

## 12. The Green Evolution Through Technological Advancements

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### **Abstract:**

*The article explores the intersection of green evolution and technology, delving into the transformative power of technological innovations in fostering sustainability and environmental stewardship. In this write up, we will cover a comprehensive range of topics that enumerate the symbiotic relationship between technology and the green movement.*

*This comprehensive exploration aims to provide a deep understanding of how technology is driving the green evolution and shaping a more sustainable future. Different sections offer a holistic view of the intricate relationship between green evolution and technology.*

### **Keywords:**

*Green evolution, Sustainability, Renewable energy, FiTs, Sustainable practices*

### **12.1 Introduction:**

In an era where environmental challenges loom large on the earth horizon, the synergy between technology and the green evolution stands as a beacon of hope. The Comprehensive Exploration of Green Evolution and Technology embarks on a journey to unravel the intricate interplay between technological advancements and the pressing need for sustainable practices. As the world grapples with the impacts of climate change and dwindling natural resources, the function of technology becomes paramount in charting a course toward a greener and more sustainable future.

The term "Green Evolution" encapsulates a dynamic shift in societal paradigms, emphasizing a devotion to environmentally conscious practices and the pursuit of sustainable solutions [1-4]. This evolution transcends mere rhetoric, manifesting in a collective effort to redefine how we interact with our planet. It includes a spectrum of initiatives, policies, and innovations aimed at mitigating environmental impact, conserving biodiversity, and fostering a circular economy. In the green evolution technologies have a crucial role.

From harnessing renewable energy to revolutionizing transportation and reimagining waste management, technology emerges as a linchpin in our quest for a sustainable future. It is not merely a tool but a spark for innovation, stretching the limits of what is possible and challenging industries to embrace greener alternatives [5-8].

## **12.2 Objectives of the Comprehensive Exploration:**

The Comprehensive Exploration of Green Evolution and Technology seeks to dissect, analyze, and illuminate the complex connection between environmental sustainability and economic growth [9, 10]. Through a meticulous examination of key topics, this exploration aims to:

- **Highlight Technological Innovations:** Showcase groundbreaking technologies that are reshaping the landscape of sustainability across various sectors.
- **Examine Real-world Impacts:** Delve into tangible examples where the combination of green principles and technology has yielded positive environmental outcomes.
- **Identify Challenges and Solutions:** Explore the hurdles along with ethical considerations connected with the green evolution, while also proposing innovative solutions to overcome them.
- **Anticipate Future Trends:** Peer into the crystal ball of technological advancement to discern the emerging trends that hold the promise of further propelling the green evolution.

## **12.3 Overview of the Green Evolution:**

The term "Green Evolution" does not refer to a specific, universally recognized concept or initiative. However, the term is often used within the frame work of various movements, policies, and technologies aimed at promoting ecological durability and addressing climate change [11, 12]. Since the word is a broad term, some key aspects regarding "Green Evolution" is the following.

- Renewable Energy Transition:*** The change towards sustainable and green energy sources for example solar, wind, hydro, and geothermal, is a crucial component of many green initiatives. Countries and regions worldwide have been spending in renewable energy infrastructure to reduce dependence on fossil fuels and decrease carbon emissions.
- Green Technologies:*** The development and uptake of environmentally friendly technology across various industries is highly needed in reducing environmental impact. This includes advancements in energy-efficient technologies, electric vehicles, sustainable agriculture practices, and eco-friendly manufacturing processes.
- Environmental Policies:*** Governments and international organizations are applying policies and regulations to promote environmental sustainability. This includes emissions reduction targets, carbon pricing mechanisms, and other measures to encourage businesses and individuals to adopt environmentally friendly practices.
- Circular Economy:*** The idea of a circular economy emphasizes reducing waste and promoting the effective use of resources. It involves recycling, reusing, and lowering the consumption of materials, contributing to a more persistent and eco-friendly approach to economic development.
- Conservation and Biodiversity:*** Efforts to preserve ecosystems, protect endangered species, and promote biodiversity are essential components of a green agenda. Conservation initiatives aim to keep the balance of ecosystems and safeguard the planet's natural resources.

