# AI for Climate Action: Enhancing Sustainable Development Through ESG Analytics

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## Abstract

Artificial Intelligence (AI) is emerging as a transformative tool in climate finance, enhancing the ability to mobilize, allocate, and manage financial resources effectively to combat climate change. This research explores the integration of AI in climate finance, emphasizing its role in advancing Environmental, Social, and Governance (ESG) investing, improving risk assessment, optimizing investment strategies, and enhancing transparency and reporting. AI-driven models can analyze vast datasets to identify climate-related risks and opportunities, forecast market trends, and support decision-making processes for sustainable investments. The study investigates various methods through which AI can enhance climate finance, including ESG analytics, climate risk modeling, green bond issuance, and automated compliance monitoring. By leveraging AI technologies, investors and policymakers can better navigate the complexities of climate finance, ensuring that financial flows are directed towards projects that mitigate emissions, promote resilience, and support global climate goals. Through empirical analysis and case studies, this paper demonstrates the potential of AI to drive efficient and impactful climate finance strategies, fostering sustainable development and environmental stewardship.

## Keywords

Climate Finance, Artificial Intelligence in Climate Finance, Environmental Social and Governance (ESG), Sustainable Development

## 1. Introduction

Climate change is one of the most pressing global challenges of the 21st century, requiring a concerted effort from all sectors of society to mitigate its impacts and adapt to its consequences.[1] The financial sector plays a critical role in this effort, as the mobilization of financial resources is essential for funding projects that reduce greenhouse gas emissions, enhance climate resilience, and promote sustainable development.[2][3] This imperative was underscored during the United Nations Climate Change Conference (COP 21) held in 2015, where 195 participating nations signed the Paris Agreement, committing to limit the global temperature increase to below 2°C above pre-industrial levels.[4] This commitment has catalyzed the growth of climate finance, a field dedicated to the allocation and management of financial resources aimed at addressing climate change.

However, traditional approaches to climate finance are often hampered by various challenges, including the complexity of climate data, the difficulty of assessing long-term risks, and the need for greater transparency and accountability in financial flows.[5][6] Environmental, Social, and Governance (ESG) investing has emerged as a key strategy within climate finance, integrating sustainability factors into investment decisions.[7] [8] Yet, despite its potential, ESG investing faces several limitations, including data inconsistency, challenges in risk assessment, and issues with transparency[9][10]. Artificial Intelligence (AI) offers a promising solution to these challenges. By leveraging AI's capabilities in data

analysis, predictive modeling, and automation, climate finance can be significantly enhanced[11]. This paper explores the potential of AI to transform climate finance, focusing on its role in advancing ESG analytics, improving climate risk modeling, optimizing green bond issuance, and automating compliance monitoring. The integration of AI into climate finance is not only a technological innovation but a necessity for ensuring that financial resources are effectively directed towards projects that contribute to global climate goals.

## 2. Understanding Climate Finance

Climate finance refers to the financial resources that are mobilized to support activities aimed at mitigating and adapting to climate change.[12] These activities encompass a wide range of projects, including renewable energy development, energy efficiency improvements, climate resilience initiatives, and carbon sequestration efforts.[13] [14] Climate finance is a crucial component of global efforts to transition to a low-carbon economy, as it provides the funding necessary to implement the technological, infrastructural, and policy changes required to address climate change.[15] The scope of climate finance is broad, encompassing both public and private sector investments.[6][16] Public climate finance is often provided by governments, multilateral development banks, and international organizations, and is typically directed towards projects in developing countries that may lack the financial resources to address climate change independently.[17] Private climate finance, on the other hand, involves investments by private sector entities, including corporations, financial institutions, and individual investors[18]. The private sector plays a key role in scaling up climate finance, as it has access to larger pools of capital and can drive innovation in climate-related technologies and solutions.[19]

Key mechanisms within climate finance include:

