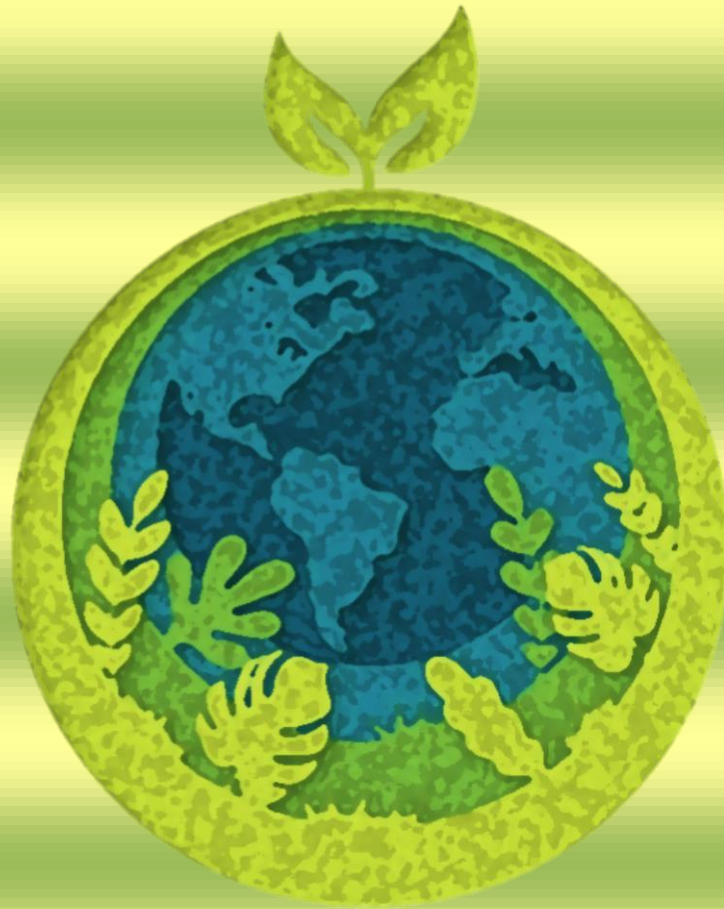


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OUR POWER, OUR PLANET



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CLIMATE JUSTICE AND EQUITABLE ACCESS TO CLEAN ENERGY

P G Dhar Chakrabarti

Swami Vivekananda Chair Professor on Environment and Disaster Management

Climate justice: Climate justice refers to the unequal impacts of climate change on countries, and within countries among various sections of population based on income, wealth, occupation, gender, age, disability etc. Climate justice seeks to achieve an equitable distribution of both the burdens of climate change and the efforts to mitigate and adapt to climate change. Climate justice is enshrined in the principle of "common but differentiated responsibilities and respective capabilities" of the UN Framework Convention on Climate Change and further reiterated in Paris Agreement on Climate Change.

However, the track records of delivering climate justice has been dismal. Industrialized countries of America, Europe, Japan and Australia have failed in reducing production and consumption of energy based on fossil fuels. Emerging economies of China, India, Brazil, Mexico, Indonesia and South Africa are burning coal, oil and gas in a scale that have broken all previous records. World is dangerously close to the tipping point of 1.5^oC rise in average surface temperature compared to the pre-industrial era. Glaciers around the world are melting, sea levels rising, and precipitation patterns changing, affecting water resources and agriculture, threatening food security, forestry and bio-diversity, and pushing global burden of diseases to unprecedented levels. The poor, vulnerable and marginal communities, especially in small islands, deltas, coastal areas, mountains and desert areas are facing the climate crisis with rise in frequencies and intensities of extreme and slow onset climatic events, resulting in irreparable damage and losses. Countries and communities that contributed the least to greenhouse gas emissions are bearing the brunt of maximum adverse impacts

There is growing clamor for climate justice all over the world, among the countries and communities at risk, civil society groups and especially among the youth who are at the forefront, fighting for climate justice. Developed countries are



cutting down fossil based energy and switching over to renewables at a cost, and are pushing developing countries to follow the same trajectory without offering them the promised support of finance and technology, driving them to starve on their energy needs for development. Climate justice does not mean that energy needs are frozen.

Equitable access to clean energy: Access to clean energy is crucial for social and economic development. It is directly linked to health, education, employment and economic growth. However, millions of people worldwide still lack access to electricity, relying on polluting and inefficient energy sources such as kerosene, biomass, and coal.

This energy poverty exacerbates inequalities and limits opportunities for economic and social advancement. UN Sustainable Development Goal 7 aims to ensure access to affordable, reliable, and sustainable energy for all.

There has been some progress in this direction - in 2010 nearly 1.2 billion people were without any access to electricity; today this has come down to 737 million, but in some countries the access rate is as low as 19 percent. Often there is access, but no assurance of continuous and quality supply of power that can at least lit the homes during night and support television and mobile charger. Urban-rural gap in access to electricity is still significant. Over 80% of world population without electricity live in rural areas.

Some 2.3 billion people still cook with unsafe and polluting fuels, contributing to air pollution and worsening health impacts. Women and children are disproportionately affected. The combined effects of ambient and household air pollution lead to an estimated 7 million deaths each year and are linked with many diseases.

Higher access to electricity has also come with an increase in greenhouse gas emissions. SDG target 7.2 seeks to reverse this trend and increase the use of renewables. Around 60 percent of electricity worldwide is generated from fossil fuels, around 10 percent came from nuclear power, and the remaining 30 percent from renewable sources like solar, wind, hydro, and geothermal. Around 10 percent of the world's electricity is generated from wind and solar.

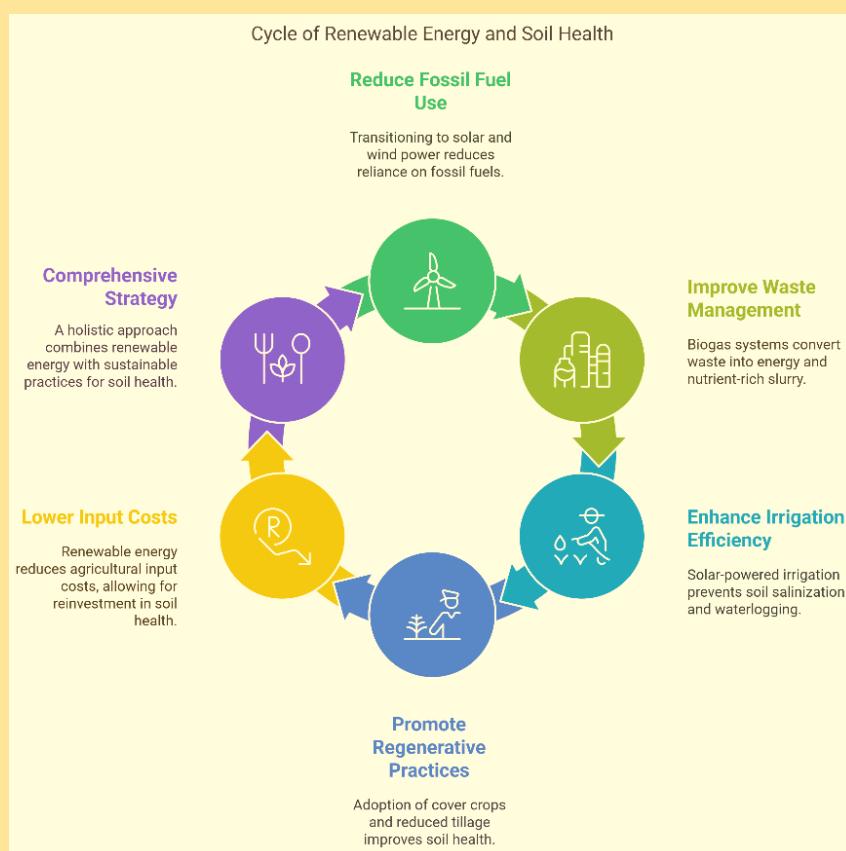
In many low-income countries in Africa and Asia, without universal access to electricity, solar energy have the potential to provide expanded access to affordable, reliable, and sustainable energy for all. Instead of following the typical path of investing in fossil fuels and then transitioning to renewables, these countries could move straight away to cleaner energy. Sub-Saharan Africa, in particular, has the potential to become a solar energy powerhouse of the world. Solar grid connecting the two hemispheres can ensure round the clock supply of solar energy that can simultaneously reduce dependence on fossil fuels and boost the economy of many low-income countries, in not so distant future, thus promoting climate justice.