- f. **Climate Action:** International agreements, such as the Paris Agreement, focus on global efforts to mitigate climate change. Countries commit to cut down GHG emissions and working collectively to limit global temperature increases.
- g. **Public Awareness and Education:** The green evolution involves educating the public about environmental issues and promoting sustainable lifestyles. Education and communication have an important role in inspiring individuals and communities to make environmentally conscious choices.

During the 1960s, M. S. Swaminathana, an agricultural scientist, led India's Green Revolution, which involved implementing technology to transform agriculture into an advanced industrial system [13].

This included the automated farm tools, modern irrigation systems, bio fertilizers, use of high yielding variety (HYV) seeds, and high-quality pesticides.

## **12.4 Technologies for Green Energy:**

Technologies for Green Energy are the change away from fossil fuels and mitigating the effect of energy production on our environment [14, 15]. Here's an overview of three key renewable energy technologies:

### **A. Solar Power: Advancements and Implementation**

- a. **Photovoltaic (PV) Technology:** Solar panels use semiconductor materials to convert sunlight into electricity. Advancements in PV technology include improvements in efficiency, durability, and cost-effectiveness. Thin-film solar cells and next-generation materials contribute to expanding the applications of solar energy.
- b. **Solar Thermal Technology:** Concentrated solar power (CSP) systems use mirrors or lenses to concentrate sunlight onto a small area, producing heat that can generate electricity. CSP systems are generally installed for large-scale power plants.
- c. **Implementation:** Solar power is widely implemented in residential, commercial, and utility-scale projects. The growth of solar farms, rooftop solar installations, and solar-powered devices demonstrates the increasing adoption of solar energy globally. Solar PV ranked the third largest renewable electricity technology producing 4.5% of world's total electricity.

### **B. Wind Energy: Harnessing the Wind for a Greener Future**

- a. **Onshore Wind Turbines:** Large wind turbines convert the kinetic energy of wind into electricity. Advances in turbine design, materials, and control systems have increased efficiency and reduced costs.
- b. **Offshore Wind Farms:** Placing wind turbines offshore takes advantage of stronger and more consistent winds. Offshore wind turbines have much bigger dimensions. The concept of offshore wind farms, consisting of an array or cluster of wind turbines, is generally recognized as a green and sustainable energy source that may effectively lower GHG and advance the goal of zero carbon emission. [16]

- c. **Wind Energy Storage:** Storage solutions, such as advanced batteries, help address the intermittent nature of wind energy. Energy storage systems store excess energy when the wind is strong and release it when the wind is low.

As per the 2023 Global Wind Report by GWEC, the total installed capacity worldwide increased to 906 GW, signifying a 9% annual growth (<https://gwec.net>). The capacity of wind power increased by around 78 GW last year. This achievement was made possible in spite of a difficult economic climate, worldwide supply chain disruption and the simultaneous global health and energy crises.

### **C. Hydroelectric Power: Sustainable Water-Based Energy**

- a. **Conventional Hydroelectric Power:** Dams and reservoirs are used to store and release water, which flows through turbines to generate electricity. This technology has been in use for decades and remains a major source of renewable energy.
- b. **Run-of-River Hydroelectricity:** This type of hydroelectric power does not require large reservoirs. Instead, it utilizes the natural flow of rivers to generate electricity, minimizing the environmental impact.
- c. **Pumped Storage:** This technology involves pumping water uphill to a reservoir during times of low electricity demand and releasing it to generate electricity during peak demand.
- d. **Implementation:** Hydroelectric power is a well-established and widely implemented technology, providing a significant portion of global electricity. It is especially prevalent in countries with abundant water resources. Since hydroelectricity is the largest source of clean energy in the world but more frequent droughts and high temperatures would increase the risk to energy security and necessitate fossil fuels to generate additional power [17].