- **Green Bonds**: These are bonds specifically issued to fund projects with positive environmental impacts, such as renewable energy installations, energy efficiency improvements, and sustainable infrastructure development.[20] Green bonds provide a way for investors to support environmentally friendly projects while earning a financial return.
- **Carbon Markets**: These markets allow for the trading of carbon credits, which represent the right to emit a certain amount of carbon dioxide. Carbon markets provide a financial incentive for companies to reduce their emissions by allowing them to sell excess credits if they emit less than their allotted amount[21].
- **Climate-Related Financial Disclosures**: These disclosures require companies to report on the financial risks they face due to climate change, as well as their strategies for managing those risks. Climate-related financial disclosures aim to improve transparency and enable investors to make informed decisions based on a company's exposure to climate risks.[22]

Climate finance is not just about mobilizing financial resources; it is also about ensuring that these resources are allocated effectively and efficiently to projects that have the greatest potential to mitigate climate change and promote sustainability. This requires a careful assessment of the environmental, social, and economic impacts of potential investments, as well as the integration of climate considerations into broader financial and economic planning.

## 3. ESG and Its Role in Climate Finance

Environmental, Social, and Governance (ESG) factors have become increasingly central to climate finance. ESG investing involves the consideration of these three pillars—environmental sustainability, social responsibility, and ethical governance—in the investment decision-making process[23]. ESG investing is based on the understanding that companies that perform well on ESG criteria are likely to be more sustainable and resilient in the long term, and therefore represent a lower financial risk.

### 3.1. Environmental Factors

Environmental factors in ESG investing include a company's impact on the environment, such as its greenhouse gas emissions, energy consumption, waste management practices, and use of natural resources.[8] Companies that prioritize environmental sustainability may invest in renewable energy, implement energy efficiency measures, reduce waste, and adopt sustainable sourcing practices. These efforts not only reduce the company's environmental footprint but also contribute to the global fight against climate change. In the context of climate finance, environmental factors are particularly important, as the primary goal of climate finance is to support projects that mitigate climate change and promote environmental sustainability. By integrating environmental considerations into investment decisions, ESG investing ensures that financial resources are directed towards projects that have a positive impact on the environment.

### 3.2. Social Factors

Social factors in ESG investing pertain to a company's impact on society, including its labor practices, human rights record, community engagement, and efforts to promote social equity.[8] Companies that perform well on social criteria may prioritize fair labor practices, provide safe and healthy working conditions, respect human rights, and contribute to the communities in which they operate. While social factors may not be directly related to climate change, they are nonetheless important in the context of climate finance. This is because climate change has significant social impacts, particularly on vulnerable populations in developing countries. By considering social factors in investment decisions, ESG investing ensures that climate finance supports projects that promote social equity and contribute to the well-being of communities affected by climate change.

### 3.3. Governance Factors

Governance factors in ESG investing relate to the quality of a company's leadership, its corporate ethics, and its transparency and accountability to stakeholders.[24] Companies with strong governance practices are more likely to be well-managed, ethically sound, and transparent in their operations. Governance factors are critical in ensuring that companies are held accountable for their environmental and social impacts and that they operate in a manner that is consistent with their stated ESG commitments. In climate finance, governance factors are particularly important in ensuring that investments are made in companies and projects that are committed to sustainability and ethical practices. Strong governance practices help to prevent greenwashing—where companies falsely claim to be environmentally friendly—and ensure that climate finance is used effectively to achieve its intended goals.[25]

## 4. Limitations of Current ESG Practices in Climate Finance

Despite the growing importance of ESG investing in climate finance, current practices face several limitations that hinder their effectiveness. These limitations include data complexity and inconsistency, challenges in risk assessment, issues with transparency and accountability, and difficulties in integrating ESG factors into traditional financial systems.[26]

### 4.1. Data Complexity and Inconsistency

One of the primary challenges in ESG investing is the complexity and inconsistency of ESG data. ESG data is often fragmented, with different organizations using different metrics and methodologies to assess ESG performance. This lack of standardization makes it difficult for investors to compare the ESG performance of different companies or projects and to make informed investment decisions. Furthermore, the quality and availability of ESG data can vary significantly, with some companies providing detailed and transparent reports on their ESG performance, while others offer limited or no information. The complexity of ESG data is further compounded by the fact that ESG factors are

inherently multidimensional and interconnected. For example, a company's efforts to reduce its carbon footprint may have implications for its energy consumption, waste management practices, and supply chain sustainability. Assessing the overall ESG performance of a company requires a comprehensive analysis of these interconnected factors, which can be challenging given the limitations of current data.

