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Green Technology, Innovation and Digital Solutions for Climate Action

S.Thaslima Banu
Department of Economics
Sri Meenakshi govt Arts college for women (A)

Abstract- Climate change is one of the most critical global challenges of the 21st century, primarily driven by human activities since the 1800s, especially fossil fuel consumption for energy, industry, and transportation. Greenhouse gas emissions have raised the Earth's average surface temperature by approximately 1.2–1.3°C above pre-industrial levels, making 2015–2024 the warmest decade on record. Fossil fuels account for around 68% of global greenhouse gas emissions and nearly 90% of CO_2 emissions, driving extreme weather events, biodiversity loss, food insecurity, health risks, and the displacement of 45.8 million people due to weather-related disasters in 2024. This study critically examines the role of green technology, innovation, and digital solutions in mitigating climate change and advancing sustainable development, in alignment with the SDGs. A qualitative research approach was adopted, based on secondary data from peer-reviewed journals, international reports, and global case studies. Findings show that renewable energy, electric vehicles, and smart grids significantly reduce emissions, while AI, IoT, GIS, blockchain, and drones strengthen climate monitoring and disaster resilience. However, high investment costs, technological disparities, infrastructure gaps, and inconsistent policy support constrain large-scale adoption. The study concludes that stronger policies, increased green investments, and international collaboration are essential for a resilient, low-carbon, sustainable future.

Keywords- Climate Change, Green Technology, Digital Solutions, Climate Action, Sustainable Development, Renewable Energy.

I. Introduction

Climate change is one of the most important challenges facing the global economy. It is no longer possible to treat climate change only as an environmental problem because its effects are increasingly connected with production, employment, agriculture, infrastructure, energy security and public welfare. Climate-related risks can influence both the availability of natural resources and the cost of economic activity.

The scientific evidence for human-induced climate change is strong. The IPCC (2023) concluded that human activities, mainly through greenhouse-gas emissions, have unequivocally caused global warming. Global surface temperature during 2011–2020 was approximately 1.1°C above the 1850–1900 average. More recently, the WMO (2025) reported that 2024 was the warmest year in the 175-year observational record, with a global mean temperature of 1.55 ± 0.13°C above the 1850–1900 average. The WMO also noted that a single year above 1.5°C does not by itself mean that the long-term Paris Agreement temperature limit has been exceeded.

The economic effects of climate change occur through several channels. Agriculture can be affected by changes in rainfall, temperature and water availability. Extreme weather can damage roads, buildings, electricity networks and other infrastructure.

Higher temperatures can also create difficult working conditions, particularly for people working outdoors. These impacts can reduce productivity and increase the cost of development (IPCC, 2023).

At the same time, technological development provides important opportunities for climate action. Renewable energy can reduce dependence on fossil fuels, electric vehicles can support cleaner transportation, and energy-efficient technologies can reduce resource consumption. Green innovation can also create new products, services and employment opportunities.

Digital technologies provide another important dimension. Artificial intelligence can process large amounts of data, Internet of Things devices can collect information in real time, and Geographic Information Systems and remote sensing can help monitor environmental changes. These technologies can improve forecasting, resource management and climate-risk assessment.

However, technology should not be treated as an automatic solution. A technology may be technically successful but still fail to reach people because of cost, lack of infrastructure or limited skills. Therefore, the central issue is not simply whether new technology exists, but whether it is affordable, accessible, environmentally useful and economically practical.

This paper therefore examines the combined role of green technology, innovation and digital solutions in climate action, with particular attention to their economic implications and selected Indian initiatives.

II. Review of Literature

Renewable Energy and Economic Development

The relationship between renewable energy and economic growth has received considerable attention in environmental economics. Renewable energy is important because it can reduce dependence on fossil fuels while supporting long-term energy security.

Bhuiyan et al. (2022) conducted a systematic literature review of 46 peer-reviewed studies examining the relationship between renewable-energy consumption and economic growth. Their review found that renewable-energy consumption does not necessarily hinder economic growth in either developed or developing economies, although the relationship varies depending on the country and economic conditions. This finding is important because it challenges the idea that environmental protection and economic growth must always be competing objectives. Investment in renewable energy can also generate economic activity through manufacturing, construction, installation, maintenance and related services.

