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Employing artificial intelligence tools to activate the role of green technology in achieving sustainable environmental development A presentation of global examples and experiences

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Abstract:

This research investigates AI's role in enhancing green technologies for environmental protection and sustainability under regulations like the EU Green Deal, targeting 55% emissions cuts by 2030 and neutrality by 2050. Valued at USD 14.3 billion in 2022, the market anticipates >19.5% annual growth to 2032, fueled by CSR yet challenged by costs mitigated through incentives. Generative AI drives innovations by 2027, including data collection, scenario simulation (e.g., GI, EDRIS, Protecting Paradis apps), with proven success in Germany and the US, opening investment amid ethical considerations**.**

Keywords: green technology, sustainable environmental development, artificial intelligence.Countries' experiences.

Jel Classification Codes: C63, Q2, Q1

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1. INTRODUCTION

The Fourth Industrial Revolution (4IR) is characterized by the convergence of artificial intelligence (AI) and data-driven technologies, enabling cyber-physical systems to optimize performance across a wide range of sectors, including health, education, transportation, industry, and energy through machine learning, the Internet of Things (IoT), and cloud computing, (Gholami, 2024) Fueled by large-scale datasets and increasingly accessible high-performance computing, AI is becoming deeply embedded in industrial and economic systems, where it contributes to improved productivity, (Vinuesa & all, 2023) cost reduction, and operational efficiency, with projections indicating a potential contribution of 14% to global GDP, equivalent to USD 15.7 trillion, by 2030. (Ojha, 2025).

AI also demonstrates considerable capacity to address complex challenges that exceed human analytical capabilities, particularly those related to the depletion of unsustainable natural resources amid growing environmental pressures such as floods, water scarcity, and ozone depletion. In this context, it is noted that 90% of green technologies rely on polluting rare-earth materials, according to a 2019 United Nations report. Meanwhile, the green technology market, valued at USD 23.1 billion in 2024, is expected to reach USD 79.65 billion by 2030, reflecting a compound annual growth rate of 23.1%. Within this trajectory, AI is projected to contribute to emission reductions of up to 4% by 2030 and to support the achievement of net-zero targets by 2050. (Huang, 2021)

Moreover, a study from the University of Massachusetts Amherst suggests that AI has the potential to contribute to 79% of the UN Sustainable Development Goals through applications such as error prediction, waste reduction, and smart city development, despite the fact that global AI energy demand is expected to double to 945 TWh by 2030. Notable international examples include the United Arab Emirates' AI-based coffee tracking system for compliance with EU deforestation regulations and China's use of AI to optimize renewable energy systems, both of which strengthen prospects for carbon neutrality by 2050. (BM, 2025)

1-1-Study Problem :

Artificial intelligence (AI) constitutes a paradigm shift in computing and software engineering, manifesting as a pervasive techno-informational paradigm that permeates all facets of human endeavor. Its core objective entails engineering intelligent systems proficient in executing intricate

tasks, positioning AI as the paramount artifact—and integral constituent—of the Fourth Industrial Revolution (4IR) owing to its versatile applicability across diverse sectors, notably environmental sustainability. (Singh, 2025)
Researchers at the University of Massachusetts Amherst, publishing in Nature, assert AI's capacity to catalyze transformative advancements in environmental science, potentially fulfilling 79% of the UN Sustainable Development Goals (SDGs) through predictive analytics for ecological anomalies, facilitation of circular economies—wherein waste minimization and resource perpetuity prevail—and efficacious smart city architectures.

Consequently, AI-green technology convergence emerges as a cornerstone for pioneering environmental sustainability trajectories. This study thus interrogates: In what manner may AI instruments be leveraged to potentiate green technologies toward sustainable environmental development?

1-2-Study questions:

* How can artificial intelligence enhance the efficiency of green technology in addressing environmental and resource challenges?
* How does artificial intelligence contribute to supporting the circular economy through predictive analytics and data-driven decision-making?
* What is the role of artificial intelligence applications in accelerating the achievement of the Sustainable Development Goals?
* What are the main technical, ethical, and regulatory barriers that hinder the integration of artificial intelligence and green technology?

1-3- Research Objective:

This research seeks to evaluate artificial intelligence's enhancement of green technology efficiency in tackling environmental challenges, explore its support for the circular economy via predictive models, analyze applications' impacts on sustainable development goals like emission reductions, and identify technical/ethical barriers to AI-green integration while proposing solutions. These efforts collectively aim to forge an AI-supported framework for sustainable environmental development. Grounded in recent studies, they address AI's transformative potential amid efficiency, innovation, and governance hurdles.