## 4.2. Challenges in Risk Assessment

Risk assessment is a critical component of climate finance, as it involves evaluating the potential financial risks associated with climate change and ESG factors. Traditional risk assessment models, however, may not fully capture the long-term risks associated with climate change, such as the physical impacts of extreme weather events, the transition risks associated with shifts in regulatory frameworks, and the reputational risks associated with failing to meet ESG commitments. Furthermore, the complexity and uncertainty of climate risks make them difficult to quantify and incorporate into financial models. Climate risks are often characterized by long time horizons, non-linear impacts, and feedback loops, which can complicate the process of assessing their financial implications. This creates challenges for investors in accurately pricing climate risks and making informed investment decisions.

## 4.3. Transparency and Accountability

Transparency and accountability are critical for maintaining investor confidence and ensuring the integrity of climate finance. However, current systems for monitoring and reporting ESG performance are often inadequate, leading to concerns about greenwashing and the misrepresentation of sustainability efforts. Greenwashing occurs when companies make false or exaggerated claims about their environmental performance, misleading investors and stakeholders about the true impact of their activities. The lack of transparency and accountability in ESG reporting is exacerbated by the absence of standardized reporting frameworks and third-party verification mechanisms. This makes it difficult for investors to verify the accuracy of ESG claims and to hold companies accountable for their commitments. Additionally, the reliance on self-reported data by companies can lead to biases and inaccuracies, further undermining the credibility of ESG reporting.

## 4.4. Integration with Traditional Financial Systems

Integrating ESG factors into traditional financial systems is a complex and challenging process. Traditional financial models and investment strategies are often focused on short-term financial returns, whereas ESG investing requires a long-term perspective that takes into account environmental and social impacts. This difference in time horizons can create tensions between ESG objectives and traditional financial goals, particularly in the context of climate finance. Moreover, integrating ESG factors into financial decision-making requires a fundamental shift in the way financial institutions assess risk, value assets, and allocate capital. This shift involves not only the adoption of new metrics and methodologies but also a change in the culture and mindset of financial professionals. The transition to ESG-integrated financial systems is a gradual and ongoing process that requires collaboration between investors, regulators, and other stakeholders.

# 5. The Role of AI in Enhancing ESG and Climate Finance

Artificial Intelligence (AI) has the potential to address many of the limitations of current ESG practices and to enhance climate finance by improving data analysis, risk assessment, transparency, and integration with traditional financial systems.[27] AI technologies, such as machine learning, natural language processing, and predictive analytics, can analyze large and complex datasets, identify patterns and trends, and generate insights that can inform investment decisions and climate finance strategies

## 5.1. AI-Driven ESG Analytics

One of the most promising applications of AI in climate finance is AI-driven ESG analytics. AI algorithms can process vast amounts of ESG data from various sources, including company reports, financial statements, social media, and news articles.[28] By analyzing this data, AI can provide investors with a more comprehensive and accurate assessment of a company's ESG performance, identifying both risks and opportunities that may not be apparent through traditional analysis. AI-driven ESG analytics can also help to address the issue of data complexity and inconsistency. By standardizing and aggregating data from multiple sources, AI can create more consistent and comparable ESG metrics, enabling investors to make more informed decisions. Additionally, AI can identify correlations and causal relationships between ESG factors and financial performance,[27] helping investors to understand the financial implications of ESG risks and opportunities.