EFFECTS OF FARMING POWERED BY RENEWABLE ENERGY ON SOIL HEALTH

Dr. Sudipta Tripathi

Assistant Professor, School of Environment and Disaster Management, RKMVERI

Renewable energy solutions are becoming more and more important as the world's agriculture industry manages the dual demands of climate change and the need to feed a growing population sustainably. In addition to its obvious environmental advantages, renewable energy sources can both directly and indirectly improve soil health, which is a crucial component of ecosystem stability and food security. A range of technologies, such as solar panels, wind turbines, methane digesters, and small-scale hydropower systems, are used in farming to provide renewable energy. In order to decrease greenhouse gas emissions, lessen dependency on fossil fuels, and build more robust energy systems is essential. The term “soil health” describes the soil's ongoing ability to support humans, animals, and plants as a viable living ecosystem—healthy soils cycle nutrients, filter pollutants, support plant and animal life, and control water. Unfortunately, over-tillage, mono-cropping, and the overuse of chemical pesticides and fertilizers have all negatively impacted soil in modern industrial agriculture. More than one-third of the world's arable land is impacted by soil degradation, which is further aggravated by erosion, nutrient depletion, salinization, and loss of organic matter. One of the most important goals of sustainable farming today is restoring the health of the soil, and renewable energy helps to achieve this goal in several ways.



Benefits of renewable energy for soil health:

Reduction of soil contamination and fossil fuel use: The risk of soil contamination from fuel spills and emissions can be decreased by switching to solar or wind-powered equipment in place of diesel generators and other fossil fuel-powered equipment. The decomposition of organic matter and the cycling of nutrients depend on microbial life in the soil, which fossil fuel leftovers can disturb.

Better Management of Waste and Manure: Animal dung and crop waste are converted by biogas digesters into biogas slurry for soil enrichment and biogas for energy. This preserves soil structure and nearby rivers by reducing runoff from raw manure onto fields and capturing methane, a powerful greenhouse gas.

Sustainable and effective irrigation: Drip irrigation systems that run on solar power can efficiently supply water to plant roots. While maintaining the integrity of topsoil, this

precision irrigation helps avoid salinization and waterlogging, two significant dangers to soil health.

Promoting Regenerative Methods: Investments in renewable energy are frequently made by farms as a component of a larger sustainability initiative. Regenerative agricultural practices, which gradually improve soil health, are more likely to be used on these farms. These practices include agroforestry, decreased tillage, and cover crops. Renewable energy also lessens the cost of agricultural inputs, freeing up funds for long-term investments in soil health.

A Comprehensive Strategy: Although incorporating renewable energy into farming systems can strengthen and enhance sustainable soil management, it is not a straight remedy for all problems about soil health. A comprehensive approach to climate-smart farming is provided by the combination of clean energy and sound farming methods.

Future vision: Policies and incentives that support the use of renewable energy sources can be modified to support soil restoration as the agriculture industry develops further. Real-time soil condition monitoring by renewable-powered farms, when combined with digital tools like AI and smart sensors, enables more accurate and sustainable farming methods. We can conserve the soil that supports our farms and power them more sustainably by utilizing waste, wind, and the sun.

ARTIFICIAL INTELLIGENCE TRANSFORMING RENEWABLE ENERGY FOR A RESILIENT PLANET

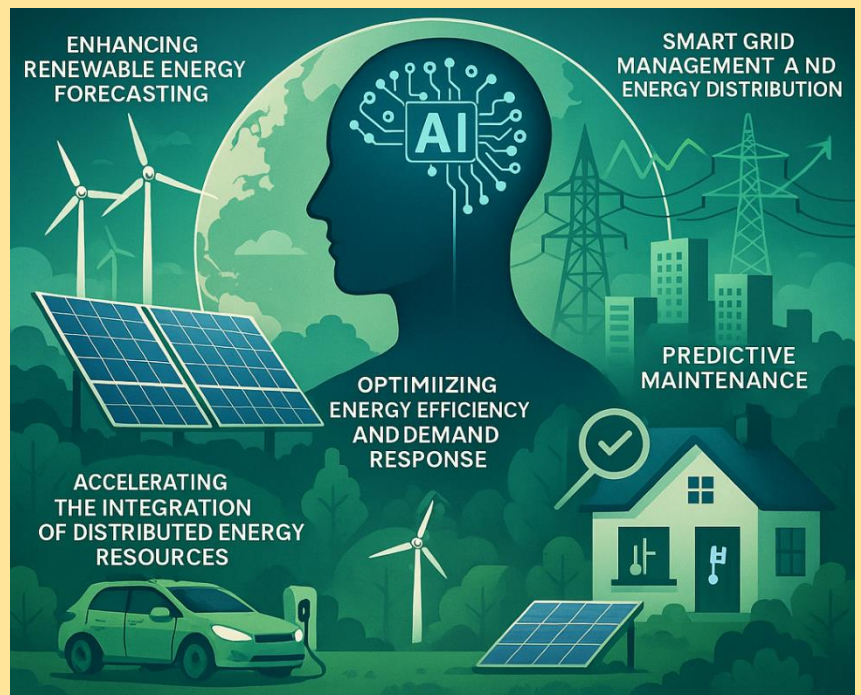
Dr. Sumanta Das, Asst. Professor, School of Environment and Disaster Management, RKMVERI

The transition to renewable energy is essential for addressing climate change and meeting growing global energy demands. However, integrating variable and unpredictable renewable sources like solar and wind into traditional energy systems presents challenges in grid management and energy distribution. Artificial Intelligence (AI) is emerging as a transformative solution to optimize the generation, distribution, and consumption of renewable energy, driving progress toward a resilient and sustainable energy future.

Enhancing renewable energy forecasting: AI, particularly machine learning (ML) models, enhances the accuracy of predicting energy output from solar and wind resources. By analyzing historical data, satellite imagery, and real-time meteorological information, AI improves energy forecasting, allowing grid operators to make informed decisions. For instance, Google's DeepMind has successfully applied AI to improve wind energy predictability by analyzing turbine data and weather forecasts, increasing the value of wind energy by nearly 20%.

Smart grid management and energy distribution: AI-powered smart grids dynamically balance supply and demand by analyzing consumption patterns, detecting anomalies, and forecasting demand fluctuations. Real-time energy management enabled by AI reduces energy wastage and minimizes reliance on fossil fuel-based backup power. AI also optimizes battery energy storage systems by determining when to store or release excess energy, ensuring grid stability and uninterrupted power supply during periods of low renewable energy generation.

Predictive maintenance and asset management: AI enhances the reliability and lifespan of renewable energy assets by enabling predictive maintenance. Through the analysis of sensor data, operational parameters, and historical performance records, AI can predict potential equipment failures before they occur, minimizing downtime and reducing maintenance costs. Siemens Gamesa, for example, uses AI-powered predictive maintenance to monitor wind turbine performance, resulting in improved asset efficiency and reduced operational costs.



Source: Author's own creation using *BioRender*

Optimizing energy efficiency and demand response: AI optimizes energy efficiency across industrial, commercial, and residential sectors by learning user behavior and adjusting heating, cooling, and lighting systems accordingly. AI-enabled smart home systems reduce overall energy consumption, while demand response systems dynamically adjust energy usage during peak hours, alleviating grid pressure. In industrial settings, AI analyzes equipment efficiency and identifies opportunities to reduce energy consumption, contributing to cost savings and lower carbon emissions.

Accelerating the integration of distributed energy resources: As distributed energy resources (DERs) such as rooftop solar panels, electric vehicles (EVs), and microgrids become more widespread, AI plays a critical role in managing their decentralized operations. AI-powered platforms optimize DER management by predicting energy production, balancing loads, and enabling peer-to-peer energy trading. Blockchain-based platforms, integrated with AI, facilitate secure and transparent energy transactions, empowering prosumers (producers and consumers) to trade excess energy, thereby fostering decentralized energy systems that promote resilience and sustainability.

In summary, AI is revolutionizing the renewable energy sector by addressing challenges in forecasting, grid management, maintenance, and energy efficiency. By improving the reliability and integration of renewable energy sources, AI is driving the transition toward a resilient and sustainable energy future.