Green Innovation

Green innovation refers to the development and adoption of products, processes and practices that reduce environmental impacts. Examples include renewable-energy technologies, electric vehicles, energy-efficient equipment and cleaner production methods.

Rahmani et al. (2024) conducted a meta-analysis examining the relationship between green innovation and environmental performance. Their research identified green innovation as an important mechanism for improving environmental outcomes. Green innovation also has an economic dimension. New technologies can create new markets and business opportunities. At the same time, the benefits of innovation depend on access to finance, research capacity, skilled labour and supportive government policies.

Digital Technology and Climate Action

Digital technologies are increasingly being applied to climate monitoring and resource management. AI can support forecasting and optimisation, while IoT systems can collect real-time environmental information. GIS and remote sensing can provide spatial information for climate-risk assessment.

The usefulness of digital technology comes from its ability to convert large amounts of data into information that can support decision-making. For example, environmental data can be analysed to identify drought conditions, monitor crops or forecast energy demand. However, digital technologies also require electricity, computing infrastructure and skilled workers. Therefore, digitalisation should not automatically be considered environmentally sustainable. Its actual environmental and economic impact depends on how the technology is designed and used.

Research Gap

Existing studies provide valuable knowledge about renewable energy, green innovation and digital technology. However, these areas are often discussed separately.
This paper attempts to connect them through an integrated framework:
Green Technology → Green Innovation → Digital Intelligence → Climate Action → Economic Development
The framework suggests that climate technology can be more effective when clean technologies and digital systems work together rather than being developed independently.

Objectives of The Study

The study has the following objectives:

- To examine the role of green technology in climate-change mitigation.
- To analyse the contribution of green innovation to sustainable economic development.
- To examine the role of digital technologies in climate monitoring and adaptation.
- To identify major barriers to the adoption of green and digital technologies.
- To analyse selected Indian initiatives through case studies.
- To suggest policy measures for an inclusive green transition.

III. Methodology

The study adopts a qualitative research approach based on secondary data.
Information was collected from peer-reviewed journal articles, systematic literature reviews, international organisations and official government publications. Major sources include the IPCC, WMO, IEA, IRENA, ILO and the Government of India. The study uses literature synthesis to understand existing research, descriptive analysis to

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examine major technology trends and case-study analysis to examine selected Indian programmes. No primary survey or econometric model is used in this study. Instead, the paper brings together existing evidence and interprets it from an economic and sustainability perspective.

IV. Green Technology for Climate Action

Renewable Energy

Renewable energy is one of the most important technological pathways for reducing dependence on fossil fuels. Solar, wind and hydropower technologies can contribute to electricity generation with substantially lower direct greenhouse-gas emissions than fossil-fuel-based generation.The global expansion of renewable energy has accelerated considerably. The IEA (2025) reported that around 700 GW of renewable power capacity was added globally in 2024. Solar photovoltaic technology accounted for more than three-quarters of these additions, while wind accounted for a much smaller but still significant share. This expansion is important because it shows that renewable energy is moving from being a limited alternative technology to becoming a major part of the global energy system. Renewable energy can also create economic opportunities. Construction of solar and wind projects requires investment, engineering, installation and maintenance. As the sector expands, demand can also increase for manufacturing, technical services and specialised skills.

Electric Vehicles

Transportation is another sector undergoing rapid technological change. Electric vehicles can reduce direct dependence on petrol and diesel and support the wider electrification of transport.

According to the IEA (2026), global electric-car sales increased by about 20% in 2025 and exceeded 20 million vehicles. Approximately one in four new cars sold globally was electric.

The economic significance of electric mobility goes beyond vehicle production. The transition creates demand for batteries, charging infrastructure, software, power electronics, maintenance and recycling services.

At the same time, electric vehicles should not be considered independently from the electricity system. Their environmental benefits are influenced by how electricity is produced and how batteries are manufactured and managed. Therefore, EV policies should be connected with renewable electricity and responsible battery-management systems.