## 5.2. Climate Risk Modeling

AI can also enhance climate risk modeling by improving the accuracy and reliability of risk assessments. AI algorithms can analyze climate data, such as temperature and precipitation patterns, and combine it with financial data to assess the potential impacts of climate change on specific assets or portfolios.[29] This allows investors to better understand the physical risks associated with climate change, such as the risk of property damage due to extreme weather events. In addition to physical risks, AI can also model transition risks, which arise from changes in regulatory frameworks, market dynamics, and consumer preferences related to climate change.[29] For example, AI can analyze policy developments, market trends, and social sentiment to predict how changes in climate regulations or shifts in consumer behavior may impact the financial performance of companies or industries. By improving the accuracy of climate risk modeling, AI can help investors to better quantify and price climate risks, leading to more informed investment decisions and more efficient allocation of capital towards climate-friendly projects.

## 5.3. Green Bond Issuance

Green bonds are a key instrument in climate finance, providing a way for investors to fund projects with positive environmental impacts.[30] However, the issuance and management of green bonds can be complex and resource-intensive, requiring extensive due diligence, monitoring, and reporting. AI can streamline the green bond issuance process by automating many of these tasks and improving the efficiency and accuracy of green bond assessments.[31] AI algorithms can analyze project data to assess the environmental impact of proposed green bond projects, ensuring that they meet the required sustainability criteria. AI can also monitor the performance of green bond projects over time, using real-time data to track progress and identify any deviations from the expected outcomes.[32] This allows issuers and investors to ensure that green bonds are delivering on their environmental objectives and to take corrective action if necessary. Moreover, AI can enhance the transparency of green bond reporting by automating the generation of reports and by providing investors with real-time updates on the performance of green bond projects. This improves investor confidence and accountability, making green bonds a more attractive investment option.

## 5.4. Automated Compliance Monitoring

Compliance with regulatory requirements and ESG standards is a critical aspect of climate finance.[30] However, monitoring compliance can be challenging, particularly given the complexity and evolving nature of climate regulations. AI can automate the compliance monitoring process by analyzing regulatory texts, company disclosures, and other relevant data to ensure that companies and projects are meeting their ESG commitments. AI can also detect potential compliance issues by identifying discrepancies between a company's reported ESG performance and the actual outcomes.For example, AI can monitor social media to detect signs of labor violations or community unrest.

## 5.5. Geospatial Data for Greenwashing Prevention

In climate finance, ensuring companies adhere to their environmental commitments is crucial. Greenwashing—where companies exaggerate their environmental friendliness—remains a significant risk. Geospatial data, analyzed by AI, offers a way to verify these commitments by tracking changes in land use, water resources, and deforestation. This not only helps investors assess whether companies are truly meeting their promises but also provides continuous monitoring to detect discrepancies. By identifying potential greenwashing and offering actionable insights, AI ensures greater transparency and accountability, strengthening the integrity of climate finance.

# 6. Future Scope and Recommendations

The integration of AI into climate finance is still in its early stages, and there are significant opportunities for further innovation and development. As AI technologies continue to evolve, they are likely to play an increasingly important role in enhancing ESG analytics, improving climate risk modeling, streamlining green bond issuance, and automating compliance monitoring. To fully realize the potential of AI in climate finance, the following recommendations are proposed:

- **Standardization of ESG Data**: The development of standardized ESG data metrics and reporting frameworks is essential for improving the consistency and comparability of ESG data. This will enable AI algorithms to generate more accurate and reliable insights, supporting better investment decisions.
- **Collaboration Between Stakeholders**: Collaboration between investors, financial institutions, regulators, and technology providers is critical for the successful integration of AI into climate finance. By working together, stakeholders can develop best practices, share knowledge, and drive innovation in AI-driven climate finance solutions.
- **Investment in AI Research and Development**: Continued investment in AI research and development is necessary to advance the capabilities of AI in climate finance. This includes the development of new AI algorithms, the improvement of existing models, and the exploration of novel applications of AI in climate finance.
- **Regulatory Support and Guidance**: Regulatory frameworks should be adapted to support the use of AI in climate finance, providing clear guidelines on the use of AI-driven ESG analytics, climate risk modeling, and automated compliance monitoring. Regulators should also encourage transparency and accountability in AI-driven climate finance solutions.

