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Natural Resources and Financial Security: The Synergy of Sustainable Development Economics and Artificial Intelligence

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Abstract

Major transformations are decisively reshaping the intersection of financial markets, artificial intelligence, and natural resource economics. The emergence of the digital age has resulted in a previously unheard-of degree of connectivity, information accessibility, and sophisticated computing power, radically altering traditional procedures and spawning novel paradigms. The proposed study aims to enrich the sustainable development literature by outlining and systematizing emerging patterns and trends in sustainable natural resources management and financial security enhancement, based on AI synergetic influence on sustainable development economy functioning. Based on the method of narrative review, theoretical provisions, practical implications, and cases are investigated, representing a systemic picture of intertwining and strong correlations between sustainable finance and sustainable management of natural resources in the landscape of continuous AI solutions development. The paper outlines the patterns of relation between sustainable development, digital transformation, and financial concerns, in particular within the sustainable finance paradigm. It is demonstrated that AI plays a key role in the green economy to generate monetary and environmental rewards, strengthening nation-state financial security. The patterns revealed in the process of review demonstrate that AI offers both financial and environmental advantages, being a potent tool for international decision-making, risk management, and investment in environmentally friendly businesses, climate investing, and renewable energy projects.

Keywords

Sustainable finance; AI-driven decisions; Sustainable economy; Financial security

Introduction

The interplay between sustainable development, financial security, and natural resource management presents a significant challenge for modern societies. Achieving long-term environmental health and economic stability requires a strategic approach to resource use, as unsustainable practices can undermine both ecological integrity and economic resilience. Understanding this relationship is essential for effective policy formulation aimed at promoting sustainability and financial security. While excellent governance guarantees efficient policy and guards against corruption, digital financial inclusion can enhance resource allocation and lessen poverty. Sustainable development necessitates striking a balance between environmental preservation, social progress, and economic expansion (Deyneha, Akimova and Kratt, 2016; Petrukha *et al*., 2025; Voronina, Lopushynskyi and Grechanyk, 2024).

When paired with financial stability, sustainable economics guarantees long-term economic expansion without depleting resources or endangering the environment, society, or culture. To support robust and just economic systems, it entails incorporating environmental, social, and governance (ESG) considerations into financial decision-making (Lobite, 2024). This strategy seeks to eliminate inequality, allocate funds to sustainable projects, and lessen the dangers brought on by climate change and other global issues (Arivazhagan *et al*., 2023; Bashtannyk, Terkhanov and Kravtsov, 2024; Ferdman *et al*., 2025).

Moreover, green transition in the 21st century implies the growing role of AI, which becomes an integral part of the sustainable development landscape. According to Georgescu *et al.* (2025), AI investments have a big and positive impact on renewable energy usage in the short and long run. Similarly, green funding has a big and statistically significant impact on the feasibility of clean energy projects. Furthermore, stable governments and the proper functioning of institutional structures help this process, both of which are observed to have a beneficial effect on renewable energy use.

Meanwhile, speaking about natural resources management as one of the crucial indicators of sustainability level, one should note that because they are responsible for more than 74% of the ecological damage caused by over-exploitation of natural resources, high-income nations are lucky to have an abundance of natural resources (Jiao, Xie and Lu, 2023). This suggests ineffective management of natural resources. The primary reason for this environmental collapse, which hurts people’s health and living conditions, is the overuse of fossil fuels, raw materials, and other resources for economic production (Su et al., 2023; Yousaf, Nekhili and Umar, 2022). The description of natural resources rent in table 1 and figure 1 illustrates the resources’ significant importance over the past few decades. This implies that the vast resource availability has spurred urbanization and industrialization in many countries as a result of increasing economic growth. Because of this, one of the major issues facing any economy in the modern world is sustainable growth, or development that does not negatively impact the environment. Sustainable ways to lower emissions, improve environmental sustainability, and protect natural resources are supported by the literature (Kaiser and Welters, 2019; Wang and Hagigi, 2019). Furthermore, COP26 (the UN Climate Change Conference in Glasgow) highlights the pressing need to put into practice sustainable

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solutions that help reduce emissions by 2030 to enhance environmental sustainability and protect natural resources, and avert climatic calamities.

Table 1: Descriptive stats for TNRNT (Total Natural Resources Rent) (Jiao, Xie and Lu 2023)

Year	*Total Natural Resources Rent*
1984	2.4
1985	2.05
1986	0.96
1987	1.15
1988	0.96
1989	1.2
1990	1.4
1991	0.85
1992	0.85
1993	0.82
1994	0.7
1995	0.75
1996	1
1997	0.9
1998	0.5
1999	0.67
2000	1.25
2001	1.1
2002	0.93
2003	1
2004	1.4
2005	1,73
2006	1.83
2007	1.78
2008	2.53
2009	1.4
2010	1.8
2011	2.5
2012	2.38
2013	2.2
2014	1,85
2015	1
2016	0.95
2017	1.27
2018	1.5
2019	1.37

