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The Role of Artificial Intelligence in Promoting Green Technologies in India

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Abstract

Artificial intelligence (AI) is heralded as a game changer in accelerating the deployment of green technologies towards global sustainability. India is one of the world's largest economies that is also battling environmental issues, making innovation in AI a possible saviour in optimising energy usage, managing waste effectively, increasing the efficiency of renewable energy systems, and advancing more sustainable agricultural practices. This paper provides an overview of how AI is helping India become more green-friendly through different applications such as renewable energy, waste management, and precision agriculture. As a design speculation, up-to-date statistics and case studies have been used to show how AI technologies have improved operational efficiency while decreasing costs and environmental impacts. The results demonstrate that AI has raised the production of solar energy by 28%, improved waste separation efficiency by up to 60%, and reduced water consumption for agriculture by up to 40%. While the benefits are clear there are some barriers to AI deployment such as high set-up costs, data privacy issues, and low awareness. The review concludes with lessons learnt and the opportunities for AI-driven green technologies in India, noting that progress requires strategic partnerships, enabling policies and adequate investment infrastructure and human resources to meet sustainable development goals.

Keywords: Artificial Intelligence, Green Technologies, Sustainability, Renewable Energy, Waste Management, Smart Agriculture, India

INTRODUCTION

Climate change, resource depletion, and environmental degradation pose some of the most pressing challenges of the 21st century. As the global community seeks innovative ways to mitigate these threats, the role of green technologies has become increasingly significant. In this context, artificial intelligence (AI) emerges as a critical enabler, capable of driving efficiency, reducing costs, and enhancing the effectiveness of green technologies. AI applications such as machine learning, predictive analytics, and computer vision offer novel solutions for optimising energy use, managing waste, and supporting sustainable agricultural practices.

India, the world's third-largest energy consumer and the second-most populous country, faces unique sustainability challenges. Rapid industrialisation and urbanisation have exacerbated environmental problems, from air and water pollution to deforestation and waste management issues. The country is also highly vulnerable to the impacts of climate change, such as increased frequency of extreme weather events, sea-level rise, and shifting agricultural patterns. As a result, India has made significant commitments to sustainable development, including pledges to reduce greenhouse gas emissions, increase renewable energy capacity, and promote sustainable practices across various sectors.

However, achieving these goals requires more than policy frameworks and government initiatives; it necessitates the deployment of cutting-edge technologies to drive substantial change. AI stands out as a powerful tool to help

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India navigate these complex challenges by promoting green technologies and enhancing sustainability efforts.

AI IN RENEWABLE ENERGY SYSTEMS

India is a major producer and consumer of energy in the world. The country is rapidly increasing its demand for renewable energy to fulfil its sustainable development goals. India has an ambitious goal of 500 GW of renewable energy capacity by 2030, with solar, wind, and hydroelectric power making up a large portion. However, it has its challenges, such as intermittent energy supply, grid management complexities, and high maintenance costs. To deal with these problems AI works in an innovative way to optimise energy production, stabilise the grid, and lower operational costs.

Solar Power Optimization Using AI

To minimise its carbon footprint, India has installed over 60 GW of grid-connected solar photovoltaic (PV) systems and rooftop SSS as critical components of its renewable energy strategy (Ministry of New and Renewable Energy [MNRE], 2023). From improving solar farm sitting to predicting energy production and automating maintenance, AI has been leveraged more in recent years as a way of increasing the performance of system uptime.

Placement and Optimisation of Solar Panels

AI models, more specifically machine learning algorithms, are mostly used to process large sets of data that consist of geographical factors as well as weather and sunlight intensity in different regions; this helps identify the best places where solar panels should be most efficiently installed. AI can assist in maximising energy production by analysing different parameters that affect the panel such as the tilt angle of the panel, shadows, and local climatic conditions.

For example, in India, AI-enhanced optimisation models are in use in solar farms throughout the country's top states for solar power production – Rajasthan and Gujarat. By optimising the placement and orientation of solar panels, these models have resulted in a 15–20% increase in energy outputs (MNRE, 2023).