# 7. ESG Risk Classification

In this study, we leverage the ESGify model, an advanced multilabel classification tool designed to assess Environmental, Social, and Governance (ESG) risks from textual data. The ESGify model is built on the MPNet architecture and features a custom classification head, enabling it to categorize texts into 46 ESG-related classes and one non-ESG relevant class, culminating in 47 distinct categories.

## 7.1. Model Architecture and Customization

The ESGify model employs the MPNet architecture, enhanced with a specialized classification head tailored for ESG risk assessment. Here's a closer look at how it operates:

- **MPNet Architecture**: The foundation of ESGify is the MPNet model, known for its robustness in understanding contextual relationships within text. MPNet's mean pooling function aggregates token embeddings into a unified sentence representation. This pooling accounts for the attention mask, ensuring accurate averaging of embeddings—a crucial aspect for effective classification.

- **Classification Head**: The ESGify classification head comprises several layers designed to process and classify textual data based on ESG risk factors. It includes:
  - **Normalization Layers**: Standardize the data for consistency.
  - **Linear Transformations**: Adjust the data dimensions for further processing.
  - **Activation Functions**: Introduce non-linearity to capture complex patterns.
  - **Dropout**: Prevent overfitting by randomly disabling neurons during training.
  - **Final Linear Layer**: Outputs logits for each of the 47 categories, translating into probability scores for classification.

## 7.2. Preprocessing and Training Methodology

To optimize the ESGify model's performance, a series of preprocessing and training steps were meticulously implemented. Initially, textual data underwent preprocessing using the FLAIR Named Entity Recognition (NER) model, which involved masking entities such as organizations, dates, countries, and individuals. This step was crucial in preventing misinterpretation and biases that could affect the classification of ESG risks. Following this, the training procedure included two key phases. First, the MPNet model was adapted to the ESG domain through Masked Language Modeling on ESG-specific texts. This adaptation helped the model better grasp and process the language and context unique to ESG reporting. Second, the model underwent fine-tuning on a dataset of 2,000 manually annotated texts, curated by ESG specialists. This fine-tuning phase significantly enhanced the model's ability to accurately classify texts into relevant ESG risk categories.

## 7.3. Risk Scoring and Categorization

The ESGify model assesses ESG risks by producing risk scores for each of the 47 categories, utilizing a sigmoid function to transform logits into probabilities. To refine the model's risk assessment capabilities, we introduced a weighted scoring system. This system assigns varying levels of importance to each category based on its relevance and impact within the ESG framework.

In this approach, each category is assigned a weight that reflects its significance in the ESG landscape. Categories deemed more critical receive higher weights, amplifying their influence on the overall risk score. Conversely, less critical categories are assigned lower weights. This weighting adjustment ensures that the model's risk scores more accurately reflect the nuanced importance of each ESG factor, enhancing the model's precision and reliability in identifying and categorizing ESG risks. The incorporation of these weights allows for a more tailored and accurate evaluation of ESG-related content, improving the model's ability to provide meaningful insights.

# 8. Practical Implications for ESG Risk Assessment

## 8.1. Real-Time Risk Evaluation from Extensive Data Sources

This method enhances ESG risk assessment by enabling the analysis of large-scale textual data, such as news articles, industry reports, and corporate disclosures. Its ability to efficiently process and categorize extensive text data provides a valuable tool for understanding and managing ESG risks.

Organizations can leverage this approach to monitor and evaluate a continuous stream of data from diverse sources. This capability allows for the timely identification of emerging ESG issues and trends. For instance, companies can use this method to analyze recent news articles and financial reports to promptly detect potential risks related to environmental compliance, social issues, or governance practices. By examining this data, businesses and investors can stay informed about potential ESG risks and make more timely decisions.

### 8.2. Enhanced Precision with Weighted Risk Scoring

The use of weighted risk scoring in this method improves the accuracy of ESG risk assessments. Each ESG category is assigned a weight based on its relevance and impact, allowing for a more nuanced evaluation of risks. This approach ensures that more significant ESG factors are appropriately highlighted, leading to a more detailed understanding of potential risks.