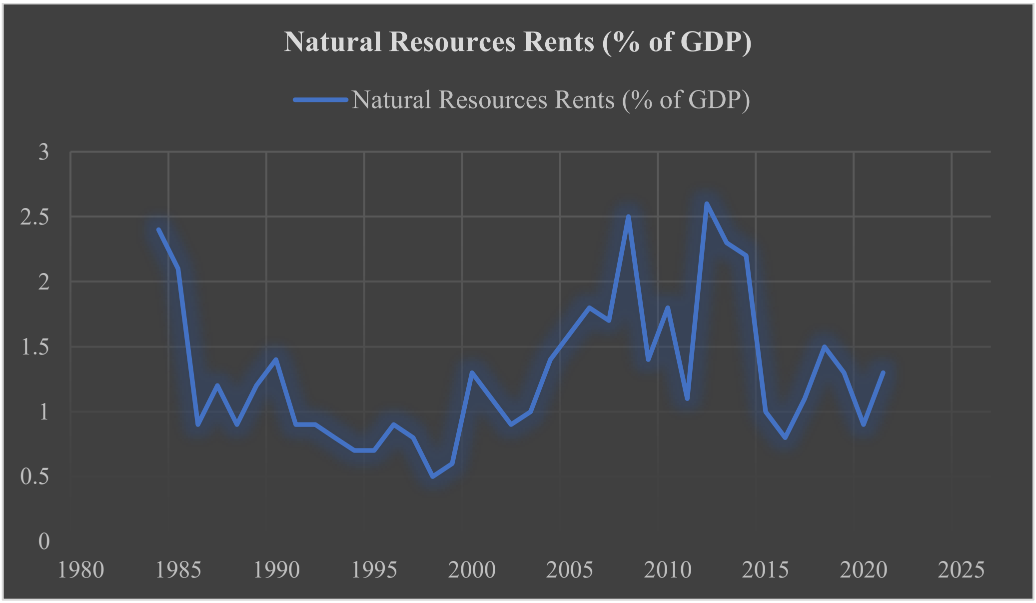

Figure 1: Descriptive stats for TNRNT (Total Natural Resources Rent) (Jiao, Xie and Lu, 2023)

The natural resource description in figure 1 indicates the resources' significance throughout the preceding several decades. This shows that increased economic growth has accelerated countries' industrialization and urbanization. As a result, in today's world, sustainable growth, defined as development that does not hurt the environment, is one of the most pressing issues confronting any economy.

In his research, Ding (2025) attempts to address the crucial and pertinent question: Is the curse of natural resources or do they contribute to sustainable financial development? The author takes data from a group of seven economies for the study. The empirical findings of the study confirm that the variables have a long-term equilibrium connection. The natural resource curse is validated by the empirical results, which clearly show that natural resources have a negative impact on financial progress. Financial development is also adversely affected by the use of renewable energy. On the other hand, exports and technological advancement significantly boost financial development across all quantiles.

Huang *et al.* (2024) examine the moderating influence of governance and reveal the effects of these factors on sustainable development (SD using data from 18 countries between 2013 and 2019. The results show that natural resources, good governance, and digital financial inclusion all have a positive impact on SD; the quality of governance strengthens the link between development outcomes and digital financial inclusion. However, the relationship between sustainability and natural resources is not substantially moderated by governance, highlighting the necessity of customized governance strategies in resource-dependent environments (Khrushch, 2021; Krysovatyy *et al*., 2025). While practical implications provide useful insights to promote resilient and holistic routes to sustainable development, theoretical implications emphasize the need for institutional theory in comprehending the dynamic nature of development processes.

Such ambiguous results represent the evidence of the high complexity of correlations, dependencies, and intertwining among natural resources and financial security. Also, one should not forget about the fact that a negative frame of these interdependencies can lead not to synergy in sustainable development and sustainable economics, but to the opposite, a dangerous effect - entropy in sustainable development, that is, worsening the level of sustainability.

Integration of the newest digital technologies, especially AI, into the landscape of financial security and financial development brings new facets and patterns. Thus, systemic research in this field is of high relevance and expediency, since a sustainable economy (including its financial plane) has become one of the most crucial factors in national security and global competitiveness of any nation-state. The article aims to outline the role of AI technologies in shaping the landscape of the economy of sustainable development.

Materials and Methods

ScienceDirect, Wiley, JSTOR, ResearchGate, Springer, Taylor & Francis Online, and the standard Google search engine were the sources of scientific articles used in this article's narrative literature review research methodology. The databases were chosen since all of them offer plenty of peer-reviewed journal articles and book chapters in many fields, including SD. All these databases use strict publishing standards that guarantee content is of the highest quality. The Consensus tool (https://consensus.app/) was used to make it easier to browse through articles covering a wide range of topics, from the fundamentals and paradigms of SD and sustainable economy subsystems (e.g., financial one) to more practical concerns. The following criteria (as eligibility criteria) were set for searching: English language; article volume no less than 3 full pages; abstract of no less than 130 words; presence of the words "sustainable development", "AI" AND/OR "sustainable economy", AND/OR "sustainable finance", AND/OR "AI and natural resources".