PRECISION FARMING: CULTIVATING A GREENER FUTURE BY REDUCING AGRICULTURAL EMISSIONS

Dr. Malini Roy Choudhury, Asst. Professor, School of Environment and Disaster Management, RKMVERI

Worldwide the pace of increasing climate change and its impact has become a major concern. Additionally, the excess emission of harmful greenhouse gases (GHG) influences these adverse impacts. Although sources like; fossil fuels, and vehicle emissions are given much emphasis, agriculture contributes significantly, around 12% to global gas emissions (CDP, 2015, Richard et al., 2019). Hence, modern-day precision agriculture with its advanced satellite and sensor-based techniques, combined with data analytics could lead to optimizing agricultural practices by not only improving crop production but also by minimizing the environmental footprint induced by agricultural practices. Hence, this modernization fathoms a pathway towards building a sustainable, climate-resilient, and environment-friendly agriculture system to secure future food, earth, and environment.

Precision agriculture uses sophisticated cutting-edge techniques such as; remote sensing-based real-time monitoring of crop and soil, geospatial mapping, modeling to estimate agricultural traits, Internet of Things (IoT), and machine learning, artificial intelligence-based systems. The precision agriculture techniques with the real-time, high-resolution monitoring ability not only improve soil and crop conditions, but also aid in the efficient use of water, chemicals, and machinery fuel in agriculture, by promoting sustainable crop management, and tracking GHG emissions to ensure a greener future.



Figure: Minimizing environmental impact (Iberdola, 2025)

Agriculture practices release greenhouse gases such as; methane from rice cultivation and livestock, nitrous oxides resulting from soil fertilization, and carbon dioxide from the combustion of fossil fuels. Excess emission by retaining heat exacerbates global warming in turn climate change. Hence, limiting emissions is of utmost importance to reach the sustainable climate and environment goals, safeguard the environment, and secure agricultural production, and food in the face of changing climatic systems.

Precision agriculture with its advanced methods could immensely aid in improving such conditions. The use of a soil sensor-based Global Positioning System (GPS) could help the farmers develop an understanding of the optimal use of the nitrogen-based fertilizers by promoting 4R nutrient stewardship as; the right amount, rate, time, and location (Figure). Such practices could restrict nitrogen oxide emission into the environment and minimize agricultural run-off pollution. Smart irrigation systems with the ability of real-time monitoring could enhance effective crop water management by reducing the chances of over-irrigation and methane emissions that are generated from waterlogged rice fields. With the help of high-resolution sensor applications and monitoring soil health in terms of maintained organic matter soil-crop productivity could be improved. Additionally, automatic tractors using a path-optimizing software system could control carbon dioxide emissions by minimizing the number of field passes and use of fuel.

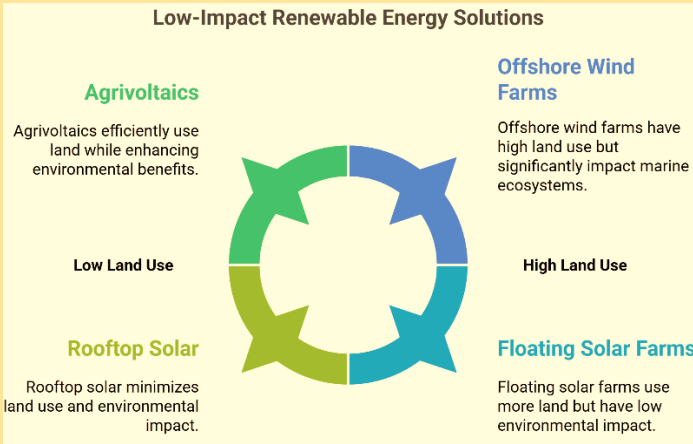
Despite several challenges at the regional scale, such as; expenses, lack of infrastructure, training, and awareness, precision agriculture as a harbinger of change with its intelligent techniques and methods indicates a better sustainable future by not only improving crop yield and profit, but ensuring shared benefit through responsible land resource consumption in the face of adverse climate change, and minimizing harmful GHG emission.

RENEWABLE ENERGY SOLUTIONS MINIMIZING HABITAT DESTRUCTION

Dr. Mahadev Bera

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As the demand for renewable energy grows to combat climate change, implementing solutions that minimize habitat destruction and biodiversity loss is crucial. While traditional large-scale solar and wind operations have low emissions, they often necessitate significant land use, resulting in deforestation, disrupted wildlife corridors, and harm to natural habitats. However, innovative renewable energy approaches are emerging that balance sustainability with environmental safeguarding.



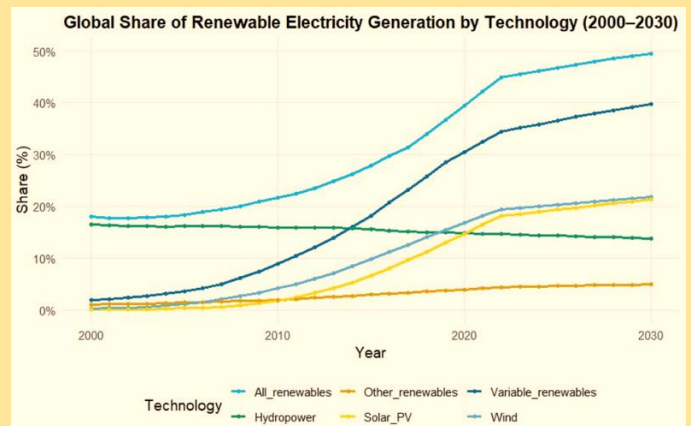
Rooftop solar stands out as one of the most effective low-impact renewable options. By making use of existing structures like homes, commercial buildings, and warehouses, this approach entirely avoids the need for additional land. As per the *International Energy Agency (IEA)*, covering just 1% of global rooftops with solar panels could meet 20–25% of the world’s electricity demand. This method also reduces transmission losses and empowers communities to generate their clean energy locally. Notably, the share of solar PV in global electricity generation has significantly increased, climbing from nearly zero in 2000 to a predicted 15% by 2030, demonstrating its rapid adoption and scalability.

Agrivoltaics offers a promising solution by placing solar panels over farmland. This dual-use approach allows for the production of both food and energy, leading to economic and environmental advantages. A study (Barron-Gafford et al., 2019) published in *Nature Sustainability* found that agrivoltaic systems can boost total land productivity by as much as 60% compared to land dedicated exclusively to agriculture or energy. Moreover, the shade from solar panels helps decrease water evaporation and promotes crop growth in hotter regions.

Offshore wind farms are increasingly recognized as a feasible low-impact substitute for onshore wind energy. Although their installation expenses are higher, they present a lower risk to land habitats and are more effective at capturing energy from the steady winds present at sea. *The International Renewable Energy Agency (IRENA)* predicts that by 2050, worldwide offshore wind capacity could reach 2,000 GW, providing electricity to billions while protecting land ecosystems. As of 2023, wind energy accounts for roughly 12% of global renewable electricity generation, with expectations for continued growth until 2030.

Floating solar farms, commonly referred to as “floatovoltaics” are a cutting-edge and environmentally friendly solution. These systems are placed on reservoirs, lakes, and various water sources, which helps conserve land for agriculture and natural habitats. Moreover, they increase the efficiency of solar panels by keeping them cooler and minimizing evaporation from the surfaces of the water they cover. Nations such as India, China, and Japan are making substantial investments in this technology. For example, China's Dezhou Dingzhuang floating solar plant, which has been in operation since 2023, is expected to produce more than 320 MW of electricity, enough to supply power to over 100,000 homes annually.

Incorporating renewable energy sources into disturbed areas such as brownfields and abandoned mines can lessen ecological harm while helping to achieve energy objectives without negatively affecting important ecosystems. Importantly, hydropower continues to hold steady at 16–17%, but variable renewables, primarily wind and solar, are projected to surpass 30% by 2030. This transition indicates a shift towards more flexible and environmentally friendly renewable technologies.



In conclusion, the path to a renewable future can align with ecological preservation. By prioritizing smart design and suitable locations like rooftops, farms, and non-productive lands, renewable energy initiatives can coexist with environmental conservation. Investing in these low-impact solutions strengthens decarbonization efforts while preserving diverse ecosystems for future generations.

TRIPLING RENEWABLE ENERGY FOR A BETTER TOMORROW

Akash Chakraborty

Today the world is standing at a point where the population continues to rise so that the energy demand, but due to reliance on fossil fuels, climate change & environmental degradation have become a global issue so the perception of energy is shifting towards renewable energy for achieving the energy security. To achieve a sustainable future fossil fuels are no longer a suitable long-term option. According to the International Renewable Energy Agency (IRENA), In 2022, in global energy demand renewable energy accounted for around 29.1 % of total energy share which grew by 7.2% over 2021.