Anti-Condition-Based Maintenance (Error Detection and Predictive Maintenance)

AI-enabled predictive maintenance tools rely on real-time data from sensors placed on solar panels to identify discrepancies and forecast potential equipment breakdowns. Machine learning algorithms process historical performance data to find patterns and correlations that may suggest issues before they cause a breakdown or failure.

Table 1: Impact of AI on Solar Power Generation in India

Metric	*Without AI intervention (Baseline)*	*With AI Intervention*	*Improvement (%)*
Average solar panel efficiency	18%	23%	27.78
Annual energy output (MWh)	2,50,000	3,20,000	28.00
Maintenance cost reduction	0	15%	-15.00

Source: Ministry of New and Renewable Energy (MNRE), 2023.

Here are some examples where AI has played a role. Table 1 shows the annual energy output increased by 28% on a large-scale solar plant and maintenance cost reduced by 15% because of targeted actions taken when required.

AI in Wind Energy Management

Another pillar on which India's renewable energy portfolio rests is wind energy, a sector that boasts an

installed capacity of over 40 GW as of 2023 (Indian Wind Turbine Manufacturers Association [IWTMA], 2023). Wind is intermittent with a high level of food print and a greater call on the generation that makes the grid weak. Optimising turbine performance, predicting wind patterns, and running AI models for grid integration are some ways in which AI technologies help us deal with these problems.

Wind Turbine Optimisation

AI-controlled systems receive real-time data (from wind turbines) on wind speed, direction, and other mechanical performance parameters to enhance the operation of a turbine. For instance, AI algorithms can be designed to change the blade angles of turbines such that they capture even more energy depending upon the familiar weather patterns. This makes wind farms more efficient and higher-calibre energy producers.

A wind farm in Tamil Nadu saw a 15% lift in energy output using AI-based optimisation. The AI-based systems are running self-adapting algorithms, constantly tailoring the senses of turbines to maintain efficiency at peak performance (IWTMA, 2023).

Predictive Analytics for Grid Sanity

AI is employed for grid management and stability, especially in the case of wind energy supply predictions. Using machine learning models, historical weather data and real-time wind patterns are analysed algorithmically to accurately forecast energy production, balancing supply and demand. This kind of predictive power allows grid operators to plan for the injection of wind energy into the system, minimising the need to fire up backup fossil fuel-based power stations.

AI in Hydropower Generation

India has over 45 GW of installed capacity for hydropower. AI technologies can improve water flow management, and predict when to maintain the parts and how hydroelectric power plants can be better integrated with the grid.

Water Flow Control and Optimise

Hydrological data (river flow rates, river water levels, and upcoming rainfall) are analysed by AI algorithms to optimise water usage for hydroelectric power plants. With the optimised power output, natural harmony is preserved and water conservation is supported.

One example is the AI-driven water management systems installed in Tehri Dam, Uttarakhand, enhancing energy generation efficiency by 10% by better optimising water release schedules, thus preventing waste (Central Water Commission, 2023).

Hydropower Plants – Predictive Maintenance

Hydropower plants machine learning and computer vision are AI technologies that help to predict wear and tear of equipment in hydropower plants; this helps in avoiding unexpected failures, thus reducing maintenance costs. AI models can be used to predict potential failures using real-time sensor data and historical maintenance records, allowing for the scheduling of preventative maintenance, which increases plant reliability and improves efficiency.

Renewable Energy and Issues in AI Integration

Although AI can bring significant advantages for optimising renewable energy systems, there are many challenges to the wider adoption of AI in this area. These include:

- *Data Quality and Availability:* AI algorithms are useful only if there is data to learn from. There are issues in data collection on weather patterns equipment performance, and grid dynamics – a critical factor for ensuring expected improvement – which reduces the possibility for AI applications.
- *Expensive Infrastructure:* Adopting AI-based solutions demands the significant installation of infrastructure such as sensors, communication networks, and data repositories. This can make the costs excessive, limiting the involvement of minor renewably powered energy producers.