Energy Efficiency

Climate action does not only mean producing more clean energy. Reducing unnecessary energy consumption is equally important. Energy-efficient buildings, appliances, industrial machinery and transportation systems can reduce energy use while continuing to provide useful services. For businesses, efficiency can reduce operating costs. For households, efficient appliances and buildings can potentially reduce energy expenditure. Energy efficiency is therefore an important link between environmental protection and economic performance.

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Smart Grids

The expansion of solar and wind energy creates new challenges for electricity-system management because renewable generation can change according to weather conditions. Smart-grid technologies can help electricity systems respond to these changes. Digital monitoring, demand management, renewable-energy forecasting and energy storage can improve system flexibility. Therefore, the clean-energy transition is not simply about building more renewable-energy plants. It also requires investment in transmission networks, storage and digital management systems.

V. Green Innovation and Economic Development

Green innovation can be broadly understood in three forms: product innovation, process innovation and business-model innovation. Green product innovation includes solar panels, electric vehicles, energy-efficient appliances and advanced batteries. Green process innovation focuses on reducing energy use, waste, water consumption and emissions during production. Business-model innovation includes shared mobility, renewable-energy services and circular-economy models. Green innovation can create economic opportunities because environmental problems themselves can create demand for new solutions. Research supports this connection. Rahmani et al. (2024) found evidence linking green innovation with improved environmental performance. This suggests that innovation can play a role in reducing environmental pressure while supporting technological development.

Employment is another important dimension. IRENA and ILO (2024) reported that global renewable-energy employment increased from 13.7 million in 2022 to 16.2 million in 2023, an increase of 18%. However, the distribution of these jobs remains uneven across countries. Therefore, green growth requires not only investment but also education and skill development. A successful green transition should create opportunities for workers who may be affected by changes in traditional energy and industrial sectors. This makes the concept of a just transition important.

VI. Digital Solutions for Climate Action

Artificial Intelligence

Artificial intelligence can analyse large datasets and identify patterns that are difficult to detect using traditional methods. Climate-related applications include weather forecasting, energy-demand prediction, renewable-energy forecasting, disaster-risk assessment and agricultural monitoring. For example, AI can combine historical weather information with current environmental data to improve predictions. Better predictions can help farmers, electricity providers and disaster-management authorities make earlier decisions.

However, AI should not automatically be classified as a green technology. AI systems require computing power, data centres and electricity. Its climate benefit depends on the purpose of the application and the efficiency of the underlying infrastructure.

Internet of Things

The Internet of Things connects physical devices and sensors to digital systems.

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In agriculture, IoT sensors can provide information about soil moisture, temperature and other environmental conditions. Such information can help farmers make more informed irrigation decisions.

The process can be understood simply:

Sensor → Data → Analysis → Decision → Resource Management

IoT can also support smart buildings, water management, waste management and energy monitoring.

GIS and Remote Sensing

Geographic Information Systems and remote sensing are valuable tools for understanding environmental changes across large geographical areas.They can be used for flood-risk mapping, drought monitoring, forest monitoring, land-use analysis, coastal-risk assessment and crop monitoring. When satellite information is combined with GIS and AI, environmental data can be transformed into location-specific climate information. This can support both government planning and local decision-making.

Digital Agriculture

Agriculture is particularly vulnerable to changes in rainfall, temperature and water availability. Digital technologies can help farmers respond to these changes.

A digital agriculture system may combine IoT sensors, satellite data, GIS and AI. Sensors provide local information, satellites provide broader geographical information, GIS identifies spatial differences and AI can analyse patterns.

This can support irrigation management, crop monitoring, weather-based decisions and resource efficiency.

However, digital agriculture also illustrates the digital divide. Small farmers may face difficulties related to internet connectivity, device costs, technical knowledge and access to digital services. Therefore, digital agricultural solutions should be designed around affordability and accessibility rather than only technical sophistication.

VII. India's Green Technology Transition

India provides an important example of the connection between climate action, energy demand and economic development.