1-4- Study Methodology:

This study relies on a qualitative analysis of the previous literature related to artificial intelligence applications in enhancing the efficiency of green technology and achieving sustainable development, while examining

the environmental and economic impacts associated with supporting the circular economy. It also investigates the technical, ethical, and regulatory barriers that limit the integration between artificial intelligence and green technology, and this framework contributes to formulating an integrated theoretical perspective on the role of artificial intelligence in supporting sustainable environmental development.

2- Conceptual rooting of sustainable development.

2-1 Definition of sustainable development :

Sustainable development is a comprehensive framework endorsed by the United Nations and was formally articulated in the 1987 Brundtland Commission report as development that satisfies the needs of the present generation without compromising the ability of future generations to meet their own needs. (MarketMuse, 2022)

2-2 Sustainable development goals :

Sustainable development seeks to improve quality of life in an equitable manner by promoting sustainable growth, ensuring the rational use of finite natural resources without causing environmental degradation (Nozari, 2024), aligning the adoption of modern technologies with community priorities and environmental safety (Marr, 2024), and addressing poverty eradication as one of humanity's most pressing challenges.

2-3 Development of sustainable development :

Table N° 01 : Sustainable development has developed according to international initiatives and conferences.

year	Organization, Authority and Conferences	Views on sustainable development
1915	Canadian Environmental Conservation Commission	Transferring natural capital to future generations
1923	International Conference on Nature Conservation in Paris	Environmental conservation and rational use of available resources
1960	Rome Conference Enough of Growth	Warning of the danger resulting from economic development and demographic growth
1972	Stockholm Conference	The emergence of the concept of development appropriate to the environment
1980	World Organization of Natural Communities	Protecting nature and preserving biodiversity
1984	International Conference on Environment and Economy	The need to pay equal attention to the economy and the environment
1987	International Commission for Development and Environment	Issuance of the report Our Common Future and the emergence of the concept of sustainable development

1992	Earth Summit in Brazil	It came after the term sustainable development became established among the general public
1997	Kyoto Protocol	Reducing greenhouse gases
2002	Johannesburg Summit	Preserving natural resources and biodiversity
2009	Copenhagen Summit	Combating global warming
2017	Paris Summit	Reducing greenhouse gases
2020	Glasgow	Strengthening the implementation of the Paris Agreement through actions that can put the world on a more sustainable and less carbon-producing path.

Source : Prepared by researchers.

2-4 Dimensions of sustainable development :

A- The economic dimension :

The economic dimension of development is grounded in material considerations, encompassing an increase in the production of goods and services as well as the expansion of capital investment across economic, agricultural, industrial, financial, and commercial sectors. (Gholami, 2024)The economic dimension revolves around achieving sustainable economic growth, capital efficiency, satisfying economic needs, and achieving economic justice.

B- The social dimension :

The social dimension of sustainable development concerns the relationships among individuals, communities, institutions, systems, and the values that shape social interaction, including beliefs, religions, constitutions, laws, and political change (Ishan, 2023). Its key elements include equitable income distribution and improved living standards, social mobility and public participation, as well as cultural diversity and the continuity of institutions (Huang, 2022; Nozari, 2024).

C- The environmental dimension :

The 1972 United Nations Conference on the Human Environment established the link between development and the environment, highlighting the need for balanced environmental management as a prerequisite for sustainable progress.. (Medaglia, 2025) Sustainable

development gained prominence as economic activities often cause degradation (Jain, 2022). Its environmental dimension focuses on preserving natural resources through rational, effective exploitation without depletion or waste (Nozari, 2024).

3- Green innovation is an engine for sustainable development.

3-1Green technology and its applications.