213 items were discovered through the use of this program, and MAXQDA (a solution that provides AI-powered capabilities for grounded theory, such as automatic coding suggestions and pattern recognition) was used to further evaluate them. Using MAXQDA app allowed revealing a range of categories and patterns which then were used for final selection of publications to be included into sample of analysis: digital enables of sustainable use of resources; AI as green finance platform; digital aspects of green economy; AI-powered resource management; AI-powered resources optimization; AI-integrated Economic Sustainability Development; sustainability of financial markets. According to Code Relations Model, the strongest connection was found between "digital enables of sustainable use of resources" and "digital aspects of green economy". These categories and pattern we used for final manual search in Google search engine.

For the final narrative assessment, 34 publications were selected as the most relevant, based on codes, categories, and patterns, after scoping titles and abstracts.

Thus, the sequence of search was as follows: 1) the use of Consensus tool, for the formation of a pull of publications for grounded theory research; 2) using MAXQDA in grounded theory research, for categories formation; 3) manual selection of publications based on formulated categories (green finance in SDGs; resource curse; resource rent; AI-driven green finance solutions; green economy in sustainability paradigm); 4) narrative review.

Data collected systematically from multiple web sources using the above-described research approach ensures a comprehensive dataset, which is critical for the study's reliability. This analytical framework provides a thorough study that sheds light on the relationship between natural resource sustainability and green finance techniques, as well as a full overview of AI's involvement in sustainable development economics.

Results and Discussion

Digital technologies as enablers of SD

Digital technologies are now widely acknowledged as critical enablers of sustainable development, with implications for the economy, society, and the environment. They provide instruments to help accelerate progress toward the SDGs by enhancing access to essential services, providing data for better decision-making, and encouraging innovation. Digital technologies can improve resource utilization, reduce waste, and reduce the environmental impact of manufacturing and consumption. Digital systems can track and manage energy consumption, resulting in lower carbon emissions and less dependency on fossil fuels. Furthermore, digital technologies can help to promote sustainable practices in agriculture, transportation, and other industries. Digital technologies are an effective tool for achieving sustainable development, but their full potential can only be achieved with careful planning, smart investments, and a commitment to inclusion and responsible innovation (Kovalenko *et al*., 2023). Addressing the challenges and ensuring that digital technologies benefit all members of society is critical to achieving a truly sustainable future (Ortina, Zayats and Karpa, 2023; Petrukha *et al*., 2025; Sydorchuk, Kharechko and Khomenko, 2024). As Bocean (2025) correctly states, leveraging emerging digital technologies aims to promote global SDG attainment. Rapid technological advancements during the digital revolution present a special chance to hasten the achievement of the Sustainable Development Goals set forth by the UN (Dhanaraju *et al*., 2024). The economic, social, and environmental aspects of sustainable development could be changed by emerging digital technologies like the Internet of Things, artificial intelligence, big data analytics, and cloud computing.

Bocean (2025) uses structural equation modeling to illustrate the complex relationship between digital progression and sustainable development indicators, using the Digital Economy and Society Index (DESI) as a comprehensive assessment of technological progress. His approach focuses on how economic performance, as indicated by GDP per capita, mediates the relationship between the advancement of SDGs and the adoption of digital technologies. This thorough investigation clarifies how economic concerns impact the effectiveness of digital solutions in addressing global issues. The results emphasize how crucial it is to implement flexible policies that make use of digital technologies while resolving possible issues and guaranteeing inclusive growth.

Economic Sustainability Development: resource issue

Economic Sustainability Development (ESD), as it is widely called, helps create the sustainable values needed to save resources through recycling, recovery, and best usage. The source of financial losses brought on by subpar ESD design should be connected to countermeasures. Therefore, integrating big data with state-of-the-art technology might facilitate real-time monitoring, motivate customers to embrace more environmentally friendly behaviors, and advance the growth of industry sustainability. Countermeasures in ESD, however, have unpredictable consequences and trade-offs that are hard to predict (Jiang and Chen, 2024). Adoption of artificial intelligence (AI) has the potential to benefit the economy and create jobs in the long run by increasing productivity and producing new items. AI might benefit ESD in the long run. Therefore, by cutting costs and boosting the economy, ESD-AI helps to solve problems. AI-integrated ESD facilitates the analysis of vast volumes of data, which may greatly boost output and enhance decision-making. To guarantee that AI systems can handle sustainability concerns without endangering other economic objectives, a well-rounded approach is necessary (Zilinska, Avedyan and Kyrychenko, 2022).

One of the biggest sources of carbon emissions worldwide is the energy industry, and artificial intelligence (AI) has the potential to greatly lessen its negative environmental effects. By evaluating data from smart grids, forecasting energy demand, and modifying supply appropriately, artificial intelligence (AI) systems can optimize energy use in real-time. As an illustration of how AI can lead to major reductions in carbon emissions, Google has utilized AI to cut the energy usage of its data centers by 40% (Davenport and Ronanki, 2018).

Additionally, by anticipating variations in solar and wind energy production, AI can help integrate renewable energy sources into the grid and guarantee a steady and effective energy supply. AI is capable of helping to reduce transportation-related emissions in addition to optimizing energy use. AI-powered autonomous cars have the potential to ease traffic jams and increase fuel economy. Real-time traffic flow optimization by AI can cut down on idle time and fuel usage. AI may also make it possible to create public transit networks that are more effective, which would further lessen the carbon footprint of cities. In cities like Singapore, for instance, AI-powered traffic management systems have reduced traffic congestion by as much as 20%, which has improved air quality and cut emissions (Chesterfield, 2025).