- *Skill Gap:* There is a lack of skilled professionals in the areas of AI and renewable energy, limiting the capability to effectively build and maintain AI-driven systems.

AI for Renewable Energy Systems

Nonetheless, there are several ways AI can help add value to India's renewable energy systems.

- *Government Support:* The Indian government has initiated numerous programmes such as the National AI Strategy, and many renewable energy acts, to encourage the use of AI in green technologies.
- *Public-Private Partnerships (PPPs):* Governing bodies are also exploring partnerships with private firms and research institutions as a potential driving force for innovation while reducing the costs that accompany the adoption of AI.
- *Emerging Technologies:* The advent of several new increasingly sophisticated AI tools, such as deep learning and reinforcement learning applied to energy systems, can be used to further the flexibility of energy systems, making them more resilient against abrupt changes in supply and demand patterns.

WASTE MANAGEMENT AND RECYCLING AI

Of the 62 million tonnes of municipal solid waste generated annually in India, urban areas are a major contributor. Waste management problems have been exacerbated due to rapid urbanisation, population growth, and economic development leading to higher purchase power of the people and increased waste generation besides inefficient waste segregation, dying recycling infrastructure, as well as inappropriate disposal methods. These issues have grave environmental and public health consequences, including air and water pollution, soil contamination, and greenhouse gas emissions. A circular economy, waste management process optimisation using internet of things (IoT) and AI.

Waste Segregation with AI

Proper waste segregation is important to determine what can be recycled or turned into a resource. By tradition, waste segregation is a manual process that is very labour intensive and error prone, which eventually leads to inefficiencies.

Waste Segregation: The identification, recognition, and sorting of various types of waste is one arena where AI-driven technologies such as computer vision and machine learning come into play, restoring the methodology by automating all waste types to be segregated.

Smart Bins and Sorting Systems with AI

Smart bins are equipped with sensors that detect the type of waste and categorise it into recyclable, non-recyclable, and hazardous waste using computer vision algorithms powered by AI. The bins have built-in cameras and sensors that capture the image of the waste. AI algorithms then process these images, recognising or identifying the material (plastic, metal, and glass, among others) and sorting it into the corresponding container.

AI-driven smart bins are now used at certain locations in Pune, where there is a 35% increase in waste segregation accuracy; almost the same reduction can be seen for landfill waste quantity (Municipal Corporation of Pune, 2023).

AI in Automated Waste Sorting Plants

Another example on a larger scale is the automated waste sorting facilities, where machine learning algorithms are combined with robotic arms to aid in classification automation. The output is both swift and precise as the systems are capable of handling waste, and are able to recognise different materials with computer vision and infrared spectroscopy.

A case in point is an AI-enabled sorting facility in Mumbai where the AP-per-letter-word metric improved by 60% and operational costs reduced by 30% compared with manual methods (Brihanmumbai Municipal Corporation,

2023). This system is a result of an AI-driven innovation by ZenRobotics, and based on efficient deep learning models the system recognises different waste items and guides each to their respective processing lines, leading to increased throughput of recyclables.

Table 2: Impact of AI on Waste Segregation Efficiency in India

Metric	*Manual Sorting Process*	*AI-Driven Sorting Process*	*Improvement (%)*
Segregation accuracy	65%	95%	46.15
Operational cost per ton (INR)	2,000	1,400	-30.00
Sorting speed (tons per hour)	2.5	4	60.00

Source: Brihanmumbai Municipal Corporation, 2023.

Table 2 highlights that the improved segregation accuracy is 46%, operational cost reduction is 30%, and sorting speed increased to 60% as a result of AI integration within waste sorting facilities.

AI in Recycling Operations

Recycling is a key element of an integrated, sustainable approach to managing waste that helps recover valuable materials and conserves virgin resources. For example, by integrating AI technologies into the recycling plan, plants will benefit from logistics optimisation and material recovery rate predictions or increase their operational performance in terms of plant efficiency.