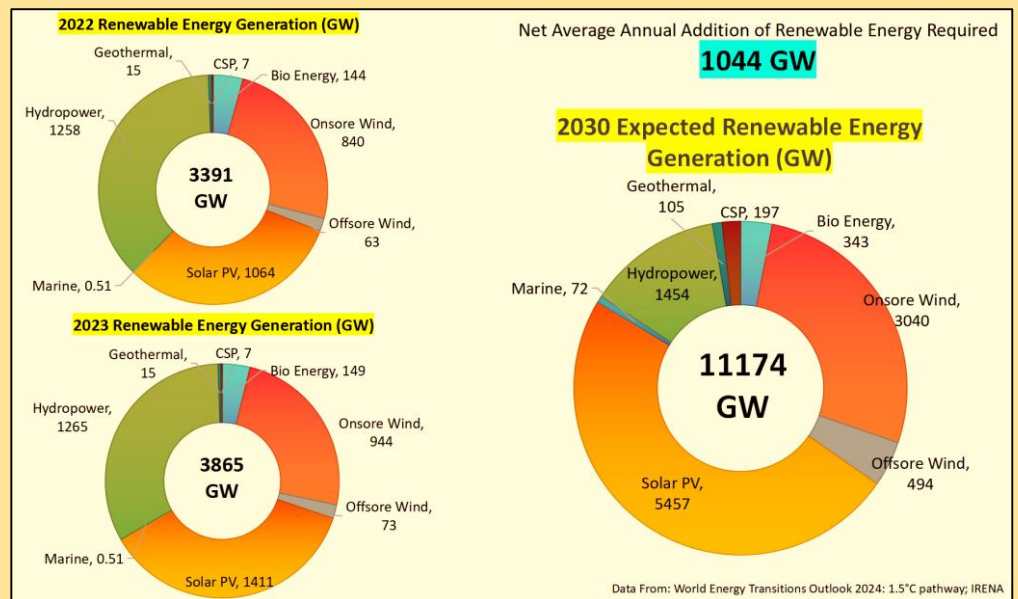
The term “tripling renewable energy” was first mentioned at the 28th Conference of the Parties (COP28), wherein the United Nations Framework Convention on Climate Change (UNFCCC) agreed to abandon fossil fuels, tripling renewable power capacity and doubling energy efficiency by 2030. This was put very firmly in the context of the Paris climate agreement, which set the target of 1.5°C, for achieving this target, global renewable capacity must grow to 11.5 TW by 2030, which is 3.4 times higher than 2022 levels. This tripling of global renewable energy can have potential benefits that extend beyond environmental considerations. This event has the potential to boost economic

growth create millions of green jobs and have the potential of enhancing energy security worldwide. The reduction in fossil fuel usage will also decrease the import between countries which can help the countries especially lower income countries to get energy independence from trade that can help to mitigate geopolitical conflicts.

The real question still lies in whether is it possible or not. In recent decades at first, we have seen for renewables we have to invest heavy

amounts for installing solar panels and wind turbines but with advancements in technologies the price of this newer technology has plummeted, making them more competitive with traditional power sources. Even in many countries, the government is financially helping the people under certain schemes to install solar panels like in India under National Solar Mission. So as the technological advancement in the renewable sector is increasing the cost of these technologies is effectively decreasing. But there are also some challenges like our today’s modern power lines and grids are incapable of holding large-scale renewables so modernization is necessary. Also, many developing countries are limited in funds so for them transformation from fossil fuel to renewable is complex to achieve. Many countries see fossil fuel as a matter of economic power and national security and also governments worldwide provide massive subsidies to fossil fuel industries. According to IMF reports, global fossil fuel subsidies reached \$7 trillion in 2022, significantly more than what is invested in renewables, this geopolitical reliance makes it difficult for some nations to pivot away from fossil fuels. Lastly, unstable policies and lack of long-term commitment make it more complex, like for renewable expansion to need government permission which takes years to get permitted meanwhile, fossil fuel projects often receive fast approvals due to political connections.

Imagine a world with free and clean energy in which every citizen has access to it, a world where air is free from pollution and climate disasters no longer threaten our future. This is not a dream far off in the future, this is something tangible, at arm’s length. However, it demands a transformation of society, the way we power our societies. For centuries, fossil fuels dominated the landscape of global energy production, yet their harm to the environment and economy has become insufferable. The answer lies in unlocking the infinite potential of renewable energy. Three times increased global renewable energy capacity allows us to accelerate our transition towards a healthier planet and stable future generations.



Ashis Sarkar

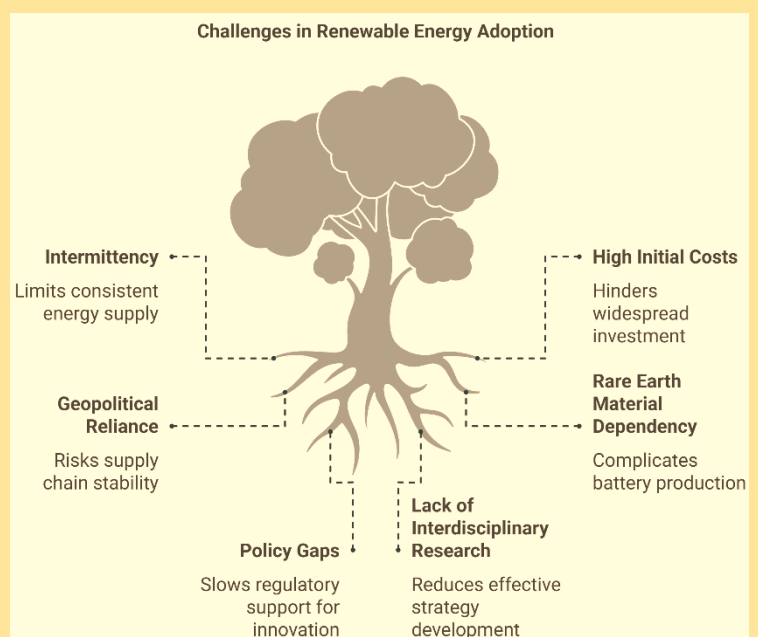
Advancing environmental science through renewable energy innovation is vital for tackling global sustainability issues. As the world faces challenges like climate change, resource depletion, and environmental degradation, renewable sources such as solar, wind, hydro, and bioenergy offer practical solutions to lower carbon emissions and lessen ecological harm. Innovations in energy storage, smart grids, and effective energy conversion technologies are transforming our approach to utilizing renewable resources. Integrating artificial intelligence and machine learning into renewable energy management further boosts efficiency and predictability, decreasing dependence on fossil fuels and fostering sustainable practices.

Economically, investing in renewable energy not only supports environmental sustainability but also generates jobs and stimulates growth. The shift from traditional energy sources to renewables has given rise to new industries—like solar panel manufacturing, wind turbine installation, and biofuel production—creating employment opportunities across various sectors. Governments globally are implementing policies and incentives to hasten this transition, acknowledging that a clean energy economy can sustain long-term economic health. Moreover, decentralized energy solutions, such as microgrids powered by renewable sources, are enabling communities, especially in remote and underserved areas, to gain access to reliable and affordable electricity.

Socially, innovations in renewable energy promote energy equity by lessening reliance on centralized fossil fuel systems. In numerous developing nations, energy scarcity hinders social and economic advancement, impacting education, healthcare, and overall quality of life. Off-grid solar and wind solutions provide sustainable methods to close this gap, delivering electricity to marginalized communities while minimizing environmental footprints. Furthermore, the transition towards clean energy cuts air and water pollution, enhancing public health outcomes. Reducing emissions from coal and oil-fired plants significantly diminishes respiratory illnesses, cardiovascular issues, and other health hazards linked to poor air quality.

From an ecological standpoint, renewable energy innovation is crucial for conserving biodiversity and restoring ecosystems. Unlike fossil fuel extraction, which results in deforestation, habitat destruction, and pollution, renewable options present a sustainable method to satisfy energy needs without endangering the planet's ecological balance. Floating solar farms, offshore wind farms, and bioenergy from waste materials illustrate how energy generation can coexist with environmental stewardship. Additionally, advancements in next-gen biofuels, hydrogen energy, and carbon capture technologies are pushing sustainability limits, further reducing environmental impacts.