Green technology refers to the development and application of products, processes, and services designed to reduce the negative environmental impacts of human activity. It seeks to conserve natural resources, lower greenhouse gas emissions, and promote the use of renewable energy. This field encompasses a broad range of practices, including clean energy production, efficient resource utilization, waste minimization, and environmentally responsible design. Examples include green energy, green buildings, green chemistry, and green nanotechnology. Its overarching purpose is to protect the environment, reduce pollution and waste, and support sustainable development without compromising the ability of future generations to meet their needs. This holistic approach considers the entire product lifecycle and promotes a sustainable future by balancing human progress with environmental preservation.n. (Medaglia, 2025)

It relies on a preventive strategy that ensures environmental protection and at the same time is an investment alternative to polluting technologies.There are many areas of application of green technology, ranging from what is used to prevent damage and pollution to what is used to treat these damages.Here are some green technology applications that we have summarized as follows:

Green buildings: Green buildings feature environmentally friendly designs that minimize energy and water use through alternative technologies like efficient heating, ventilation, natural lighting, and clean energy systems. Proper insulation reduces reliance on industrial energy, replacing it with green alternatives. These structures lower pollution, combat climate change, cut consumer costs, and generate jobs. (Gholami, 2024)

Waste recycling : Waste is a harmful environmental problem that many countries suffer from. In recent years, it has become a major part of environmental policy, due to the high costs of disposing of solid and hazardous waste, the scarcity of natural resources, and growing concern about phenomena on planet Earth, water, and air. Recycling technology has been used as an effective solution to eliminate this damage, as the waste is reused to produce other products, a process that has existed in nature since ancient times, as the waste of some living organisms is considered food for other living organisms.

Clean energy : Clean energy is derived from natural sources that are replenished at a faster rate than they are consumed, such as sunlight. Renewable energy helps countries mitigate the impacts of climate change, reduce exposure to price volatility, and lower energy costs. Solar and wind power are among the most important technologies due to their abundance and cost-effectiveness, particularly when paired with battery storage, while hydropower also offers an affordable and clean source of energy. In addition, small-scale solar grids can provide reliable electricity to underserved communities, thereby contributing to the reduction of the global energy access gap by 2030. Through green technology, environmental resources can be utilized sustainably without depletion, thereby protecting natural systems, reducing pollution, and supporting sustainable development. In this sense, green technology enables the efficient and safe use of natural resources at relatively low cost, which has contributed to the emergence of the green economy as an alternative to polluting energy sources and a means of reducing environmental and health harms (Jain, 2022).

3-2 Evidence from international environmental law within green technology options.

The World Bank projects that the future low-carbon economy will rely more on clean energy technologies, leading to a dramatic increase in global demand for strategic minerals such as lithium, graphite, and nickel—expected to rise by approximately 965%, 383%, and 108% respectively by

2050. While this surge offers opportunities for mineral-rich developing countries, it also poses environmental challenges due to the impacts of mining activities. To address these, the World Bank plans to invest $50 million over the next five years to support sustainable mining practices through policy and regulatory frameworks. Their focus includes climate change mitigation, adaptation, reducing material impacts, and promoting decarbonization across the supply chains of critical minerals essential for clean energy technologies. Alongside challenges in transitioning to clean energy, many countries are also advancing efforts in environmental transformation and climate change mitigation through comprehensive strategies. (BM, 2025)

Despite the importance of green technology as technologies that have proven effective in protecting the environment, the results of an American study issued by the University of Cambridge proved that the effectiveness of green technology is temporary and impractical due to several reasons listed by the World Environment Organization in Europe, namely:

Mining : Although green technology aims to achieve sustainability and protect the environment, it relies heavily on minerals extracted from the ground that contain environmentally harmful substances such as lithium used in electronic device batteries, which poses a threat to biodiversity, especially plant diversity. (Huang, 2022)

Waste recycling : Recycling materials like electronics and batteries poses health risks to workers and consumers due to hazardous chemicals such as lead, mercury, and arsenic, which can cause respiratory diseases, cancer, and poisoning. To promote green technology adoption, WIPO established the IPC Green Inventory, an international patent classification system for environmentally sound technologies. In May 2019, the World Bank launched the Climate-Smart Mining Facility, the first fund dedicated to sustainable mineral extraction for clean energy technologies like wind, solar, batteries, and electric vehicles. The $50 million initiative helps resource-rich developing countries capitalize on mineral demand while minimizing environmental and climate impacts through better practices (Heitman, 2022)

The WIPO Global Innovation Index 2021 reveals that high-income countries dominate green technology adoption, despite low-income nations needing them most due to high costs and limited transfer of adaptation innovations. These technologies contribute slowly to economic development in poorer economies compared to traditional resources, necessitating efficiency improvements through new innovations. A report from The Next Web highlights concerns that transitioning to green technology may harm the environment due to its substantial expense. (BM, 2025)