AI role and landscape

Artificial intelligence techniques could be crucial in today's smart cities to increase energy efficiency and promote the use of inexpensive, renewable energy sources. Artificial intelligence can estimate future energy needs by analyzing historical and current data, which helps to address a number of issues. By taking into account locations and periods of peak demand, smart grids can distribute electricity more efficiently. The following factors may reduce overall energy use and the requirement for additional capacity:

1. AI can control energy use in real time. Demand response systems that offer reduced pricing may encourage consumers to use less energy during peak hours. This reduces the need for expensive energy sources like fossil fuel power plants. The best possible management of production and consumption is made possible by AI's ability to forecast the output of renewable energy sources. This reduces the need for fossil fuels by ensuring that clean, renewable energy sources, such as wind and solar, are utilized to their maximum capacity.
2. Energy storage systems could be controlled by AI to store excess power during periods of low demand and release it during periods of high demand. This facilitates the use of intermittent renewable energy sources and helps to stabilize the system. AI has the potential to enhance smart grid monitoring and control, enabling real-time energy distribution modifications, problem identification, and self-healing capabilities.
3. AI-powered building management systems have the potential to drastically lower operating costs by adjusting a building's lighting and temperature in response to variations in occupancy and ambient conditions. A more aesthetically pleasing and energy-efficient structure is the end result. AI can be used to manage microgrids and distributed energy resources (DERs), allowing for the easy integration of distributed solar panels, wind turbines, and battery storage systems. As a result, the energy system becomes more resilient and relies less on centrally placed generating facilities.
4. AI can identify inefficiencies and areas for power conservation improvement by evaluating data on energy usage. AI-powered solutions could encourage energy trade between individuals and businesses, increasing the use of locally generated renewable energy and lowering costs. By reducing unscheduled outages and increasing the reliability of renewable energy systems, artificial intelligence (AI) may help with predictive maintenance for energy infrastructure.
5. AI's support for data-driven decision-making and regulatory development may promote the use of renewable energy sources and energy efficiency in smart cities.

AI is a vital tool for resource optimization in a variety of industries due to its real-time, massive data analysis capabilities. For instance, farmers can now monitor crop health, weather patterns, and soil conditions with previously unheard-of accuracy thanks to AI-powered precision farming techniques. Farmers can adopt more sustainable farming methods by using AI to improve irrigation, cut down on fertilizer consumption, and minimize waste (Ali *et al*., 2025). Similar to this, AI-driven predictive maintenance systems in manufacturing can cut down on material waste by making sure that machinery runs as efficiently as possible, which prolongs equipment life and lessens the need for frequent replacements (Liu, Wu and Xu, 2025).

Additionally, AI can support effective water resource management, which is essential for sustainable growth. Artificial intelligence (AI) algorithms are able to forecast water demand, identify water distribution system leaks, and maximize water use in sectors like industrial and agricultural. AI-based water management systems, for example, have been used in California to alleviate the state's ongoing water scarcity, leading to notable water savings and better resource distribution. Smart cities that implement various AI techniques to optimize energy efficiency, reduce expenses, reduce greenhouse gas emissions, and boost the use of renewable energy sources create a more resilient and sustainable urban environment. For AI solutions for energy management to be properly implemented, cities, utilities, and other stakeholders must collaborate. Figure 2 shows how an AI can analyze enormous volumes of data and significantly enhance the decision-making process in economic sustainability development. New markets, sectors, and goods could increase demand from customers and open up new revenue streams.