### **D. Renewable Energy Incentives: Feed-in Tariffs (FiTs)**

Governments incentivize investment in the projects of renewable energy including solar, hydro power and wind, by providing guaranteed payments to renewable energy producers. The tariff is usually intended to decrease over time in order to monitor and promote technological advancement. It may vary depending on technology, location, size, and area. FITs often provide producers with incentives to enhance output and efficiency and also guaranteed purchasing agreement for extended periods of time (15–25 years). The set rate for photovoltaic solar installations is ₹ 17.90/kWh in India. For solar thermal installations, the tariff is set at ₹15.40/kWh [18]. Periodically, the Central Electricity Regulatory Commission, or CERC, will review the tariff.

These renewable energy technologies contribute to diversifying energy sources, lowering greenhouse gas (GHG) emissions, and encouraging a more stable and sustainable energy infrastructure.

Continued research and implementation of innovative ideas will continue to get better efficiency, decrease costs, and enhance the entire amount from the world's energy mix to renewable energy.

## **12.5 Green Building Technologies:**

Green building technologies have a significant role in promoting energy efficiency, sustainability, and environmental responsibility in the construction and operation of buildings.

Here's an overview of sustainable architecture and smart homes giving priority on energy efficiency:

**a. *Passive Design Principles:*** Sustainable architecture incorporates passive design principles that optimize the building's orientation, layout, and natural ventilation to reduce the requirement for mechanical heating and cooling.

**b. *Energy-Efficient Materials:*** The choice of eco-friendly and energy-efficient building materials is a cornerstone of sustainable architecture. This includes recycled materials, locally sourced materials, and those with low embodied energy.

**c. *Green Roofs and Walls:*** Incorporating green roofs and walls promotes energy efficiency by providing insulation, reducing the urban heat island effect, and promoting biodiversity.

**d. *Day lighting:*** Maximizing natural daylight through well-designed windows and skylights reduces the reliance on artificial lighting, enhancing energy saving measure and occupant well-being. Use of Low-E windows help to block infrared light and keep interior of the building cool in the summer.

**e. *Renewable Energy Integration:*** Sustainable buildings often include renewable energy sources, usually wind turbines and roof top solar panels to generate clean and on-site power.

**f. *Water Conservation:*** Sustainable architecture emphasizes water-efficient fixtures, rainwater harvesting systems, shower regulator, Faucet Aerators, deep irrigation and other technologies to reduce water consumption and promote conservation.

**g. *Home Automation Systems:*** Smart homes integrate automation systems that allow residents to regulate and monitor various electronic devices of their homes, including light, fan, room heater, air circulation, air conditioning (HVAC), and security.

**h. *Monitoring and Analytics:*** Smart home systems give homeowners access to real-time analytics and data on energy use, enabling them to make proper decisions for energy use and conservation.

**i. *Building Codes and Standards:*** In order to lower energy usage and encourage the use of energy-efficient technology, governments set energy efficiency requirements for structures and appliances. The criteria for controlling building construction activities throughout the nation are maintained by the National Building Code of India (NBC). All agencies engaged in building construction, whether they are public, government, municipal authorities, or private construction agencies, are required to accept it as a Code Model. The Code primarily consists of asset and facility management, building and plumbing services, development

control requirements, administrative rules, structural design and construction including safety. The Code was initially published in 1970. It underwent a second review in 2005, and in 2015, two modifications were released. (<https://www.bis.gov.in>).

The combination of sustainable architecture and smart home technologies adds to the creation of buildings that are energy-efficient, environmentally friendly, and comfortable for occupants.

These methods will probably be integrated more widely and smoothly as technology develops, which will improve the built environment's sustainability even more.