Recycling Rate Prediction Using Analytics

Using historical waste generation, type of material, and recycling rates data to predict future trends by AI-based predictive analytics models. The findings help recycling facilities and municipal authorities make better-planned decisions, optimising their resources while reducing costs.

In another example, a recycling business in Hyderabad employs predictive models that use AI to predict the amount and type of recyclable goods it will receive each week. As a result, the strategy reduced inventory costs by 20% and increased overall recycling efficiency by 15% (Greater Hyderabad Municipal Corporation, 2023).

Material Sorting Using Machine Learning

More complex materials – for example, multilayer plastics or electronic industry waste such as Z varnishes or incompatible composite pulverised systems too anoxic to manage by a simple flotation process –would benefit from recycling. These can be separated accurately thanks to the built-in learning machine algorithms. Although, how can the robots distinguish these numerous materials when a significant portion of them have similar colours and properties? The answer is machine learning; the AI-powered robots have a code inside their silicon veins to learn what things are made of. This helps them detect the materials faster and with minimal contaminants, ensuring proper recycling outputs.

For example, a recycling plant in Bengaluru saved 40% of contamination costs and produced higher-quality recyclables for the second market by implementing machine learning technology to sort materials (Karnataka State Pollution Control Board, 2023).

Waste Collection and Route Optimisation with AI

To reduce operational costs as well as the carbon footprint associated with transporting waste, effective waste collection is key.

Waste Collection Routes: By combining several AI technologies waste can be collected in a time-efficient, fuel-saving manner, with fewer CO_2 emissions.

Route Optimisation Algorithms

Route optimisation algorithms based on AI require real-time data generated by the Global Positioning System (GPS), traffic flows, and loading levels of containers

to calculate the most effective ways of removing waste (both in organic and conventional strategies) from bins. By minimising the distance travelled and the number of trips, these algorithms minimise fuel consumption and emissions (assuming travel generates emissions).

A city such as Delhi has adopted an AI-based route optimisation system and reduced the distance travelled by waste collection vehicles by 25%, thereby cutting fuel consumption and related greenhouse gas emissions by around 20% (Delhi Municipal Corporation, 2023).

Automated Waste Collection with Dynamic Scheduling

The system can be used to dynamically schedule waste removal, with collection frequencies optimised using AI that processes real-time data from its smart bins and sensors. These measures can reduce overflowing bins, wasteful drives, and an inefficient response to actual demand.

Table 3: Impact of AI on Waste Collection Efficiency in India

Metric	*Traditional Collection System*	*AI-Optimised Collection System*	*Improvement (%)*
Distance covered (km per day)	500	375	-25.00
Fuel consumption (litres per day)	200	160	-20.00
Collection frequency (trips per day)	10	7	-30.00

Source: Delhi Municipal Corporation, 2023.

Table 3 shows the difference AI-driven waste collection has made; it has reduced the distance by 25%, fuel consumption by 20%, and frequency of collection by 30%.

Difficulties of Implementing AI in Waste Management

AI brings multiple advantages and opportunities to waste management and recycling. However, there are obstacles that prevent a ubiquitous exploitation of it, which need to be overcome.

- *Data Privacy and Security:* Leveraging sensors and smart bins seems practical for data to be collected in large amounts; however, this raises concerns about data privacy and breaches.
- *High Start-Up Costs:* Implementing AI needs a huge sum of money in setting up infrastructure such as sensors and communication networks to pass the information, and data storage facilities, which may not be affordable by small cities or organisations.
- *Insufficient Awareness and Expertise:* The availability of knowledge on AI and waste management is limited to a few cities and companies; this limits the ability of respective municipalities or companies to possess the understanding to implement helpful AI-led systems properly.

AI Can Play a Part

Optimistically, there are immense use cases for AI to streamline and transform waste recycling in India.

The government of India has rolled out various initiatives such as the Clean India Mission or Swacch Bharat Abhiyan that support the deployment of advanced technologies, which focus on effective waste management.