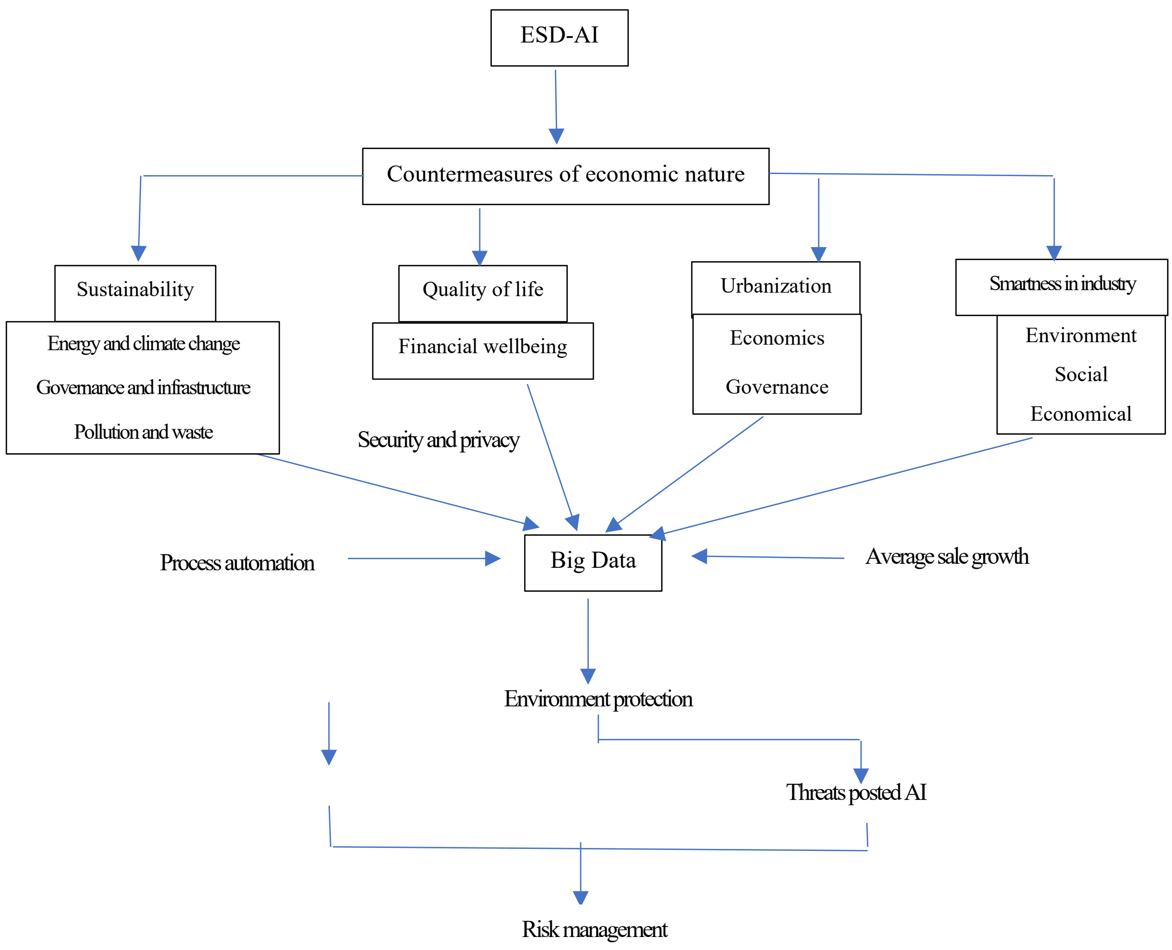

Figure 2: ESD-AI (Jiang and Chen, 2024)

AI has become a key factor in promoting long-term financial and economic growth. Global industries are changing as a result of AI, which presents previously unheard-of chances for economic expansion and sustainable development. AI is not only enhancing existing industries but is also creating entirely new ones. For example, the market for AI-generated material, such as text, photos, music, and video, is growing as a result of the development of generative AI. According to IDC, generative AI will make up 33% of China's overall AI market by 2027, indicating that this sector is anticipated to expand at an exponential rate (Liu, Wu and Xu, 2025). Moreover, in the digital economy, data has become as valuable as oil, and AI is making it possible to monetize this resource. Businesses are using AI to glean insights from enormous databases, generating new sources of income and gaining a competitive edge. But this tendency also calls into question the security and privacy of data, underscoring the necessity of strong regulatory frameworks.

AI and sustainable finance

It is also important to note that the financial markets, which have historically been impacted by human knowledge and market conditions, are undergoing a dramatic change as machine learning models and artificial intelligence algorithms become increasingly important in decision-making. As it opens the door for advancements in trading strategies, risk management, and predictive analytics, the intersection of AI and finance presents both new opportunities and challenges. In addition, it raises significant questions about algorithmic bias, legal frameworks, and the moral implications of automated financial decision-making (Gedikli *et al*., 2024).

In order to address social concerns and climate change, AI and sustainable finance come together to provide investors and financial institutions with AI-driven solutions for sustainable development and return maximization in the face of mounting urgency. Artificial intelligence algorithms can evaluate a company's sustainability performance and predict possible dangers related to social and environmental concerns by evaluating enormous volumes of data from many sources, such as financial reports, social media, and satellite images. According to Al-Sabahi *et al*. (2025), AI-based models excel at capturing intricate, non-linear interactions that are challenging to include in conventional models. However, managing these models can be more difficult and calls for evaluating aspects like explainability and fairness. Large financial institutions and asset managers are increasingly using AI-driven risk management and ESG integration technologies. The adoption of these technologies by institutional investors and smaller businesses is still in its infancy, though (Wipfier, 2024).

Artificial intelligence's introduction into the financial industry has completely changed how financial institutions function and presented previously unheard-of chances for risk management, efficiency, and personalization. This shift is supported by the quick development and use of AI technologies, which are now a mainstay of contemporary financial services and are changing the face of the sector (Oyewole *et al*., 2024). In their systematic study of Explainable Artificial Intelligence (XAI) applications in finance, Weber, Carl and Hinz (2023) stress the significance of understandability and transparency in AI-driven financial choices. Their work demonstrates the use of XAI to demystify AI algorithms, increasing stakeholder trust and accessibility. By addressing ethical and regulatory issues, this strategy not only promotes the use of AI in finance but also ensures that its integration is sustainable and responsible.

The effectiveness and impact of AI applications in sustainable finance, as shown by recent studies, are significant and transformational. Ali *et al*.'s (2023) examination of green finance for sustainable development sheds lighter on the role of green finance in achieving the SDGs and advancing sustainable financial practices in enterprises. This investigation demonstrates that green finance, which is supported by AI analytics, plays an important role in channeling funds to ecologically friendly efforts, thereby actively supporting the SDGs. Sustainable finance, in turn, promotes long-term economic stability, resilience, and responsible resource management, all of which contribute to national financial security. It entails incorporating ESG factors into financial decisions, which can reduce risks while also creating potential for long-term gain.