Nevertheless, challenges persist in increasing the adoption of renewable energy. Issues like intermittency, high initial costs, and geopolitical reliance on rare earth materials for battery production pose significant hurdles. Innovative solutions, including advancements in energy storage, policy reforms, and international cooperation, can help to mitigate these challenges. The contribution of interdisciplinary research in environmental science is essential for developing comprehensive strategies to address these issues, ensuring that renewable energy not only advances global sustainability objectives but also strengthens resilience to future environmental uncertainties. As the world transitions to a low-carbon future, the alignment of renewable energy innovation with environmental science will play a pivotal role in shaping a cleaner, greener, and more sustainable planet for generations to come.



THE ROLE OF SMART GRIDS IN MINIMIZING ECOLOGICAL IMPACTS OF ENERGY USE

Ashmita Rakshit

Traditional electromechanical power grids are becoming outdated, inefficient, and increasingly prone to failures, leading to frequent blackouts and service interruptions. As energy demand continues to grow, these conventional systems struggle to balance supply and demand effectively. Rising energy costs, changing consumer expectations, and environmental concerns further highlight the urgent need for modernization. Today's consumers seek not only affordable power but also real-time data on their usage and more control over how they consume energy. Moreover, the harmful environmental impacts of fossil fuel-based power generation emphasize the importance of transitioning to cleaner, renewable energy sources.

Smart grids offer a promising solution by enabling a more sustainable, efficient, and reliable energy infrastructure. They incorporate digital technologies such as sensors, automation, and data analytics into the traditional grid, allowing for real-time monitoring and improved management of electricity flow. This digital overlay functions similarly to the internet, just as routers manage the flow of data, smart grids optimize electricity distribution, making the system more responsive and adaptive. The electric grid itself is composed of two main parts: the transmission system, which carries electricity from power plants to substations, and the distribution system, which delivers it from substations to end users. Smart grids enhance these systems by adding computing and communication capabilities that enable automated responses and more efficient operation. They are particularly valuable in integrating renewable sources like solar and wind, which are naturally variable.

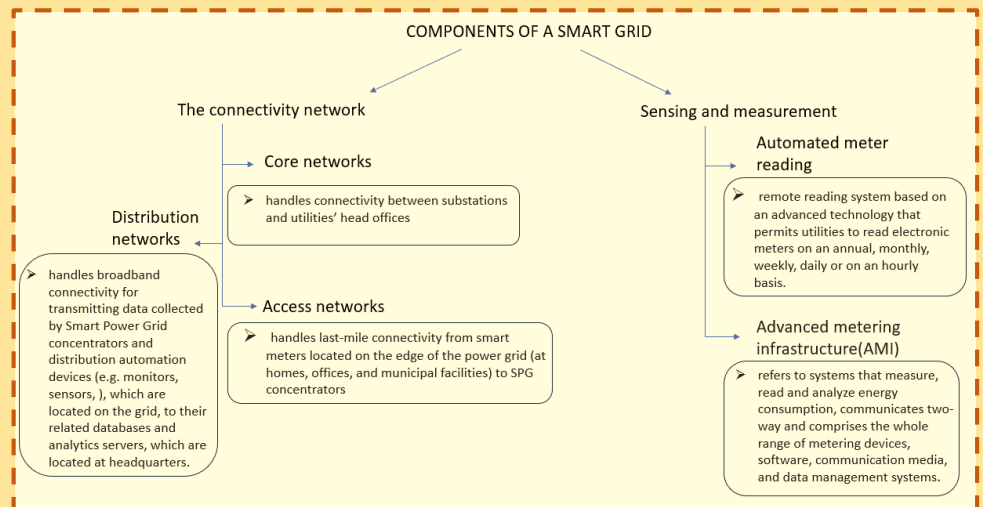


Figure: Components of a smart grid

One of the major advantages of smart grids is their ability to detect and respond to problems before or as they occur. Unlike traditional systems that often rely on customer reports to identify outages, smart grids use embedded sensors to automatically locate issues, potentially preventing failures altogether. In addition, they offer consumers greater visibility into their energy usage. Smart meters and home energy monitoring tools can display real-time consumption data, helping users understand which appliances use the most energy and compare their usage with others—encouraging smarter, more efficient habits. Smart grids play a crucial role in advancing environmental sustainability. By improving efficiency and reducing transmission losses, they help cut down on energy waste. Their capacity to incorporate renewable energy sources helps lower carbon emissions and reduce dependence on fossil fuels. Furthermore, smart grids support decentralized power generation—such as rooftop solar panels—and enable technologies like electric vehicle (EV) charging and smart microgrids, both of which are essential for sustainable urban growth.

Despite their benefits, the adoption of smart grids faces significant hurdles. A major barrier is the slow pace of innovation within the utility sector. Unlike the fast-moving tech industry, utilities are traditionally conservative and prioritize reliability over rapid technological advancement. This cautious approach, coupled with limited investment in research and development, has slowed the integration of new systems. Another challenge is the high initial cost of upgrading to a smart grid. Transforming existing infrastructure requires significant investments in advanced sensors, smart meters, energy storage, data analytics, and communication networks. For many utility companies, the upfront expense is difficult to justify, even though long-term gains include improved efficiency and cost savings. Additionally, the industry's lack of standardized technologies complicates the integration process. With so many different components, ranging from automated demand response systems to grid management software—the absence of universal protocols has created a fragmented environment, making it harder to scale and coordinate smart grid technologies effectively.

In summary, smart grids represent the future of energy management, offering greater efficiency, cleaner energy, and more empowered consumers. While there are challenges in terms of cost, speed of adoption, and standardization, the long-term benefits of smart grids in reducing emissions, conserving energy, and enabling renewable integration make them essential for a sustainable energy future.

WIND POWER REVOLUTION TRANSFORMING LANDSCAPES AND LIVELIHOODS

Dipayan Laha

The wind power revolution is changing our energy landscape by offering a renewable alternative to fossil fuels, while also altering the physical and social environments of communities. As the fastest-growing source of renewable energy in the world, wind power is not just about generating electricity; it is about redefining our relationship with nature and our responsibilities as energy consumers.

In recent decades, wind power has made significant strides due to the urgent need to combat climate change and reduce greenhouse gas emissions. Unlike conventional energy sources, wind power harnesses natural energy from the wind, making it a clean and renewable option. The development of wind farms has become commonplace in many regions, especially in areas where wind conditions are ideal, such as San Geronio Pass in California. This location is now well-known for its extensive array of wind turbines, which represent a major advancement in renewable energy.

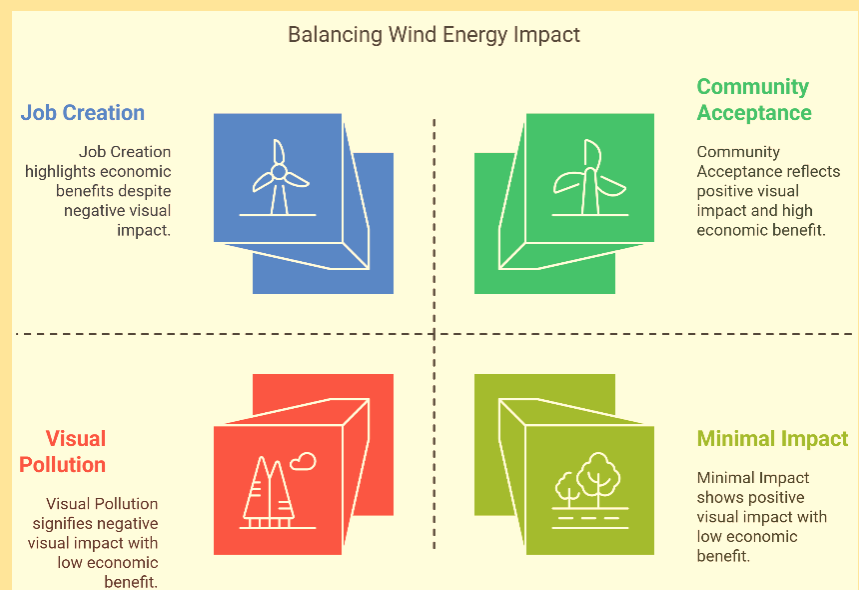
The installation of wind turbines inevitably alters both the physical and visual landscapes. While many people appreciate the clean energy generated by wind farms, the presence of large turbines can evoke mixed feelings. Some view them as an eyesore that detracts from natural scenery, while others see them as a necessary step toward a sustainable future. The visibility of wind power serves as a constant reminder of our energy consumption and the environmental costs associated with it. This coexistence sparks significant debates about balancing energy demands with the conservation of natural beauty.