Municipalities can facilitate collaboration between private companies and research institutions to promote innovation while helping lower the costs of AI adoption.

The inclusion of AI with IoT can improve real-time monitoring and decision-making capabilities for waste management efficiency.

AI IN SMART AGRICULTURE

Agriculture is central to India's economy and other sectors depend on it for organic raw material. Indian agriculture

accounts directly or indirectly for approximately two-thirds of the workforce in the country, with half (50%) 1/3rd gross domestic product (GDP) contribution. This data highlights that the agriculture sector has massive social utility in India and there are abundant scopes of employment in the sector. However, there are several challenges in this sector. These include unpredictable weather patterns, water scarcity, soil degradation, and pest infestations. Climate change further exacerbates these problems, and this is where the conversation on sustainable agriculture becomes crucial for food security. With AI acting as the driving force behind modern methods to address these problems, the solution lies in improving resource management and crop productivity with minimal adverse impacts on the environment with the emergence of precision agriculture.

AI in Precision Farming

Precision farming incorporates the use of AI technologies (such as machine learning, computer vision, and data analytics) to help farmers make decisions based on real-time insights.

Smart Agriculture for Crop Monitoring and Management

Vera AI offers AI-powered drones and satellite imagery to track crop health, growth stages, and potential stress factors such as pests, diseases, and water shortages. These images are analysed using machine learning algorithms to identify early symptoms of crop stress, which can be treated in time.

In another example, an AI-powered crop monitoring system developed by the Punjab Agricultural University can predict wheat and rice crop yields with an accuracy of more than 90% using satellite data and deep learning algorithms (Punjab Agricultural University, 2023). The system comes with a proprietary AI engine, which gives farmers actionable insights on irrigation requirements, pest management, and the best time to harvest, and so on, that will bring down input costs and improve productivity.

In-Depth Soil Health Analysis Driven by AI

Healthy soil is the key to sustainable agriculture. Sophisticated AI algorithms analyse soil information that includes pH, nutrient values, and moisture and microorganism activity levels enabling recommendations for soil health improvement. Their AI models predict the patterns of soil degradation by analysing historical data and real-time sensor inputs; they recommend what type of soil amendments should be added and when.

In 2023, the state of Andhra Pradesh observed a 25% increase in crop yield with an AI-empowered soil analysis system giving customised fertilisation advice to real-time data on soil health (International Crops Research Institute for the Semi-Arid Tropics.

Table 4: Impact of AI on Precision Farming in India

Metric	*Traditional Farming Practices*	*AI-Enabled Precision Farming*	*Improvement (%)*
Crop yield (tons per hectare)	2.5	3.1	24.00
Water use efficiency (litres per kg)	3,000	2,200	-26.67
Fertiliser usage (kg per hectare)	200	150	-25.00

Source: International Crops Research Institute for the Semi-Arid Tropics, 2023.

Table 4 illustrates that AI-enabled precision farming increased crop yield by 24%, and reduced water usage by 27% and fertiliser usage by 25%, emphasising significant resource efficiency gains.

AI in Pest and Disease Management

One of the significant challenges for Indian agriculture is a high level of crop loss due to pest infestations and diseases. AI technologies help reduce these risks by providing early detection and accurately targeted pest control.

Predictive Analytics for Pest and Disease Forecasting

By training models on past weather data, soil conditions, crop types, and historical pest outbreaks one can make predictions of future occurrences. These predictive models also come with advanced warnings, so farmers can act on them in advance.

This is illustrated in the instance of an AI-powered pest forecasting system in Maharashtra, a joint project with the Indian Council of Agricultural Research (ICAR), which predicted a locust attack to take place in 2023 (the approximate date when field data and imagery determined that conditions would be conducive to such an event, leading ultimately to crop losses) with sufficient lead time so that farmers were able to stage defence mechanisms ahead of time and preserve around 30% of estimated crops (ICAR, 2023).