India has expanded renewable-energy capacity rapidly in recent years. According to MNRE (2026), total renewable-energy capacity reached 288.59 GW as of 30 June 2026. Solar capacity reached 162.15 GW and wind capacity reached 57.44 GW.

Solar energy has therefore become a major part of India's renewable-energy transition. This expansion can support energy diversification while creating opportunities in project development, installation, manufacturing and maintenance.

India's transition is also important because the country has to balance economic development, rising energy demand and climate commitments. This makes affordable and scalable clean technologies particularly important.

Case Study I: Pm Surya Ghar – Muft Bijli Yojana

PM Surya Ghar – Muft Bijli Yojana is an important example of decentralised renewable-energy adoption in India.

The programme promotes rooftop solar systems for residential households. Its importance lies in bringing renewable-energy generation closer to individual consumers rather than relying only on large power plants. The programme can change the traditional relationship between the household and the electricity system. Instead of being only a consumer, a household can also generate electricity through rooftop solar.

The basic model is:

Household → Rooftop Solar → Electricity Generation → Household Consumption

The programme also has economic implications because rooftop solar creates demand for installation, maintenance and related technical services. However, the success of rooftop solar depends on financing, consumer awareness, installation quality, grid connectivity and after-sales service. Therefore, policy support needs to extend beyond subsidies and include reliable implementation.

Case Study II: Pm-Kusum And Solar Agriculture

PM-KUSUM is significant because it connects renewable energy with agriculture. The scheme supports decentralised renewable-energy plants, standalone solar agricultural pumps and solarisation of grid-connected agricultural pumps. Its importance comes from the fact that agriculture requires reliable energy for irrigation. Solar technology can therefore connect climate policy with rural economic activity.

The economic pathway can be understood as:

Solar Energy → Agricultural Energy → Reduced Conventional-Energy Dependence → Rural Economic Benefits

The programme demonstrates that renewable energy can serve purposes beyond electricity generation. It can become part of rural development and agricultural infrastructure. However, technology adoption alone is not sufficient. Farmers also need maintenance services, financing, reliable equipment and technical support. Without these supporting systems, the benefits of solar irrigation may not be evenly distributed.

VIII. Economic Benefits of Green and Digital Technologies

Employment

The green transition can create employment in manufacturing, construction, installation, operation, maintenance, engineering and research.

Global renewable-energy employment reached 16.2 million in 2023, compared with 13.7 million in 2022 (International Renewable Energy Agency [IRENA] & International Labour Organization [ILO], 2024).

This demonstrates that climate action can create employment opportunities when supported by investment and appropriate skills policies.

Investment

Renewable energy, batteries, electric vehicles, charging infrastructure, smart grids and digital climate services can create new areas for public and private investment. Investment in these areas can also encourage technological learning and the development of domestic industries.

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Energy Security

Greater use of domestic renewable resources can reduce exposure to international fossil-fuel price fluctuations. Energy security is particularly important for countries that depend heavily on imported fossil fuels. Renewable energy can therefore have both environmental and economic value.

New Industries

The green transition is creating new economic sectors, including battery manufacturing, EV charging, solar manufacturing, recycling, climate analytics and energy-management services. This means climate policy can also support industrial development when countries develop domestic skills and production capacity.

IX. Challenges

High Initial Cost

Many green technologies require significant initial investment. Even when a technology produces long-term savings, the upfront cost can prevent households, farmers and small businesses from adopting it.

Infrastructure Gaps

Renewable energy requires transmission networks, storage systems and modern electricity grids. Electric vehicles require charging infrastructure. Digital climate solutions require reliable internet connectivity and computing infrastructure. Therefore, technology adoption depends heavily on complementary infrastructure.

Digital Divide

The benefits of digital climate technologies are not automatically shared equally. Rural communities and low-income households may have less access to devices, internet services and digital skills. This creates a risk that technological progress could increase existing inequalities.

Skill Shortages

The green economy requires workers with new combinations of technical, environmental and digital skills. Educational institutions therefore have an important role in preparing students for emerging green industries.