For example, if a news report highlights significant environmental issues, the method's weighted scoring will emphasize the importance of this factor in the overall risk assessment, providing a clearer picture of its potential impact. This precision in scoring helps stakeholders prioritize their actions based on the severity and relevance of the identified risks.

### 8.3. Strategic Application in ESG Reporting and Decision-Making

The capabilities of this method also enhance ESG reporting and decision-making processes. By integrating this approach into risk assessment frameworks, companies can improve the accuracy and reliability of their ESG disclosures. This integration aids in producing more comprehensive and transparent ESG reports that reflect current risks and opportunities identified through advanced text analysis.

Furthermore, this method supports strategic decision-making by providing stakeholders with actionable insights derived from current data. Investors can use it to evaluate the ESG risk profiles of potential investments, while companies can utilize the insights to refine their sustainability strategies and address identified risks proactively.

In summary, this approach facilitates real-time analysis of extensive textual datasets, refining risk scoring accuracy through weighted categorization. It supports advanced climate finance strategies by enabling more precise reporting and decision-making. By enhancing the evaluation of climate-related financial risks, this method aligns with evolving climate finance standards and regulations. As the integration of sophisticated risk assessment tools becomes crucial for adherence to emerging climate finance frameworks, companies will be better positioned to align with stringent sustainability criteria, thus mitigating climate-related financial risks and fostering broader industry-wide advancements in environmental stewardship.

## 9. Conclusion

This study underscores the transformative potential of AI in climate finance, particularly through advanced risk scoring and enhanced ESG evaluations. The proposed method leverages AI to analyze extensive textual data in real time, offering a more precise approach to ESG risk categorization. By incorporating weighted scoring, the model enhances the accuracy of climate risk assessments, facilitating more informed financial decisions and robust ESG reporting.

While this study provides a detailed exploration of AI's potential in refining climate risk scoring, further empirical validation is required. Future research should focus on applying these AI-driven methods to real-world data, assessing their practical effectiveness in diverse climate finance contexts. This includes developing standardized ESG metrics and fostering collaborations among stakeholders to optimize these tools.

Addressing these research needs will be crucial for advancing climate finance strategies, ensuring that financial resources are effectively directed towards initiatives that support global climate objectives and promote sustainable investment practices.

## References

[1] S. Awuni, F. Adarkwah, B. D. Ofori, R. C. Purwestri, D. C. Huertas Bernal, M. Hajek, Managing the challenges of climate change mitigation and adaptation strategies in ghana, Heliyon 9 (2023) e15491. URL: https://www.sciencedirect.com/science/article/pii/S2405844023026981. doi:https://doi.org/10.1016/j.heliyon.2023.e15491.

[2] R. Agrawal, S. Agrawal, A. Samadhiya, A. Kumar, S. Luthra, V. Jain, Adoption of green finance and green innovation for achieving circularity: An exploratory review and future directions, Geoscience Frontiers 15 (2024) 101669. URL: https://www.sciencedirect.com/science/article/pii/S1674987123001366. doi:https://doi.org/10.1016/j.gsf.2023.101669.

[3] A. Gupta, Chapter 1 - climate change and kyoto protocol: An overview, in: V. Ramiah, G. N. Gregoriou (Eds.), Handbook of Environmental and Sustainable Finance, Academic Press, San Diego, 2016, pp. 3–23. URL: https://www.sciencedirect.com/science/article/pii/B9780128036150000017. doi:https://doi.org/10.1016/B978-0-12-803615-0.00001-7.

[4] S. Delbecq, J. Fontane, N. Gourdain, T. Planès, F. Simatos, Sustainable aviation in the context of the paris agreement: A review of prospective scenarios and their technological mitigation levers, Progress in Aerospace Sciences 141 (2023) 100920. URL: https://www.sciencedirect.com/science/article/pii/S0376042123000362. doi:https://doi.org/10.1016/j.paerosci.2023.100920, special Issue on Green Aviation.

[5] B. Steffen, A. Michaelowa, Policies for climate finance: Status and research needs, PLOS Climate 1 (2022) e0000083. URL: https://doi.org/10.1371/journal.pclm.0000083. doi:10.1371/journal.pclm.0000083.