The incorporation of artificial intelligence into sustainable finance marks a watershed moment in the evolution of financial processes, ushering in a new era in which technology and sustainability intersect to change the landscape of global finance. The use of AI technologies, such as the Financial Maximally Filtered Graph (FMFG) algorithm, has shown remarkable capabilities in processing and analyzing large datasets, allowing for more informed and sustainable investment decisions. Furthermore, research into AI's various applications in the banking and finance sectors demonstrates its potential to improve operational efficiency, cut expenses, and promote a more sustainable approach to financial services (Oyewole *et al*., 2024).

Over the past few years, AI for sustainable finance has been used more and more to address the SDGs. Institutional and social AI for sustainable finance are the two main strategies that have surfaced. In general, societal AI for sustainable finance is used to assist underbanked and unbanked people through financial inclusion programs, whereas institutional AI for sustainable finance is utilized for activities like environmental, social, and governance (ESG) investing. Even though the use of these digital tools has increased, especially during the COVID-19 epidemic, governance and regulatory frameworks are still disjointed, underutilized, or impede the achievement of the 17 UN SDGs. The COVID-19 pandemic did, in fact, cause significant setbacks to adoption and implementation, which in turn have resulted in inconclusive data and lessons learned, although standard-setting and regulatory agencies had produced significant proposals and studies before 2020 (Pashang and Weber, 2023). Through multilateral and cross-sector agreements, policymakers were actively seeking to update governance systems that reduce both new and current risks while promoting sustainability and fostering innovation as the world community recovered from the pandemic.

Artificial intelligence is significant in the green economy since it provides both financial and environmental benefits. Climate investing and sustainable finance are becoming increasingly important, and artificial intelligence is a powerful instrument for global decision-making, risk management, and investment in ecologically beneficial enterprises. The green economy, which includes AI, promotes sustainable business by balancing corporate profits with social and environmental responsibility. When financial institutions use AI to improve data analytics, strengthen risk management, and optimize decision-making processes to meet sustainability goals, there may be societal and environmental benefits in the long-term perspective.

Germany and Denmark case: AI-driven green finance strategies for SD

Ramzani *et al*. (2024) conduct a comparative analysis of renewable energy investments in Germany and Denmark to investigate trends in the integration of AI-driven green finance strategies for sustainable development. Their research looks into the impact of synthetic intelligence (SI) and inexperienced financing practices on the development of renewable energy sectors, with a focus on Denmark and Germany during the critical years 2019 and 2020. The findings illustrate the efficiency of AI-driven green finance solutions in achieving huge improvements, positioning Denmark as a potential paradigm for long-term growth. In evaluation, Germany's consistent electrical infrastructure, combined with a stunning relationship identified through regression analysis, demonstrates the long-term feasibility of its environmentally beneficial economic practices. Figure 3 displays Germany's green energy production between 1990 and 2022, illustrating constant and significant output levels. The graph shows the yearly evolution from 1990 to 2022, with output levels ranging from 0 to 60,000 GWh. More particularly, it clarifies how different renewable energy sources contribute to total energy output. Importantly, biogases have emerged as a prominent feature, indicating a consistent emphasis on using this particular renewable energy source to generate electricity.

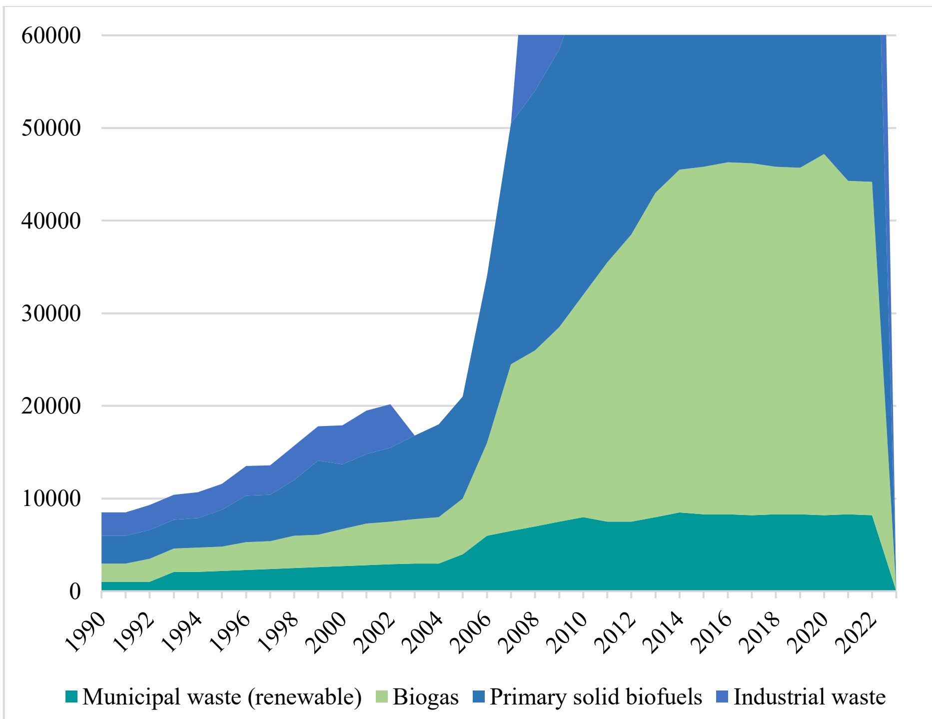

Figure 3: Electricity generation from biofuels and waste by source, Germany 1990–2022 (Ramzani *et al*., 2024)