## **12.6 Precision Agriculture and Sustainable Food Production:**

Precision agriculture and sustainable practices in agriculture are essential components of modern farming methods aimed at optimizing crop yields with minimum environmental impact. Here's an overview of both:

### **A. Precision Farming: Optimizing Crop Yields with Technology**

Precision agriculture involves using to maximize a range of agricultural productivity factors. It uses site-specific, data-driven management to boost farming techniques' sustainability, productivity, and efficiency.

Key technologies are the following:

- a. **Global Positioning System (GPS):** GPS technology enables precise mapping and tracking of field conditions, allowing farmers to create accurate field maps and plan their activities with high precision.
- b. **Sensors and IoT Devices:** Real-time data on soil parameters, crop growth, and meteorological variables are provided by a variety of sensors, including soil sensors, temperature sensors, moisture sensors, drones, and satellite photography. This information helps the farmers to make well-informed decisions regarding pest management, fertilization, and irrigation.
- c. **Variable Rate Technology:** This technology allows farmers to apply inputs (such as water, fertilizers, and pesticides) at variable rates across a field, depending on the specific needs of different areas. This maximizes resource efficiency and minimizes waste.
- d. **Automated Machinery:** Tractors and other farm machinery outfitted with automation technologies, such as autosteer systems, improve the precision of field operations, reducing overlap and optimizing fuel use.
- e. **Data Analytics:** Advanced data analytics tools process large datasets to provide insights into trends, patterns, and correlations, helping farmers to make decisions in a right way.

Benefits from Precision Farming include higher yields from crops and resource efficiency, reduced use of inputs (water, fertilizers, pesticides) through targeted application, improved soil health, reduced environmental impact and enhanced farm management

## **B. Sustainable Practices in Agriculture:**

- a. **Agroecology:** Agroecological practices focus on creating innovative model after natural ecosystems. This includes crop diversification, intercropping, and the integration of livestock, contributing to improved soil health and biodiversity.
- b. **Conservation Tillage:** Reduced or no-till farming methods minimize soil disturbance, helping to retain moisture, prevent erosion, and preserve soil structure.
- c. **Cover Cropping:** Planting cover crops during the off-season helps prevent soil erosion, suppress weeds, and improve soil fertility by adding organic matter.
- d. **Integrated Pest Management (IPM):** IPM combines biological, cultural, and chemical control methods to manage pests in an eco-friendly way to optimizing the pesticides use.
- e. **Water Conservation Practices:** Efficient irrigation systems, such as drip irrigation, and technologies like soil moisture sensors, enable farmers to optimize water use and reduce water waste.
- f. **Organic Farming:** Organic farming avoids synthetic pesticides and fertilizers, emphasizing natural processes to enhance soil fertility and control pests.
- g. **Agroforestry:** Planting suitable trees into agricultural landscapes helps sequester carbon, improve biodiversity, and also offer further sources of revenue for farmers.
- h. **Precision Agriculture Integration:** Sustainable agriculture often incorporates precision farming technologies to optimize resource use and minimize environmental impact.
- i. **Certification Programs:** Various certification programs, such as organic and sustainable agriculture certifications, promote and verify adherence to environmentally friendly farming practices.

Both sustainable practices and precision farming assist in the growth of farming systems that are socially and ecologically responsible additionally being commercially feasible. The integration of technology with sustainable farming practices holds the capacity to solve issues with global food security while minimizing the ecological footprint of agriculture.