[6] H. Hong, G. A. Karolyi, J. A. Scheinkman, Climate Finance, The Review of Financial Studies 33 (2020) 1011–1023. URL: https://doi.org/10.1093/rfs/hhz146. doi:10.1093/rfs/hhz146. arXiv:https://academic.oup.com/rfs/article-pdf/33/3/1011/32502054/hhz146.pdf.

[7] C. Fu, L. Lu, M. Pirabi, Advancing green finance: a review of sustainable development, Digital Economy and Sustainable Development 1 (2023) 20. URL: https://doi.org/10.1007/s44265-023-00020-3. doi:10.1007/s44265-023-00020-3.

[8] H. Ahmad, M. Yaqub, S. H. Lee, Environmental-, social-, and governance-related factors for business investment and sustainability: a scientometric review of global trends, Environment, Development and Sustainability 26 (2024) 2965–2987. URL: https://doi.org/10.1007/s10668-023-02921-x. doi:10.1007/s10668-023-02921-x.

[9] S. Bhagat, An inconvenient truth about esg investing, 2022. URL: https://hbr.org/2022/03/an-inconvenient-truth-about-esg-investing, accessed: 30 August 2024.

[10] L. Pérez, D. V. Hunt, H. Samandari, R. Nuttall, K. Biniek, Does esg really matter—and why?, 2022. URL: https://www.mckinsey.com/capabilities/sustainability/our-insights/does-esg-really-matter-and-why, accessed: 30 August 2024.

[11] Z. Zong, Y. Guan, Ai-driven intelligent data analytics and predictive analysis in industry 4.0: Transforming knowledge, innovation, and efficiency, Journal of the Knowledge Economy 15 (2024) 123–145. URL: https://doi.org/10.1007/s13132-024-02001-z. doi:10.1007/s13132-024-02001-z, accessed: 30 August 2024.

[12] C. Watson, L. Schalatek, The global climate finance architecture, Climate Finance Fundamentals, 2021. URL: https://climatefundsupdate.org/wp-content/uploads/2021/03/CFF2-ENG-2020-Digital.pdf, heinrich Böll Stiftung | Washington, DC - USA, Canada, global dialogue.

[13] E. Rasoulinezhad, F. Taghizadeh-Hesary, Role of green finance in improving energy efficiency and renewable energy development, Energy Efficiency 15 (2022) 14. URL: https://doi.org/10.1007/s12053-022-10021-4. doi:10.1007/s12053-022-10021-4, published: February 11, 2022.

[14] C. Fu, L. Lu, M. Pirabi, Advancing green finance: a review of climate change and decarbonization, Digital Economy and Sustainable Development 2 (2024) 1. URL: https://doi.org/10.1007/s44265-023-00026-x. doi:10.1007/s44265-023-00026-x.

[15] S. Giglio, B. T. Kelly, J. Stroebel, Climate Finance, Working Paper 28226, National Bureau of Economic Research, 2020. URL: https://www.nber.org/papers/w28226. doi:10.3386/w28226.

[16] K. Georgieva, T. Adrian, Public sector must play major role in catalyzing private climate finance, 2022. URL: https://www.imf.org/en/Blogs/Articles/2022/08/18/public-sector-must-play-major-role-in-catalyzing-private-climate-finance, iMF Blog.

[17] W. P. Pauw, M. König-Sykorova, M. J. Valverde, L. H. Zamarioli, More climate finance from more countries?, Current Climate Change Reports 10 (2024) 61–79. URL: https://doi.org/10.1007/s40641-024-00197-5. doi:10.1007/s40641-024-00197-5.

[18] S. Liu, An Econometric Analysis of the Influence of Public Interventions on Private Investment in Climate Finance, Master of public policy thesis, Georgetown University, Graduate School of Arts and Sciences, 2024. Submitted in partial fulfillment of the requirements for the degree of Master of Public Policy.