Wind turbines require materials like iron and zinc for corrosion-resistant steel and engines, while electric vehicles need lithium, cobalt, nickel, manganese for batteries, and neodymium plus other rare earth metals for motors. These materials and their extraction contribute significantly to environmental pollution, with emissions exceeding 53.4%. Although some materials can be recycled, key elements like lithium have insufficient recycled supplies, making mining the primary source for future demand, which poses environmental challenges due to the resource-intensive extraction processes. (Nalini, 2021)

A German study from the University of Berlin, in collaboration with the German Federation for Environmental Protection, found that green technologies for clean energy generation require additional resources, leading to higher emissions of buried carbon materials. Green digital industries may also cause a 6.9% shortage of rare earth elements, exacerbating pollution. While green technology demonstrates human adaptability to environmental challenges like climate change, it is not a perfect solution and requires ongoing improvements; integrating artificial intelligence with green technologies has shown promising results for environmental development. (Vinuesa & all, 2023)

4- Artificial intelligence applications to activate green technology :

4-1 Definition of artificial intelligence :

Artificial intelligence is a branch of computer science that aims to design intelligent systems that exhibit the same properties we know as intelligence

in human behavior. It deliberately operates on the principle of matching formations, by which objects, events, and processes can be described using their qualitative properties and their logical and computational relationships. (Beautiful, 2012)

There is disagreement and controversy about finding a comprehensive and comprehensive definition of the concept of artificial intelligence, but there is almost agreement among researchers that artificial intelligence is a scientific and technical trend that includes methods, theories, and techniques that aim to create capable machines (Li, 2017)

Artificial intelligence simulation is a branch of computer science that is concerned with the study and formation of computer systems that show some forms of intelligence. These systems have the ability to draw very useful conclusions about the problem in question. These systems can also understand natural languages or understand living perception and other capabilities that require intelligence whenever they are implemented by humans. (Hadjira, 2018, p82)

Among the available definitions, one also defines artificial intelligence as : "Artificial intelligence is defined as the ability of a machine to perform cognitive functions that link it to human minds, such as perception, reasoning, learning, interaction with the environment, problem solving, and even creativity."

Artificial intelligence is also defined as the ability of a machine to perform cognitive functions associated with human minds, such as perception, reasoning, learning, interacting with the environment, and solving problems, including practicing creativity. However, in reality, artificial intelligence is a combination of advanced computational techniques with varying degrees of maturity (Geetha.A, 2021, p110)

Artificial intelligence is more about process and the ability to think strongly and analyze data than it is about any particular format or function. Although AI provides an image of high-performance, human-like robots taking over the world, AI is not intended to replace humans. Its purpose is to significantly enhance human capabilities and contributions, which makes it an extremely valuable business asset (oci, 2022)

Figure : 01 Expected gains from artificial intelligence in different regions of the world by 2030



Source : (Szczepański, 2019, p. 4)

4-2 Types of artificial intelligence.

Artificial intelligence has three important types, which are as follows :

-Narrow artificial intelligence : In short, it specializes in only one field.

- General artificial intelligence : which is similar to humans in the way of thinking, such as self-driving cars.

- Super-artificial intelligence : It is the one whose intelligence exceeds that of humans, and it performs better tasks than humans. (Diab, 2022).

4-3The most important economic sectors that use artificial intelligence technology :

There are many sectors that use artificial intelligence technologies, namely :

Table N° 02 : The expected economic value of modern artificial intelligence technologies by 2025

N°	Sector	Expected value in Billion USD	Percentage of total industry Revenue
01	Retail	(0.4-0.8)	**(3.2-5.7)**
02	Transportation and logistics	(0.4-0.5)	**(4.9-6.4)**
03	Aviation Sector	(0.3-0.5)	**(7.2-11.6)**
04	Consumer Goods	(0.2-0.5)	**(2.5-4.9)**
05	Public and Social Sector	(0.3-0.4)	**(1.1-1.4)**
06	Automotive and Assembly	(0.3-0.4)	**(0.3-0.4)**
07	Healthcare Systems	(0.2-0.3)	**(2.6-4.0)**
08	Services	(0.2-0.3)	**(2.9-3.7)**
09	Banking Services	(0.2-0.3)	**(2.5-5.2)**
10	Advanced Electronics and Semiconductors	(0.2-0.3)	**(3.3-5.3)**

Source : Muhammad Amin Hanafi Abdullah, 2002, p. 12.