In addition to their environmental benefits, wind farms also provide economic advantages for surrounding communities. The installation and maintenance of wind turbines create jobs in various areas, including production, installation, and daily operations. Landowners can also benefit financially through leasing agreements, which offer a new source of income that can help sustain local economies. This economic aspect is particularly important as it encourages public acceptance of wind energy projects, especially in areas where traditional industries are declining.

The incorporation of wind power into local environments raises important questions about public perception and social dynamics. Many communities have traditionally valued open spaces and the natural environment, which has led to opposition against wind farm developments. Martin Pasqualetti's article highlights the need for planning and community consultation to address these concerns. By involving local stakeholders in the decision-making process, developers can better understand and mitigate the social and visual impacts of wind energy projects.

As society continues to confront the challenges of climate change, the rise of wind power represents a significant shift towards sustainable energy practices. Embracing wind energy not only helps reduce our carbon footprint but also encourages us to reconsider our relationship with the environment. The ongoing conversation about wind energy's role in our lives will influence the future of energy production and consumption.

The wind power revolution is fundamentally transforming lives and landscapes. By understanding the nuances of public attitudes, economic potential, and ethical implications, we can better navigate the challenges and rewards of this clean energy source. Moving forward, it is essential to strike a balance between harnessing wind energy and preserving the natural beauty that many communities cherish. The journey toward a sustainable future is not just about energy; it involves fostering a deeper connection with our world and taking responsibility for the energy we consume.



ECOFRIENDLY MATERIALS REVOLUTIONIZING RENEWABLE ENERGY TECHNOLOGY

Ditsa Maity

Green energy storage solutions like solar, wind, and hydroelectric power are becoming more and more popular worldwide in the pursuit of a more environmentally friendly and sustainable future. Although these sources offer clean energy, their intermittency poses a special problem. Green energy storage systems have become an essential part of the shift to a sustainable energy landscape in order to meet this challenge. With its sustainable solutions to fight climate change and lessen our reliance on fossil fuels, renewable energy is revolutionizing the global energy scene. Biomass boilers stand out as a ground-breaking method in the use of renewable energy among the cutting-edge technologies spearheading this movement. These boilers provide an environmentally beneficial substitute for conventional fossil fuels by producing heat and energy from organic resources such as wood, agricultural waste, and other biological stuff. Key innovations in revolutionizing renewable energy technology using eco-friendly materials are summarized below:

Biomass boilers: Biomass boilers are heating systems that generate heat and, occasionally, electricity by burning organic materials, also known as biomass. Biomass boilers, as opposed to traditional boilers that run on coal, oil, or gas, employ renewable resources such as wood pellets, chips, and agricultural waste.

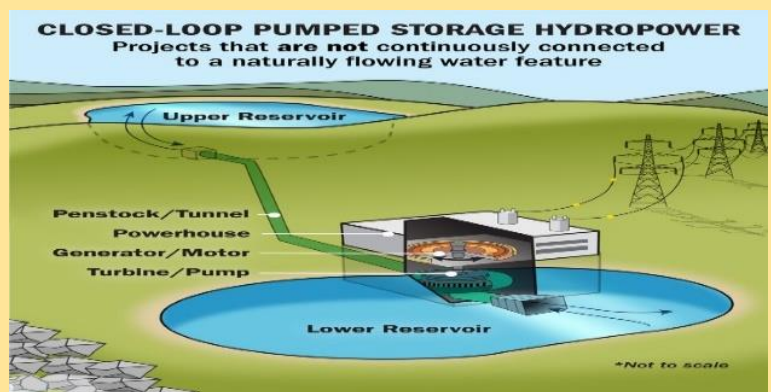
Battery energy storage system: BESS stores electricity using a variety of battery types, including flow and lithium-ion batteries. The most popular type of energy storage for green technology is lithium-ion batteries. They are frequently utilized in home solar arrays and electric cars to store extra energy for later usage.

Pumped hydro storage: This technique stores potential energy by pumping water to a higher height using excess electricity. The water is released and flows through turbines downhill to produce energy when it's needed.

Compressed air energy storage (CAES): CAES devices compress air and store it in subterranean caverns to store extra energy. Compressed air is released and used to power turbines to produce electricity when needed. CAES is long-lasting and effective.

Hydrogen storage: Electrolysis is a process that uses surplus electricity to create hydrogen. When electricity is required, the hydrogen that has been stored can be used in fuel cells. A clean and adaptable energy source, hydrogen has potential uses in a number of industries.

Furthermore, there is much research going on for integrating eco-friendly materials into renewable energy technology. Quinones are one of them. Quinones are widely distributed in nature and are essential to the maintenance of life because they actively participate in cellular respiration and photosynthesis. These compounds have garnered a lot of attention in the last decade, primarily concerning redox flow batteries. The potential of sugars, amino acids, and cellulose-based compounds as electrolyte materials has also drawn attention as these substances can break down naturally without leaving any hazardous residues when the battery reaches the end of its life cycle. Despite their abundance, natural products are frequently overlooked, yet they have a lot of promise for creative uses. Another example of a significant development in sustainable battery technology is a study that aims to develop separator membranes for Li-ion batteries by utilizing the latent potential of wool and soy protein isolate (SPI). The addition of wool to these membranes improves their porous shape and favorable wettability with electrolyte solutions. Except for enhancing the mechanical robustness of SPI membranes, the addition of wool has little effect on the physicochemical characteristics of the membranes, even if it results in abnormalities in pore sizes and distributions. The reinforcing properties of wool are responsible for this increased mechanical strength. The developed membranes exhibit exceptional performance in Li-ion battery applications.



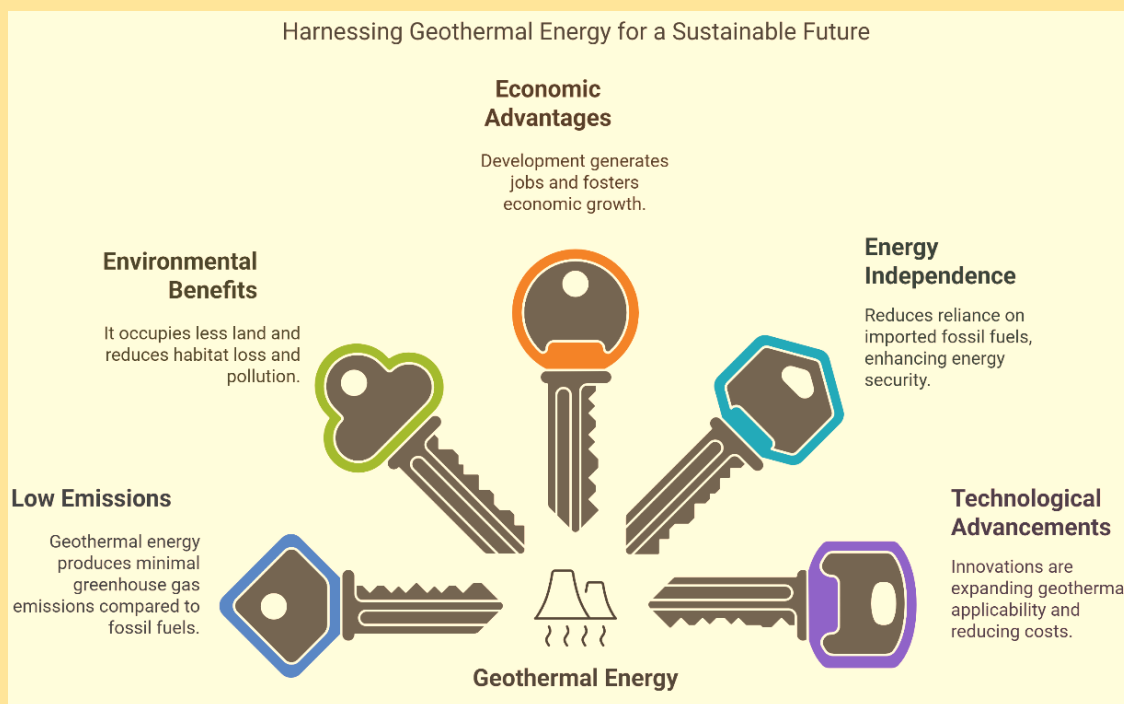
GEOTHERMAL ENERGY: A SUSTAINABLE SOLUTION FOR CLIMATE CHANGE

Riyanka Das

As threats from climate change escalate, the global pursuit of sustainable energy sources has never been more urgent. Among the green energy options, geothermal energy stands out as a particularly attractive choice. Harnessing the Earth's internal heat, geothermal energy offers a clean and efficient alternative that can mitigate climate change. Its capability to deliver a stable power supply with minimal greenhouse gas emissions positions geothermal energy as a vital contributor to a cleaner future. This energy source derives from the heat below the Earth's crust, sourced from the planet's liquid core and brought to the surface through natural geological processes, including volcanic activity and hydrothermal circulation. Geothermal power plants generate electricity using steam or hot water extracted from deep within the Earth, while geothermal heat pumps provide direct heating and cooling for buildings by leveraging the Earth's relatively constant underground temperatures.