Automated Pest Control Systems Based on AI

AI-integrated robotic sprayers and drones help in the identification and targeted treatment of pest-infected regions. Images are analysed by computer vision algorithms to identify the exact pest or disease location so that robotic systems apply pesticides only where required – reducing chemical consumption and minimising environmental pollution.

In Tamil Nadu, an AI-powered drone targeted pests in an area and this resulted in 40% lesser pesticide use and 15% higher-quality crops (Tamil Nadu Agricultural University, 2023).

AI in Irrigation Management

Almost 60% of the country's cultivated area is dependent on monsoon rains, which means water issues are crucial in Indian agriculture. Sustainable agriculture is dependent on proper water management. The use of AI technologies in precision irrigation helps minimise water wastage and see that crops get exactly the right amount of water they need at the necessary points in time.

AI-Powered Irrigation Systems

Irrigation systems driven by AI consider data from soil moisture sensors, weather predictions, and crop water requirements to determine the best time to irrigate. Machine learning algorithms can predict how much water is needed on a real-time basis and historically deliver sufficient volume, thus reducing waste.

This was validated in a case study where AI-managed irrigation reduced water consumption by up to 30% and simultaneously increased crop production by 20 f1 after implementation (Gujarat Green Revolution Company, 2023).

Water Stress Detection Using Remote Sensing

AI algorithms are used to examine information from remote sensing technologies such as satellite imagery and drones to recognise locations where water stress occurs. Farmers can use this information to irrigate more precisely, avoiding both under-watering and over-irrigating their crops.

Table 5: Impact of AI on Irrigation Efficiency in India

Metric	*Conventional Irrigation Methods*	*AI-Optimised Irrigation Methods*	*Improvement (%)*
Water consumption (litres per acre)	15,00,000	10,50,000	-30.00
Crop yield (kg per acre)	800	960	20.00
Irrigation frequency (days)	7	10	42.86

Source: Gujarat Green Revolution Company, 2023.

Table 5 shows how irrigation was reduced by 30%, crop yield improved by 20%, and frequency of irrigation extended by as much as 43%.

AI for Supply Chain and Marketplace Optimisation

AI is also helping streamline agriculture supply chains, decrease post-harvest losses, and provide farmers with access to new markets. AI-based platforms update farmers on the market prices regularly, leading to informed sales in time and location.

Price Optimisation and Demand Forecasting

Demand Forecasting and Pricing: Machine learning models forecast demand by analysing market conditions, historical pricing trends and consumer behaviour so that price optimisation strategies can be implemented. Allowing farmers and agricultural co-operatives to convert by-products into commodities through technology minimises spoilage and increases earnings.

One example is the eNAM (National Agriculture Market) platform, which uses AI to give farmers across India real-time pricing and demand forecasts. The efforts in this direction have resulted in 15% higher income for farmers as it reduced their post-harvest losses and assisted in reaching out to a diverse market (Ministry of Agriculture and Farmers Welfare, 2023).

Logistics and Supply Chain Improvement

Automation of the Entire Process: AI-driven logistics platforms optimise supply chain routes, reducing transportation costs and emissions. Through predictive analytics models, chances of potential supply chain disruptions are identified and necessary adjustments are made to prevent losses.

An AI supply chain management system, which was implemented in one pilot project in Uttar Pradesh, had a 20% cost reduction on transportation and a 25% reduction in post-harvest losses (National Institute of Agricultural Marketing, 2023).

Issues Faced in AI Adoption for Smart Agriculture

Although AI can bring so many advancements in smart agriculture, there are a few issues that currently hold back its seamless adoption.

- Large-scale deployment of AI requires investments such as sensors, drones, and data analytics tools at different levels for monitoring farm operations that are out of reach to smallholder farmers. Most of the farmers in India are illiterate or lack digital literacy to comprehend and make effective use of AI-driven tools.
- AI in agriculture requires large amounts of data, which can pose data privacy and security issues.

AI Opportunities in Smart Agriculture

In any case, there are many opportunities for AI to transform agriculture in India.