Modern AI technologies in retail and supply chain management significantly reduce stockouts, with reported reductions of around 30% or more. For example, Focal Systems uses AI to detect inventory gaps instantly, improving restocking efficiency. These technologies also reduce storage time by up to 30% and increase sales volume by about 10%. Companies like ViSenze and Zalaro enhance online shopping experiences through AI-driven image recognition and product recommendations. Giants like Ocado and Amazon use AI and robotics to optimize warehousing, distribution, and logistics, automating manual tasks to increase speed, accuracy, and reduce costs. By 2025, the economic impact of such innovations in logistics and distribution is expected to grow substantially.

4-4 Market size and level of global investments in artificial intelligence :

Data on investment in AI technologies shows that global companies, including Alibaba, Amazon, Baidu, Facebook, and Google, have made significant investments. In 2016, companies invested about $20 billion in Asia-Pacific markets, with this figure expected to increase to around $30 billion globally, between 2011 and 2021. These companies were behind around 29 to 55 major acquisitions in the United States, with 09 out of every 10 major deals in China. (Coco, L., 2017)

Global revenues from AI applications, both direct and indirect, are expected to reach $1.4 billion in 2016 and are expected to increase to about $60 billion by 2025. The study indicates that reliance on AI and modern technologies in many industries will contribute to increasing global revenues to more than $47 billion (IDC, 2021)

The following table shows the volume of investments in artificial intelligence applications.

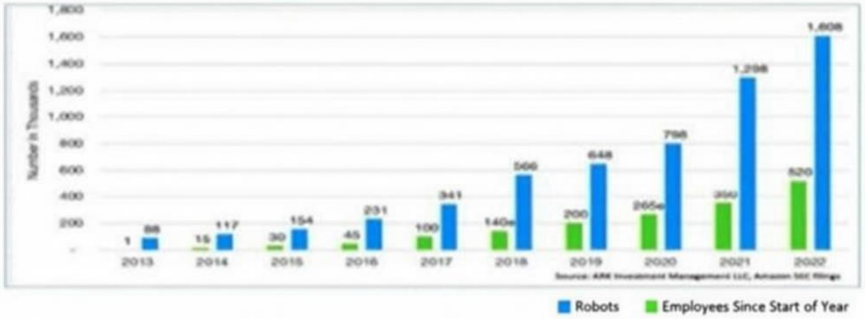
Table N°03 : Volume of investments in artificial intelligence applications during the period (2022 – 2018 Unit) (billion dollars)

Year	2018	2019	2020	2021	2022
Investment volume	0.2	1.3	0.27	1.55	2.65

Source : Prepared by the researcher based on statistics from The Economist magazine, published on January 30, 2023

The table shows significant AI investments attracting numerous startups, with $17.1 billion invested and $15.1 billion financed in Q1 2023. The global AI market reached approximately $328 billion in 2021 and is projected to grow to $1.1-1.4 trillion by 2029. As companies invest in robotics, employment in high-skilled digital jobs is expected to rise 40-50%, displacing traditional roles and disrupting labor markets.

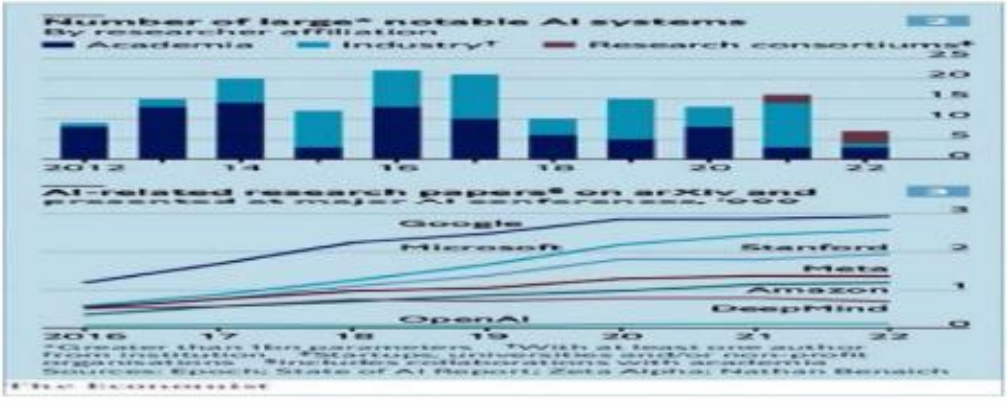
Figure N°04 : The percentage of robots employed compared to the human element at Amazon during the period (2013-2021)