This outcome is consistent with Ramzani *et al*.'s (2024) extensive study of AI-powered sustainable financing projects in Germany. The graph demonstrates a methodical and informed strategy for utilizing biogas for renewable energy projects. AI optimization was a critical component of determining and improving biogas's future potential. This highlights how technology improvements are strategically related to the objective of sustainable energy. This increases the dependability of Germany's renewable energy industry and highlights the benefits of AI-driven techniques for designing and sustaining ecological initiatives.

Table 2 and figure 4 (Ramzani *et al*., 2024) display the percentage of renewable energy resource generation in Denmark from 1990 to 2022, with annual outputs ranging from 0 to 10,000 GWh. Denmark's commitment to using AI methods is particularly evident. Denmark deployed artificial intelligence technologies to increase its energy output, with a focus on data accuracy. The graph depicts the enormous influence of artificial intelligence, highlighting the link between Denmark's emphasis on precise data collection and a significant increase in energy generation. After reviewing the graph, it is clear that primary solid biogas is a significant renewable energy source for electricity generation in Denmark. This discovery is strongly tied to Denmark's concentration on AI-powered sustainable financing strategies. The emphasis on resilient biogas reflects a deliberate alignment between AI technology and Denmark's sustainable energy goals.

Table 2: Electricity generation from biofuels and waste by source, Denmark 1990–2022 (Ramzani *et al*., 2024)

Year	*Municipal waste (GWh)*	*Biogas (GWh)*	*Primary solid biofuels (GWh)*
1990	100	130	170
1991	150	180	210
1992	200	210	250
1993	300	310	260
1994	400	410	450
1995	450	460	500
1996	500	510	550
1997	500	510	580
1998	550	560	600
1999	550	560	600
2000	600	610	700
2001	650	660	750
2002	700	710	800
2003	700	710	1100
2004	700	710	1500
2005	800	810	1700
2006	850	860	1800

Thus, both countries strategically used AI technologies, emphasizing the importance of data quality and prioritizing renewable energy sources. The focus of both countries on biogas, as well as the accuracy given by AI in data collection, contributes to sustainable and ecologically conscious energy planning, intending to boost the state's financial stability while also enhancing the sustainable development economy. The way financial institutions evaluate, oversee, and encourage ecologically conscious investments is undergoing a radical change as a result of the convergence of artificial intelligence and sustainable finance. AI's role in promoting green investments is more important than ever in light of the growing worries about climate change and the need for a sustainable global economy. The application of AI technologies in sustainable finance is examined in this study, with a focus on how these technologies might yield data-driven insights that facilitate more intelligent and significant green investments. Investors and financial institutions are better able to identify ESG aspects, find lucrative green investment possibilities, and reduce risks by utilizing AI techniques like machine learning, big data analytics, and predictive modeling. AI integration promotes the creation of eco-friendly portfolios, sustainable funds, and green bonds, supporting the worldwide transition to sustainability (Doddipatla, 2023).

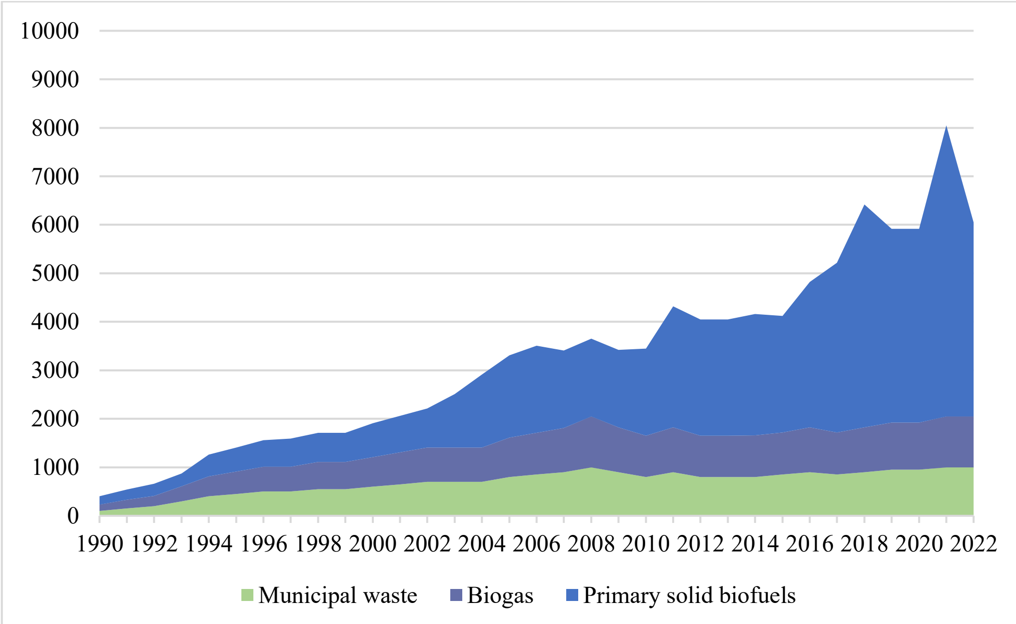

Figure 4: Electricity generation from biofuels and waste by source, Denmark 1990–2022 (Ramzani *et al*., 2024)