In contrast to fossil fuels, which release large amounts of carbon dioxide (CO₂) and other harmful pollutants, geothermal energy is a low-carbon alternative. Geothermal plants emit very few greenhouse gases, making them cleaner than coal, oil, and natural gas. By transitioning to geothermal energy from traditional sources, nations can significantly reduce their carbon footprints and contribute to global climate goals. In addition to its low emissions, geothermal energy presents various environmental benefits. It occupies much less land compared to solar and wind farms, resulting in a cost-effective energy source that avoids deforestation and habitat loss. Closed-loop geothermal systems recycle water used in energy production, minimizing water waste and environmental impact. Furthermore, geothermal energy helps decrease air pollution by replacing coal and gas plants, which produce toxic emissions such as sulfur dioxide and nitrogen oxides. Investing in geothermal energy benefits both the environment and the economy. Development in this sector generates jobs in engineering, drilling, maintenance, and research, providing stable employment opportunities for communities, particularly in geothermal-rich areas.

Moreover, geothermal energy enhances energy independence by reducing reliance on imported fossil fuels, shielding economies from price fluctuations and geopolitical unrest. Though geothermal energy has its challenges, such as high initial development costs due to deep drilling and exploration, advances in technology and government incentives are making it more



affordable. Geographically, it is mainly suited for tectonically active areas like Iceland, the Pacific Ring of Fire, and geothermal regions in the United States. Nevertheless, innovations in enhanced geothermal systems (EGS) are expanding its applicability to less active areas. The future of geothermal energy is promising, with increasing investment and technological progress driving its growth. Countries like Iceland, the Philippines, and Kenya have successfully implemented large-scale geothermal power. As more governments commit to reducing carbon emissions, geothermal energy will become an increasingly vital part of the global energy landscape. Tax credits, subsidies, and research grants can further accelerate its deployment. International collaboration can facilitate knowledge sharing and technology transfer, unlocking the full potential of geothermal power. As the world seeks sustainable solutions to tackle climate change, geothermal energy shines as a beacon of hope. Its low carbon emissions, reliability, and environmental sustainability make it a key player in the transition to renewable energy. By investing in geothermal technologies and infrastructure, nations can decrease greenhouse gas emissions, improve energy security, and foster economic growth while safeguarding the planet for future generations. Embracing geothermal energy today paves the way for a cleaner and greener tomorrow.

SCIENTIFIC ADVANCES POWERING THE INTERNATIONAL RENEWABLE ENERGY TRANSITION

Saikat Dutta

The world energy scenery is experiencing a groundbreaking transformation towards renewable foundations, propelled by scientific advances that increase competence, affordability, and scalability. As the weights of climate change and energy safety intensify, solar, wind, battery storage, and substitute fuel innovations are driving the transition to a clean energy future. This article examines some of the most thoughtful advancements defining the renewable energy rebellion.

Next-generation solar knowledge: Solar energy is in the lead in the renewable changeover, with developing research confidence, competence, limitations, and dropping prices. Arguably the most exciting breakthrough is perovskite solar cells, with the advantages of high efficiency, cheap production, and suppleness. Coupled with silicon in tandem solar cells, perovskites have reached more than 30% efficiency and are a real scene for wide-scale deployment. Yet, another solar technology innovation is the invention of see-through solar panels, which can be joined into windows and building facades, levitating the cohort of solar power outside conservative panels. Also, nanomaterial-based solar concentrators are decorative energy imprisonment and conversion, translation solar farms more well-organized.

Progressions in wind energy: Wind energy has seen remarkable progressions in turbine design, physical principles, and aerodynamics. Fluctuating seaward wind farms are a game-changer, enabling turbines to be arranged in deeper waters where there is more powerful and reliable wind. New technologies like vertical-axis wind turbines and bladeless wind arrangements are also on the horizon, cutting down on upkeep costs and minimizing environmental footprint. AI-based predictive maintenance and real-time data analytics are also cumulative wind energy competencies. By refining blade performance and forestalling failures, this knowledge stretches turbine lifetimes and lowers downtime, making wind energy more lucrative and reliable.

Energy storing breakthroughs: One of the biggest tests of renewable energy is intermittency. Progressive energy storage explanations are speaking this issue, ensuring a steady and continuous power supply. Lithium-ion batteries have seen important developments in energy density and cost reduction, but alternate storage solutions are also ahead of traction. Solid-state batteries with their better energy capacity and safety assistances are anticipated to convert electric vehicles and grid storage. On the other hand, flow sequences that employ liquid electrolytes for storing energy for long periods are beginning to appear as scalable means of grid storage. Green hydrogen and gravity-based storage are being measured as future long-term storage options.

Alternate fuels and green hydrogen: Hydrogen is also evolving as a favorite in the renewable revolution, particularly for hard-to-electrify subdivisions like heavy transportation and industry. Green hydrogen, made from renewable electricity and electrolysis, is becoming an alternative clean fuel. Recent efficiency gains and cost drops in electrolyzers are increasing hydrogen's reach. Furthermore, synthetic fuels and biofuels are being produced to supernumerary fossil fuels in delivery and aviation. Carbon capture and utilization (CCU) innovations are also making it conceivable to produce e-fuels, which are produced by manufacturing captured CO₂ and green hydrogen.

Smart grids and digital energy arrangements: The combination of renewable energy into the prevailing power grids stresses smart energy management. Artificial intelligence and blockchain-based smart grids allow real-time nursing and optimization of energy spreading. Smart grids support dispersed energy generation, allowing homes and businesses to produce, store, and convert energy effectively. Moreover, advancements in energy prediction based on machine learning are enhancing grid stability by forestalling demand and supply variations. This provides a smooth shift towards an energy system conquered by renewables.

In summary, scientific advances in solar, wind, energy storage, hydrogen, and smart grids are foremost the world towards renewable energy. As expertise continues to advance, the dream of a carbon-neutral world develops more and more actual. With continuing novelty and speculation, renewable energy will push a maintainable and resilient future for compeers to come.

EXPLORING OCEAN-BASED ENERGY SOLUTIONS AND THEIR EFFECTS ON MARINE ECOSYSTEMS

Sanchari Roy

The world's oceans represent a vast reservoir of potential as a renewable energy source, offering alternatives to fossil fuels through wave, tidal, and offshore wind energy. While these technologies hold the promise of reducing carbon emissions and addressing climate change, their implementation carries the risk of impacting marine ecosystems. Striking a balance between harnessing ocean-based energy and safeguarding marine biodiversity is essential for achieving sustainable development.

Marine renewable energy technologies, including tidal energy, offshore wind farms, and wave energy converters, have gained significant traction due to their ability to generate electricity with a minimal carbon footprint. The theoretical energy potential of ocean-based sources is estimated at up to 7,400 exajoules per year, which far exceeds global energy requirements. Offshore wind power, in particular, has seen rapid development, with global capacity increasing threefold in under five years to reach 15,000 MW by 2016. This shift toward marine renewables plays a crucial role in reducing greenhouse

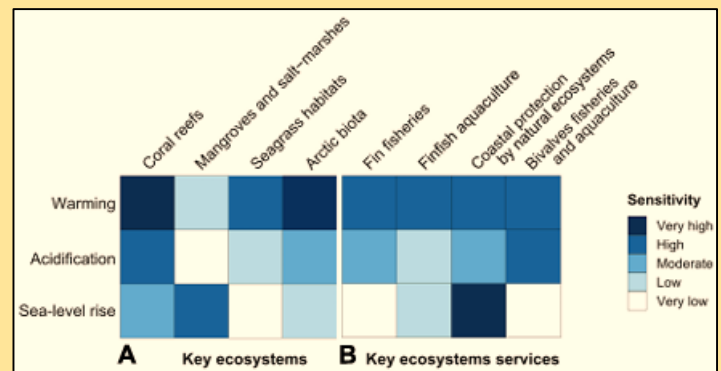
gas emissions, thereby supporting global climate mitigation efforts. One of the most compelling advantages of ocean-based energy solutions is their capacity to permanently replace dependence on fossil fuels. Unlike terrestrial renewable sources, ocean energy systems leverage natural phenomena such as tides and currents, which are highly predictable and reliable. Additionally, marine energy infrastructure can be designed for long operational lifetimes, ensuring consistent energy output with low emissions for decades to come.