Source : (Adel Abdel Sadek, 2023)

Statistical data indicate that modern AI applications have spread significantly in the Asia-Pacific region, with about 24 companies in China, 25 companies in India, 26 companies in Japan, and 27 companies in South Korea. This proliferation confirms that artificial intelligence has been applied primarily in sectors such as commerce, technology and communications, entertainment, financial services and manufacturing. (ESCAP, 2021), as shown in the following figure

Figure N° 05 : Number in which major companies participated according to the academic, industrial, and joint research aspects during the period (2012-2022)



Sources : (Nathan Benaich , 2023)

4-5 Describing artificial intelligence outputs in the green environment matrix.

Artificial intelligence offers powerful tools to protect the environment by analyzing large environmental datasets, extracting patterns, and producing insights that support better policy and decision-making. It is used to build predictive models for climate change impacts, identify unsustainable behaviors, and monitor social media and online platforms to detect threats such as illegal trade in hazardous chemicals. AI applications highlighted in Owen Mulhern's report include tracking air pollution and energy emissions, improving transport networks, monitoring deforestation, forecasting extreme weather, and detecting land-use change and vegetation loss. Combined with satellite imagery, AI also enables early detection of forest fires, which has helped reduce severe wildfire events in countries such as China and Zambia. (Rolnick, 2022)

A study conducted by the Center (CSTEP) indicated that artificial intelligence provides powerful tools to support decision-making in the field of environmental protection. The most prominent of these tools are analyzing big data, predicting environmental risks, building advanced simulation models, and simplifying complex systems to facilitate understanding and making appropriate decisions about them.

The global flood database at the platforms «Cloud to Street», which relies on artificial intelligence, is also a technological advance for mapping floods and integrating data from the National Aeronautics and Space Administration «NASA» and the US National Oceanic and Atmospheric Administration to track floods around the worldThe results of this study also demonstrated that the four French companies studied correctly used artificial intelligence as an alternative technology to polluting energy technology, which directly led to a reduction in carbon dioxide emissions into the atmosphere, which helped create the best policy to mitigate the effects of climate change using high-quality data.

A- Application : AI-"Protecting Paradis" To protect and preserve forests, this application helps identify areas with Fire protection is a priority and the images taken by this application can give an overview of the health status of

the forest plants to be maintained.

b- Applying (gi) : to simulate future environmental scenarios: This application makes it easier for specialists to predict various environmental disasters that may occur in the future, thanks to the machine learning feature that the latter has, which allows building complex models of the environmental phenomenon that will occur in the future. This technology also allows providing solutions and making the appropriate decision for the prediction that occurs through the explanatory artificial intelligence technology. This technology was adopted in ChinaIt has been used to predict hurricanes, and experiments have proven the truth and validity of these predictions. (Marr, 2024)

C- Application of AI (EDRIS) ; to collect environmental data: This application is used to monitor a huge amount of data related to the environmental situation in the place where the application operates, through radars that are connected to the application, which allow accurately determining the weather conditions and determining the percentage of pollution in the air and the intensity of hurricanes in that area. One of the successful experiments that resorted to such applications is the experiment conducted by researcher Tanya Berger Wolf, Director of the Institute for Translated Data Analysis "TDAI)" (TDAI, State and Head of the Fuelless Train Project in the United States of America, where artificial intelligence contributed to interpreting and presenting environmental data for the region, while providing an accurate plan for building the train. Automated artificial intelligence technology was also used to reduce carbon emissions that pollute the air, and the project obtained a patent (Volker, 2023)

5- Pioneering international experiences in harnessing environmental sustainability by integrating artificial intelligence and green technology.

Germany’s AI-based KIWA and FutureForest projects have demonstrated the capacity of artificial intelligence to support continuous forest monitoring, identify suitable afforestation sites, and design rapid reforestation strategies, including responses to the 10,000-hectare Black

Forest fire in Brandenburg, one of the world's most renowned forest areas in 2023. Similarly, Owen Mulhern's report underscores the potential of AI-enabled green technologies to advance environmental sustainability through the monitoring of air pollution, deforestation, energy-related emissions, transportation systems, and extreme weather events by means of deep learning, smart sensors, satellite imagery, and machine-learning-based data analysis, thereby contributing to biodiversity conservation and climate mitigation (Dalias, 2021).