The concerns regarding AI

AI, meanwhile, offers both prospects and difficulties for economics and sustainable development. AI is expected to have both short-term and long-term effects on sustainable development, with both good and negative results anticipated (Gohr *et al*., 2025). The development and application of AI raises worries about energy consumption, job displacement, and the escalation of already-existing inequalities, even while technology can spur efficiency, innovation, and resource optimization. According to several experts today, ESG frameworks are challenged by AI's hidden environmental cost (Litvinets, 2024). As businesses scramble to integrate AI into every aspect of their operations, the technology's skyrocketing resource and energy needs are causing blind spots in ESG reporting that might jeopardize stakeholder trust and climate promises. Data centers used 460 TWh of electricity worldwide in 2022, which accounted for 2% of all electricity used worldwide. However, as AI adoption picks up speed, this amount is expected to double by 2026. The infrastructure requirements for contemporary AI data centers are substantial, often encompassing areas equivalent to 25 football fields and housing thousands of GPU racks. Each rack generates significant heat, necessitating continuous cooling solutions (Chi, Hang and Vnong, 2025). Effectively distinguishing among different types of AI is essential to address these challenges. Smaller AI applications, such as those used in environmental monitoring, can provide substantial benefits with little environmental impact, but generative AI requires enormous data center resources. Business executives must give the AI-ESG intersection their full focus right now. Organizations must create thorough frameworks that take into consideration AI's environmental impact while utilizing its promise for sustainability solutions as stakeholder expectations and regulatory scrutiny increase.

Conclusions

Comprehending the modern natural resource economy is essential to guaranteeing the nation-state's financial stability and sustained growth. The notions of national financial security and sustainability are linked; financial security serves as the basis for investing in and accomplishing sustainable development goals, while sustainable practices support long-term economic stability and resilience. On the other hand, sustainable practices can reduce risks and improve long-term economic growth, and a stable and safe financial system is essential for promoting them.

The results of this study indicate that by boosting efficacy, accuracy, and efficiency, the application of AI, ML, and big data can enhance the management of natural resources. Better decision-making and a more sustainable use of natural resources may result from this. To prevent any detrimental effects on the environment or society, it is crucial to make sure that these technologies are used morally and sensibly. Examining how AI development and use fit into larger sustainability initiatives is crucial to comprehending AI's dual nature. Enabling a sustainability AI ecosystem will depend more and more on ongoing research at the nexus of AI and sustainability, as well as increased intentionality on the how, why, and when of GenAI use by enterprises.

When all of these factors are taken into account, it is clear that AI technologies contribute to the energy transition in both complementary and transformational ways. To achieve efficiency, environmental compatibility, and social welfare, it is essential to advance digital infrastructure, link financial support with AI, adapt governance structures to digitalization, and secure long-term energy policies through political commitment. Therefore, a governance model based on institutional coherence and multi-stakeholder engagement is just as important to the energy transition's success as technological innovation. The long-term viability of digital energy systems will be guaranteed by strategic collaboration between national and local governments, financial institutions, commercial sector players, and civil society organizations. Energy policy must also take into account societal resilience, development plans, and climate goals in addition to production-consumption balances. In particular, SDG 7 (cheap and clean energy), SDG 9 (business, innovation, and infrastructure), SDG 13 (climate action), and SDG 16 (peace, justice, and strong institutions) are all directly impacted by the study's conclusions. By highlighting the significance of financial and technological tools in boosting the availability and sustainability of clean energy, the robust and statistically significant benefits of green finance and artificial intelligence investments on the use of renewable energy clearly support SDG 7.

The favorable long and short-term effects of green financing, in particular, emphasize how important it is for securing long-term, reasonably priced funding sources for clean energy projects. The two-way causal relationship between institutional quality and the use of renewable energy suggests that, in addition to facilitating the advancement of clean energy, sound governance may also encourage institutional growth during the energy transition, creating a positive feedback loop that is in line with the governance-centered SDGs. Furthermore, as the results demonstrate, the incorporation of AI into energy systems advances innovation-driven development and smart infrastructure, which in turn supports SDG 9. These multifaceted relationships demonstrate how the energy transition, bolstered by financial sustainability, governance reforms, and technical innovation, makes a comprehensive contribution to the larger global sustainability agenda.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*	*Author 6*
Conceived and designed the research or analysis	Yes	No	Yes	Yes	No	No
Collected the data	No	No	Yes	Yes	Yes	Yes
Contributed to data analysis and interpretation	Yes	Yes	No	No	No	No
Wrote the article/paper	Yes	Yes	No	No	No	No
Critical revision of the article/paper	No	Yes	No	Yes	No	No
Editing of the article/paper	No	Yes	Yes	No	Yes	Yes
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Research involving human bodies or organs or tissues (Helsinki Declaration)
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