardized Metrics	Clarity AI

	SESAMm Arabesque S-Ray RepRisk ISS ESG Truvalue Labs

6. Scope, Limitations and future directions for the research

The current systematic review article underscores the growing part of AI in green finance, examining the overall framework of green finance and the increase in total investments attributed to AI usage in both public and private sectors, which contribute to the green economy and aim to achieve sustainable development goals by 2030. It identifies specific areas where AI introduction influences growth, highlighting the need for more expertise and research in the future.

Understanding the available AI-driven tools is crucial for improving risk assessment in green finance by enhancing accuracy, speed, and efficiency. This study investigates the role of ethical AI in sustainable finance by balancing environmental sustainability (Green AI) and fairness (Fair AI).

The research focuses on:

AI Applications in Sustainable Finance – Examining how AI is utilized in ESG investing, impact assessment, risk management, and financial decision-making.

Ethical Considerations – Identifying biases, transparency issues, and fairness concerns in AI-driven financial models.

Regulatory and Governance Aspects – Analyzing existing regulations and ethical frameworks for AI in finance.

Trade-offs Between Green and Fair AI – Exploring whether AI-driven sustainable finance solutions prioritize environmental impact over fairness, or vice versa.

The study draws on literature reviews, case studies, and expert opinions to evaluate current challenges and propose solutions for integrating AI ethically in sustainable finance. Limitations Despite its contributions, this research has several limitations:

Data Constraints – AI models in sustainable finance depend on ESG data, which can be inconsistent, unverified, or biased.

Evolving Regulatory Landscape – AI ethics and sustainable finance regulations are continuously changing, making it difficult to reach definitive conclusions.

Sector-Specific Focus – The findings may be more relevant to certain financial sectors (e.g., investment management, banking) and less applicable to others.

Computational and Interpretability Challenges – AI models, chiefly deep learning-based systems, often operate as "black boxes," making it difficult to ensure full transparency and explainability in decision-making.

Lack of Standardized Metrics – Measuring both fairness and sustainability in AI-driven finance remains a challenge due to the absence of universally accepted evaluation frameworks.

Future Directions To address these limitations and build on the findings, future research should explore:

Development of Ethical AI Frameworks – Creating standardized guidelines for balancing sustainability and fairness in AI-driven financial systems.

Improved Explainability Techniques – Enhancing AI interpretability to make financial decisions more transparent and accountable.

Longitudinal Studies – Conducting empirical studies on the long-term impact of ethical AI in sustainable finance.

Regulatory Adaptation – Examining how policymakers can develop dynamic regulations to govern AI in finance while ensuring ethical sustainability.

Cross-Sectoral Analysis – Investigating how AI-driven sustainable finance models can be adapted across industries and global markets.

Integration of Alternative Data Sources – Exploring how non-traditional data (e.g., satellite imagery, social media analytics) can improve AI-driven ESG assessments.

By addressing these areas, future research can deliver more equitable and environmentally responsible AI-driven financial ecosystem.

7. Discussion

The shortfall of a coherent regulatory framework results in discrepancies within green finance initiatives. This absence of optimization is strenuous for the evaluation and oversight of green assets, making it tedious to verify their environmental impact. Many investors are not well-versed in green financial instruments, leading to misunderstandings and decreased involvement in green projects. This lack of awareness limits the flow of capital into sustainable ventures. Green projects often require substantial initial capital.

Furthermore, the limited availability of suitable debt financing options and the dominance of short-term loan maturities discourage investments in renewable energy and other green sectors. Financial institutions find it difficult to predict the timing, frequency, and severity of climate-related events, complicating the risk assessment of green investments. This uncertainty can result in hesitance to fund green projects. In India, the renewable energy sector has faced weak demand for tenders, delays in power agreements, and project cancellations. These challenges threaten the achievement of renewable energy targets and may deter future investments. There is a significant gap between current investment levels and the funds needed to meet India's renewable energy objectives.

In 2024, the investment amount significantly fell short of the $68 billion required annually to achieve the target of producing 500 gigawatts of non-fossil fuel energy by 2030. The risk of greenwashing, where projects are falsely promoted as environmentally friendly, threatens the

credibility of green finance initiatives. This can undermine investor confidence and lead to the misallocation of resources. The lack of standardized criteria for evaluating environmental outcomes makes it difficult to assess the true impact of green finance projects. This uncertainty might deter investors who seek outcomes that are both quantifiable and verifiable. In realm of all these challenges mentioned, AI is revolutionizing risk assessment and management in green finance by utilizing predictive analytics, machine learning, and real-time insights. These technologies assist investors and institutions in navigating uncertainties in sustainable investing, accelerating the transition to a greener economy.

In India, predictive analytics is vital for identifying growth sectors, evaluating financial performance, and integrating ESG data into investment strategies. With India's ambitious renewable energy goals and significant investment projections in green energy and storage, AI-driven models help investors make data-informed decisions. Additionally, AI enhances portfolio optimization by incorporating environmental scores into financial performance evaluations and aids investors in adapting to regulatory changes like SEBI's proposed sustainable finance framework. AI also performs a crucial act in the green bond market, enhancing efficiency, transparency, and credibility. AI-powered models analyze extensive datasets to ensure accurate pricing, automate bond issuance processes, and monitor the environmental impact of funded projects. By processing ESG data, AI strengthens reporting standards and reduces risks like greenwashing.

Furthermore, AI-driven platforms optimize green bond trading, improving liquidity and accessibility for investors. Beyond green bonds, AI's capabilities in real-time market monitoring, NLP-driven ESG analysis, and sentiment tracking enable investors to make more informed, timely decisions. Overall, AI is transforming sustainable finance by streamlining processes, mitigating risks, and fostering transparency in green investments.

8. Conclusion

In conclusion we find that implication of artificial intelligence in green finance in context to growth investments in both private and public sectors is evident by the yearly raise in funds against green projects. Also, the specific area of AI implication in troubleshooting green finance system hindrances by the utilization of AI driven tools might be responsible for raised funds against green finance in India. Future research should concentrate on empirical case studies, real-world applications, and standardized ethical assessment metrics. By employing this structured methodology, the review pursues to offer a comprehensive thought of how AI can be ethically integrated into sustainable finance while ensuring responsible financial practices.

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