### **12.7 Biodiversity Conservation and Monitoring:**

Biodiversity conservation is a significant aspect of environmental sustainability, and technology which has a vital role to monitor and protect biodiversity. Here's an overview, regarding the function of technology, conservation drones, and wildlife tracking:

- a. **Remote Sensing:** Satellite imagery and remote sensing technologies provide valuable data for monitoring changes in land cover, deforestation, and habitat loss. This information is essential for assessing the effect of human activities on biodiversity. Satellite tags attached to marine animals transmit data on their location and migration routes, aiding study on the marine biodiversity.
- b. **Geographic Information System (GIS):** GIS technology helps researchers and conservationists map and analyze spatial data, allowing for better decision-making in habitat management, restoration, and protection. Wildlife fitted with GPS collars or tags allow researchers to monitor animal movements, migration patterns, and habitat use.
- c. **Camera Traps:** Motion-activated cameras placed in natural habitats capture images and videos of wildlife, offering insights into species behavior, distribution, and population dynamics. Unmanned Aerial Vehicles (UAVs) or drones are employed for surveillance

to detect and prevent illegal activities such as poaching and deforestation and also provide a bird's-eye view of ecosystems, enabling rapid surveys of large areas for monitoring changes in habitat and wildlife populations.

- d. **Acoustic Monitoring:** Specialized microphones and sensors capture sounds in ecosystems, enabling researchers to study animal vocalizations, track migration patterns, and assess biodiversity based on acoustic data. Several pilot projects on bioacoustics are running by NINA (Norwegian Institute for Nature Research) from 2018.
- e. **DNA Barcoding:** Paul Hebert created DNA barcoding in 2003 as a way to sequence a standardized short DNA fragment, or "DNA barcode," for identifying a wide variety of species [19]. DNA analysis is used for species identification, tracking illegal wildlife trade, and understanding genetic diversity within populations.
- f. **Citizen Science Apps:** Mobile apps engage the public in biodiversity monitoring, allowing users to report sightings of plants, animals, and insects. This crowd sourced data contributes to broader research efforts.
- g. **Artificial Intelligence and Machine Learning:** These technologies analyze large datasets to find trends and patterns in biodiversity. AI is applicable to different species identification, monitoring, and predicting the effect of climate change on ecosystems.

## **12.8 Case Studies: Real-world Examples of Successful Green Technology**

### **A. Solar City (Tesla Solar):**

Solar City, founded by Elon Musk's cousins, pioneered solar leasing programs that made solar power accessible to homeowners without the upfront costs [20]. The company's innovative financing model has significant contribution to the widespread adoption of residential solar installations. Tesla's acquisition of Solar City further integrated solar energy solutions with energy storage technologies [21, 22].

### **B. Copenhagen's Wind Power Strategy:**

In 1973, Denmark's energy mix was remarkably dependent on oil, accounting for almost 90% of its energy supply was imported. Copenhagen, Denmark, implemented an ambitious wind power strategy, aiming to become carbon-neutral by 2025 [23].

The city invested in wind turbines, both onshore and offshore, and established wind farms. The strategy not only minimizes carbon emissions but also created jobs and positioned Copenhagen as a global leader in sustainable urban development.

### **C. Waste-to-Energy in Sweden:**

Sweden has advanced significantly in lowering GHG emissions and managing trash. 99% of its municipal solid waste is used for energy production or recycling, with less than 1% going to landfills. Sweden's waste management model is an example of turning a potential environmental issue into a sustainable energy solution [24]. These case studies illustrate the potential benefits that properly integrating green technology may have for both the economy and the environment.



## **12.9 Discussion:**

The term "green technology innovation" refers to the evolution of environmentally friendly inventions with the object of limiting environmental damage and conserving natural resources. The 2030 Agenda for Sustainable Development was endorsed by the UN General Assembly in September 2015, and it lays forth a revolutionary vision for the 193 UN Member States that have approved it regarding economic, social, and environmental sustainability (<https://sdgs.un.org/2030agenda>). In particular, since the International Standard Organization published its environmental management standards in the 14000 series, green technology is considered a cutting-edge technological paradigm that might support businesses in achieving long-term success [25]. For creating eco-friendly environment for future generations, green technology is essential. Even though the world is progressing well towards green technology, more work has to be done. We need to start considering the effects of what we do and start achieving our main goal, which is to save the Earth from further damage.

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