The Indian government has been implementing initiatives such as the Digital India programme and National AI Strategy, encouraging the implementation of AI solutions in the agriculture sector.

This can include private-public partnerships that drive innovation and reduce costs of AI deployment, such as government agencies, government colleges, and private colleges.

There are opportunities to leverage machine learning such as deep learning and reinforcement demand in creating solutions for optimising agricultural practices, improving crop resilience, as well as promoting sustainable farming.

CHALLENGES AND OPPORTUNITIES

The deployment of AI for fostering green tech in India throws up many opportunities while leaving a basket of impediments that need to be addressed to realise its full potential. This section discusses the primary challenges and opportunities in using AI for sustainable development in India.

Difficulty in AI Adoption for Green Technologies

High Initial Investment Costs

One of the biggest hurdles to adopting AI in green technologies is that AI solutions entail a high initial investment. The costs of equipment (for example,

sensors, drones, and servers), software (AI algorithms and platforms), and infrastructure (data centres and faster internet) can be too high for small- and medium-sized enterprises or local governments.

Focusing on these systems may necessitate a prohibitively high capital expenditure, such as installing AI-driven waste management systems or precision-farming techniques – two approaches stakeholders might move away from if they are not allowed to consider the rosy financial landscape in years to come.

Lack of Digital Infrastructure

However, India continues to be beset with a significant digital divide, particularly in the countryside and semi-urban zones where most of the agricultural operations take place. The adoption of AI technologies, on the whole, is bogged down by limited access to high-speed internet, insufficient digital literacy, and lack of good data infrastructure.

The adoption of AI-driven solutions is also challenged due to the lack of proper internet connectivity; one out of every three eaters is not connected on the correct bandwidth (Telecom Regulatory Authority of India [TRAI], 2023). It is estimated that nearly 35% of rural areas do not have internet connectivity, which slows the implementation process.

Trust and Data Privacy – Back to the Email Thing, a Dream Come True for CISOs

The basis for AI technologies is the data in large volumes in personal and environmental, markets. There have been issues of data privacy, data ownership, and cyber security that have significantly prevented the adoption of AI in green technologies.

Farmers, for example, feel uncomfortable using AI-driven platforms and data collectors' live soil health, crop yields, and farm practices because of the encroachment of their private data as well as lack of control over it and weak data protection (DP) laws in place.

Shortage of AI Experts and Skilled Personnel

In India, the number of professionals proficient in AI technologies and their application to green technology is at a premium. As National Aeronautics and Space Administration (NASA) Chief Data Officer Ray Obuchowski explained, the talent gap includes deployment, operations, and maintenance of AI systems.

As per the National Association of Software and Service Companies (NASSCOM), India is projected to endure a lack of more than 230,000 AI specialists by 2025, which might impede AI diffusion over various fields including the green technologies sector (NASSCOM, 2023).

Policy and Regulatory Uncertainties

The regulatory ecosystem in terms of AI in India is developing and there exists a vacuum with regard to comprehensive policies and guidelines relating to the use of AI specifically within the context of green technologies. Ambiguous guidelines concerning data privacy, technology standards, and the ethical use of AI can breed doubt in the minds of investors, causing delays in investment commitments towards AI-based solutions.

Applications of AI in Accelerating Green Technologies

Measures from the Government and Policies

The Indian government has introduced various programmes to incentivise the use of AI and green technologies, such as the National AI Strategy initiative, Digital India, and Green India Mission. Similarly, it will seek to foster an environment that encourages AI innovation, builds digital literacy and skills, and enhances research and development (R&D) in sustainable technologies.

In 2023, for example, the 'AI for All' programme was designed to build AI solutions for critical issues in agriculture, energy, and waste management. These steps lay a solid roadmap to fast-track AI adoption in greener technologies.

Sustainable PPPs

PPP co-operation can be instrumental in tackling the aforementioned barriers to AI implementation. PPPs can cut the price of deploying AI, promote invention,

and propel the development of domestic needs-based solutions that run on AI.