Policy Uncertainty

Investments in renewable energy and other clean technologies often involve long payback periods. Investors therefore need stable and predictable policies. Frequent policy changes can increase uncertainty and reduce investment incentives.

Data & Cybersecurity

Digital climate systems create new concerns about data security, privacy and cybersecurity. As more infrastructure becomes connected, protecting digital systems becomes increasingly important.

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Unequal Distribution of Benefits

Technological benefits can initially be concentrated among larger firms and higher-income consumers. Therefore, climate policy should focus not only on technological growth but also on who can access and benefit from that growth.

X. Findings and Discussion

The study identifies several important findings.

First, renewable energy has moved into large-scale global deployment. Around 700 GW of renewable power capacity was added globally in 2024, with solar PV accounting for more than three-quarters of the additions (IEA, 2025). This indicates that renewable energy is becoming a central component of the global energy transition.

Second, electric mobility is expanding rapidly. Electric-car sales exceeded 20 million globally in 2025, and approximately one-quarter of new cars sold were electric (IEA, 2026). This demonstrates that technological change in transport is already occurring at a significant scale.

Third, green innovation can contribute to environmental improvement while creating new economic opportunities. Research indicates a positive role for green innovation in environmental performance (Rahmani et al., 2024).

Fourth, digital technologies can strengthen climate action by improving information. AI, IoT, GIS and remote sensing can help convert environmental data into useful decisions.

Fifth, technology does not operate independently of economic and social conditions. Finance, infrastructure, skills and policy support determine whether technology can be adopted successfully.

The overall relationship can therefore be understood as:

Green Technology
↓
Green Innovation
↓
Digital Intelligence
↓
Climate Mitigation and Adaptation
↓
Investment, Employment and Resource Efficiency
↓
Sustainable Economic Development

The main implication is that climate technology should be approached as a system rather than as a collection of separate products.

XI. Policy Suggestions

Increase Green Research and Development

Governments should encourage research in renewable energy, energy storage, smart grids, green hydrogen and climate-smart agriculture.

Expand Green Finance

Affordable finance should be made available to households, farmers, small businesses and start-ups adopting climate-friendly technologies.

Develop Green Skills

Educational institutions should strengthen courses that combine economics, environmental studies, technology and data analysis.

Improve Rural Digital Infrastructure

Digital climate solutions should be supported by better connectivity, affordable services and digital-literacy programmes.

Promote Domestic Manufacturing

India can strengthen domestic capabilities in solar equipment, batteries, EV components and other clean technologies.

Focus on Inclusive Technology

Climate technology should be designed for different income groups and not only for large companies or high-income consumers.

Maintain Policy Stability

Stable and predictable policies can encourage long-term private investment in renewable energy and other green sectors.

Strengthen International Cooperation

Developing countries need access to finance, technology and technical knowledge. International cooperation can support technology transfer and capacity building.

XII. Conclusion

Climate change is an environmental challenge with major economic and developmental consequences. The evidence discussed in this paper shows that green technology, innovation and digital solutions can provide important opportunities for addressing these challenges.

Renewable energy is expanding rapidly at the global level, while electric vehicles are becoming an increasingly important part of the transportation system. Green innovation is supporting new products, processes and industries, and renewable-energy expansion is already associated with millions of jobs globally (IRENA & ILO, 2024).

Digital technologies add another important dimension. AI, IoT, GIS and remote sensing can improve climate monitoring, forecasting and resource management. When these technologies are combined with renewable energy and green innovation, they can contribute to more effective climate action.

India's experience demonstrates the practical importance of this transition. The rapid growth of solar and wind capacity, along with initiatives such as rooftop solar and solar-powered agricultural applications, shows how climate technology can be connected with household energy and rural development.

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At the same time, the transition is not free from challenges. High initial costs, infrastructure gaps, skill shortages, digital inequality and policy uncertainty can limit adoption. Technology can therefore create opportunities, but it cannot guarantee sustainable development by itself.

The most important conclusion of this study is that climate action requires an integrated approach:
Green Technology + Innovation + Digitalisation + Finance + Skills + Inclusive Policy
The objective should not simply be to create a technologically advanced economy.