Likewise, Microsoft's "AI for Earth" initiative illustrates how the integration of AI with green technologies can strengthen sustainable development, for example by improving geothermal energy systems for electricity generation and supporting farmers. In the same context, SoftBank reportedly reduced electricity waste by 65% through AI-based forecasting, monitoring, and verification of renewable energy, while also improving water efficiency and food security for participating farmers (Europäischen, 2023). Shell's German program further demonstrates this trend by using AI tools such as Zephyre in combination with zero-emission electric vehicles to reduce carbon emissions, optimize charging infrastructure, lower costs, and improve air quality (Ishan, 2023).

More broadly, the application of artificial intelligence in environmental domains creates promising investment opportunities in green technology by supporting sustainable development while simultaneously promoting economic growth and environmental protection. Its applications are extensive and include agriculture, where AI can analyze data to improve crop yields, estimate soil moisture, reclaim contaminated land, detect food fraud, and enhance irrigation systems; water management, where it can track hydrological cycles and climate-related changes; and nuclear energy, where machine learning can improve reactor design and safety, increase efficiency, and reduce costs (IAEA, 2023). In addition, AI can facilitate the expansion of renewable energy use and contribute significantly to emissions reduction, thereby helping address the climate crisis. It also supports biodiversity conservation through advanced wildlife monitoring using pattern recognition, behavioral analysis, and drone surveillance, which provide real-time information on animal populations. Overall, this integration strengthens environmental sustainability across multiple sectors and offers a robust basis for future investment and policy development.

6- The forward-looking prospects for creating artificial intelligence within environmental and sustainable development issues.

Integrating artificial intelligence with green technology can play a pivotal role in accelerating progress toward the Sustainable Development Goals by strengthening environmental protection and improving the efficiency of resource use and conservation through a range of proven automated applications, including smart agriculture, enhanced energy efficiency, and green construction. The scope for further developing these applications, as well as designing more advanced green technological tools, remains substantial. As artificial intelligence continues to advance, it is expected that increasingly sophisticated solutions will emerge to support environmental protection and sustainability, thereby contributing to broader efforts to preserve the planet.

At the same time, this integration raises important ethical, legal, and social concerns that must be addressed to ensure environmental sustainability. If misused, artificial intelligence may generate adverse consequences, including irresponsible data use, breaches of privacy, widening disparities between wealthy and less wealthy countries, and reduced demand for human labor, which may pose future risks to occupations such as farming. These challenges underscore the need for an ethical framework governing the use of artificial intelligence in green environments, one that ensures responsible and sustainable application while also encouraging investment in research and development in green artificial intelligence, with a focus on environmentally friendly solutions.

7- Conclusion :

This study concludes that artificial intelligence is no longer merely a supporting technical tool; rather, it has become a strategic lever capable of reshaping the relationship between green technology and the requirements of sustainable development. The theoretical review of the literature shows that the use of artificial intelligence in the environmental domain contributes to improving resource-use efficiency, strengthening environmental monitoring, and enhancing the quality of public decision-making, thereby supporting transitions toward more sustainable patterns of production and consumption.

The findings also confirm that the study's initial assumptions are clearly supported by the contemporary literature. Artificial intelligence appears to enhance the effectiveness of green technology and to support the circular economy through predictive analytics and intelligent data-driven decision-making. It also accelerates progress toward the Sustainable Development Goals, particularly in the areas of emissions reduction, environmental monitoring, risk management, and smart city development. However, this integration remains constrained by several barriers, including high costs, limited human capacity, the technological gap between countries, and the ethical and regulatory challenges associated with governance, accountability, and the responsible use of data.

The theoretical value of this paper lies in its provision of an interpretive framework that links artificial intelligence, green technology, and sustainable development within a single analytical perspective. It highlights that the effectiveness of artificial intelligence in the environmental field is not measured solely by its computational capabilities, but also by the extent to which it is embedded within an institutional and legislative environment capable of directing it toward the desired environmental and social objectives. In this sense, the study expands the scholarly debate on sustainable artificial intelligence by emphasizing its dual role as both an instrument of environmental empowerment and a field requiring strict governance.

Accordingly, the study recommends strengthening regulatory frameworks and public policies that support green innovation, expanding investment in digital infrastructure and human skills, and fostering collaboration among universities, policymakers, and the private sector in order to make artificial intelligence an effective tool for advancing sustainable environmental transition. It also recommends narrowing the knowledge and technology gap between countries in order to ensure a more equitable distribution of the benefits of this transition.

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