[19] OECD, Scaling Up the Mobilisation of Private Finance for Climate Action in Developing Countries, OECDiLibrary, 2023. URL: https://www.oecd-ilibrary.org/content/publication/17a88681-en. doi:https://doi.org/https://doi.org/10.1787/17a88681-en.

[20] N. Nguyen, N. Luu, A. Hoang, M. Nguyen, Environmental impacts of green bonds in cross-countries analysis: a moderating effect of institutional quality, Journal of Financial Economic Policy 15 (2023) 313–336. URL: https://doi.org/10.1108/JFEP-01-2023-0020. doi:10.1108/JFEP-01-2023-0020.

[21] R. G. Newell, W. A. Pizer, D. Raimi, Carbon Markets: Past, Present, and Future, NBER Working Paper Series 18504, National Bureau of Economic Research, 2012. URL: http://www.nber.org/papers/w18504.

[22] P. Le Goff, M. Lequain, B. Caire, Research Paper on Climate-Related Financial Disclosures, Research Paper, Office of the Auditor General of Canada, ???? Principal: Philippe Le Goff, Director: Mathieu Lequain, Senior Audit Professional: Brian Caire.

[23] E. Napoletano, Environmental, social and governance: What is esg investing?, 2024. URL: https://www.forbes.com/advisor/investing/esg-investing/, reviewed by Paul Katzeff, Investing Editor.

[24] IMD, Esg: Environmental, social and governance investing explained, 2024. URL: https://www.imd.org/blog/sustainability/esg-environmental-social-and-governance/#:~:text=Governance%20considerations,create%20long%2Dterm%20shareholder%20value., last updated: January 2024.

[25] J. Dempere, E. Alamash, P. Mattos, Unveiling the truth: Greenwashing in sustainable finance, Frontiers in Sustainability 5 (2024). URL: https://doi.org/10.3389/frsus.2024.1362051. doi:10.3389/frsus.2024.1362051.

[26] A. Chidambaram, Tackling the data challenge in esg investing, Tata Consultancy Services (????). URL: https://www.tcs.com/content/dam/tcs/pdf/insights/tackling-the-data-challenge-in-esg-investing.pdf.

[27] T. Lim, Environmental, social, and governance (esg) and artificial intelligence in finance: State-of-the-art and research takeaways, Artificial Intelligence Review 57 (2024) 76. URL: https://doi.org/10.1007/s10462-024-10708-3. doi:10.1007/s10462-024-10708-3.

[28] O. B. Adeoye, C. C. Okoye, O. C. Ofodile, O. Odeyemi, W. A. Addy, A. O. Ajayi-Nifise, Artificial intelligence in esg investing: Enhancing portfolio management and performance, International Journal of Science and Research Archive 11 (2024) 2194–2205. doi:https://doi.org/10.30574/ijsra.2024.11.1.0305.

[29] H. Jain, R. Dhupper, A. Shrivastava, D. Kumar, M. Kumari, Ai-enabled strategies for climate change adaptation: Protecting communities, infrastructure, and businesses from the impacts of climate change, Computational Urban Science 3 (2023) 25. URL: https://doi.org/10.1007/s43762-023-00100-2. doi:10.1007/s43762-023-00100-2.

[30] T. Segal, Green bond: Types, how to buy, and faqs, 2024. URL: https://www.investopedia.com/terms/g/green-bond.asp#:~:text=Green%20bonds%20are%20a%20type,either%20in%20part%20or%20whole., reviewed by Michael J Boyle, Fact checked by Katrina Munichiello.

[31] M. Vogelsang, How ai will impact due diligence in ma transactions, 2024. URL: https://www.ey.com/en_ch/strategy-transactions/how-ai-will-impact-due-diligence-in-m-and-a-transactions, senior Manager, International Tax and Transaction Services, EY Switzerland.

[32] M. J. Bachelet, L. Becchetti, S. Manfredonia, The green bonds premium puzzle: The role of issuer characteristics and third-party verification, Sustainability 11 (2019) 1098. doi:10.3390/su11041098, department of Economics and Finance, University of Rome Tor Vergata, 00135 Rome, Italy.