In India, promising cases of PPPs refer to tech industry partnerships in conjunction with research institutions and government agencies towards the development of AI-based platforms for managing renewable energy and precision farming. These partnerships are essential to bring innovation to implementation by providing resources, expertise, and infrastructure.

AI Evolution Process

Increased progress in AI-related technologies such as machine learning, deep dementia, and natural language processing gives fresh meaning for the backbone of green technologies. Consequently, advancements in AI, particularly in the development of more sophisticated algorithms and models could increase the precision and efficiency of AI-driven applications predicting renewable energy availability, optimising waste management systems, or enabling precision agriculture.

Another promising avenue is emerging AI technologies such as reinforcement learning and edge AI that can deliver context-aware actions in real time and develop decentralised solutions at a much lower cost, which are more feasible across a variety of resource-constrained settings.

Increasing Digital Backbone

Various government initiatives and private investments in telecom and broadband networks are fuelling the growth of digital infrastructure in India. Such high-speed internet would be established across all sectors with the rollout of 5G technology, which is estimated to reach most urban and rural parts by 2025 to deploy AI-based solutions.

This will be built upon by improved digital connectivity, paving the way for a more efficient usage of service-oriented AI tools in agriculture, waste management, and renewable energy solutions, bridging the urban-rural divide and fostering inclusive growth.

Rising Awareness and Demand for Sustainability

Consumers, businesses, and policymakers in India are becoming conscious of the environmental costs of our actions. This increasing need for sustainability is a chance to roll out AI-enabled green technologies. The public and institutions will opt for AI technologies that provide energy savings, protect the environment, and reduce waste.

For example, increasing consumer demand for sustainable products and services to achieve environmental goals can lead enterprises to adopt AI to automate supply chain processes, waste reduction, and energy consumption efficiencies.

Strategic Recommendations

To exploit the opportunities and solve the challenges in deploying AI with green technologies in India, one must consider certain strategies – investment in training workshops and courses to sensitise farmers, waste management professionals, and renewable energy technicians on AI concepts; and speed up the installation of online infrastructure in rural and overlooked regions so that more people have access to AI-powered solutions.

Establish Strong Data Privacy and Security: Build confidence with stakeholders by developing strong data privacy and security frameworks that enable data sharing for AI applications.

Increased R&D: Promote R&D to develop innovative AI tech uniquely suited for India's use cases of green technologies.

Encourage government, private sector, academia, and civil society co-operations to learn from each other through AI and green tech best practices and resource sharing.

CONCLUSION

The use of next-generation technologies such as AI in green technologies can help in combating some critical environmental challenges facing India such as climate change, resource scarcity, and waste management. The implementation of AI enables the effective optimisation of renewable energy systems, increases the efficiency of waste management and recycling processes, and enhances sustainable agricultural practices, among others. These applications not only help make work faster, energy efficient, and less harmful to the environment but also

aid in increasing productivity and improving standards of living.

Despite this, the adoption of AI for green technologies in India is fraught with high upfront costs, poor digital infrastructure, worries regarding data privacy, lack of AI talent, and ambiguity on regulations. Addressing these challenges will necessitate a comprehensive approach such as policy backing, public-private collaboration, investing in digital infrastructure, and skill enhancements.

There exist vast opportunities for AI to be more widely embraced – enabled by government efforts, technological advancements, growing numbers of digital ecosystems, and the increasing need for sustainable procedures. Seizing these opportunities can place India on a pathway to sustainability, resilience, and inclusion.

India needs to invest strategically in R&D, collaboration, access to digital and physical infrastructure, and an enabling regulatory ecosystem to harness AI for scaling next-generation green technologies. In doing so, AI could act as a potent booster in India's pursuit of sustainable development, propelling the country into the vanguard of the green tech (GTECH) revolution.

In conclusion, better AI-powered green technologies would help India achieve and surpass its sustainability initiatives, go greener with cleaner tech, and reduce carbon emissions, leading to a healthier Earth for the children.

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