While large-scale offshore energy installations offer significant advantages, they also pose ecological challenges. Offshore wind farms, wave energy converters, and tidal turbines can disrupt marine habitats, impact regional biodiversity, and alter water currents. The location of offshore wind farms and tidal barrages can change the natural environments of various marine species. Disturbances to the seafloor during installation may adversely affect benthic organisms, and the underwater noise emitted by turbines can hinder communication among fish and marine mammals. Additionally, the electromagnetic fields generated by underwater cables may disrupt species that depend on natural geomagnetic navigation.

Tidal and wave energy systems extract kinetic energy from ocean currents, potentially altering sediment transport and nutrient distribution. Such changes can affect marine ecosystems by disrupting feeding patterns and reproductive behaviors of certain species. For instance, modifications in water movement near tidal energy installations may interfere with fish migration routes, leading to shifts in populations and imbalances in the ecosystem. Marine energy projects can have both positive and negative influences on biodiversity. Artificial structures, such as turbine bases and offshore wind platforms, can act as artificial reefs, creating new habitats for marine life. However, the risk of collisions with rotating blades in tidal energy farms poses a threat to marine mammals and fish populations. Furthermore, the disruptions to ecosystems caused by energy extraction can have cascading effects throughout the food chain, ultimately impacting fisheries and aquaculture.

To minimize the ecological impact of marine energy projects, effective strategic planning and robust environmental safeguards are crucial. Careful site selection and comprehensive environmental assessments play a vital role in reducing habitat disruptions. Advancements in technology, such as quieter turbine designs and deep-water floating wind turbines, can further mitigate risks to marine life. Integrating energy projects with Marine Protected Areas (MPAs) ensures a harmonious balance between renewable energy production and ecosystem conservation. Furthermore, long-term monitoring of species behavior and habitat changes facilitates adaptive management and regulatory enhancements. By combining responsible planning, innovative solutions, conservation efforts, and ongoing research, we can develop ocean-based energy sources sustainably, thus supporting clean energy objectives while safeguarding marine biodiversity.

Ocean-based energy solutions hold remarkable potential in addressing climate change, providing clean and abundant power. However, their implementation must be carefully managed to protect marine ecosystems. Although challenges such as habitat disturbance and shifts in biodiversity exist, strategic planning and technological advancements can help mitigate these adverse effects. By finding a balance between renewable energy development and ecosystem conservation, society can pave the way for a sustainable future in which both clean energy and ocean biodiversity thrive.



TRANSFORMING DEGRADED LANDS INTO SOURCES OF LARGE-SCALE RENEWABLE ENERGY PROJECTS

Sangita Saha

The need for sustainable and clean energy is growing globally as countries work to mitigate climate change and switch to more environmentally friendly options. Creating expansive renewable energy hubs on damaged terrain, such as polluted, deforested, and barren places, is one solution to expand the use of renewable energy. These unused lands minimize rivalry between urban and agricultural land usage while providing enormous potential for solar, wind, and bioenergy initiatives. The inadequate land is a significant barrier as the demand for renewable energy increases. Food security depends on agricultural fields, and urbanization further reduces the amount of space available for energy infrastructure. However, degraded soils offer a chance to build massive renewable energy projects without interfering with necessary land uses. Countries may improve energy security, boost economies, and rebuild ecosystems by reusing these lands. Arid and decertified because of their high solar radiation are perfect for large solar farms, but unsuitable for farming. Renewable energy projects can be built on contaminated or repurposed mining and industrial sites without uprooting local populations or agricultural practices. Saline and waterlogged lands can be used to produce bioenergy, such as by growing algae and salt-resistant biofuel crops. By converting closed landfills and abandoned locations into solar and wind energy, environmental liabilities can be turned into assets.

By stabilizing soil and encouraging vegetation growth, solar farms and biofuel plants can help restore land. Installing solar panels helps lessen soil erosion by reducing exposure to water and wind. Switchgrass and algae are examples of bioenergy crops that enhance soil structure and encourage carbon sequestration, gradually repairing damaged ecosystems. Reducing greenhouse gas emissions and dependence on fossil fuels could be achieved by using degraded areas for renewable energy. Carbon dioxide emissions are greatly decreased by the extensive use of solar and wind energy on these areas, supporting international efforts to combat climate change. Bioenergy plantations also have the ability to absorb carbon from the atmosphere, which increases their significance in climate mitigation plans. Renewable energy projects in regions boost job creation, economic growth, and local economies. They create thousands of jobs, boost local companies, and generate revenue for governments. Research and development for sustainable energy solutions also contribute. Additionally, degraded lands offer less conflict between land use and development, allowing for renewable energy projects without causing displacement or disturbance, unlike conventional projects. Degraded lands can enhance energy resilience, reduce reliance on imported fossil fuels, and improve grid stability by utilizing domestic renewable energy production, thereby ensuring long-term sustainability. India's Rewa solar project restores degraded land while producing sustainable electricity in an arid area. To aid in the country's energy transformation, abandoned mine areas in Germany are being converted into wind.



Fragile ecosystems can still be found in some degraded areas. The answer is to guarantee that there is as little ecological disturbance as possible by carrying out comprehensive environmental impact assessments. Local resistance could come from worries about aesthetics and land rights. Benefit-sharing programs and community involvement can increase public support. There is a great deal of opportunity to turn degraded lands into clean energy hubs, thanks to developments in renewable technologies and expanding regulatory support. The sustainability of these projects can be further improved by using solutions like dual-use agrivoltaics, floating solar farms over waterlogged areas, and bioenergy-driven reforestation. There are social, economic, and environmental advantages to repurposing damaged lands for the production of renewable energy. Countries may speed up their clean energy transitions while fostering economic growth and land restoration by utilizing these neglected places. Unlocking these lands' full potential for a sustainable future will need technical advancements, community involvement, and strategic investments.

EMPOWERING TOMORROW: DECARBONIZING OUR FUTURE WITH RENEWABLE ENERGY AND CLEAN TECHNOLOGY

Shreya Mitra

"Renewable energy is not just a solution for climate change; it is also the key to energy security, economic growth, and cleaner air." – Ban Ki-moon (Former Secretary-General of the United Nations)

As climate change effects continue to rise globally, the urgent need to decarbonize our energy systems becomes increasingly clear. Moving away from fossil fuels toward renewable energy sources and clean technology is not merely a necessity; it represents a pivotal opportunity to reshape our future. This shift is driven by two main goals: reducing greenhouse gas emissions and promoting sustainable economic development.

Renewable energy options like solar, wind, hydro, and geothermal are essential to leading the global energy transition. These sources are abundant, eco-friendly, and becoming more cost-effective due to advancements in technology. Solar energy has seen significant improvements in both efficiency and affordability, leading to wider adoption in residential, commercial, and industrial sectors. Additionally, offshore wind energy has emerged as a prominent player due to its substantial energy production. Hydropower remains a key contributor, especially in regions rich in water resources, while geothermal power provides consistent base load electricity. Moreover, the adoption of clean technologies such as smart grids, energy storage solutions, and carbon capture and storage (CCS) is transforming the energy landscape. These innovations play a vital role in improving energy efficiency and reducing carbon footprints. Smart grids enable effective electricity distribution, minimizing waste and optimizing resource utilization in real-time, while energy storage systems, particularly lithium-ion batteries, stabilize the renewable energy supply when sun and wind are lacking. CCS technologies serve to capture carbon dioxide emissions produced by industrial processes and power plants, preventing their release into the atmosphere. Collectively, these technologies accounted for about 30% of global electricity generation in 2023, which is projected to support the target of achieving net-zero emissions in the future.



Decarbonisation is a complex strategy that encompasses electrification, the adoption of renewable energy, and supportive policies aimed at reducing carbon emissions across various sectors. Electrification plays a vital role, particularly in transportation and industry, where electric vehicles (EVs) and renewable-powered machinery are replacing traditional gasoline-powered vehicles. Additionally, industries are shifting to electric heating and renewable-powered equipment to decrease their dependence on fossil fuels, leading to significant emission reductions. The decarbonisation process also fosters economic growth, as investments in renewable energy generate jobs and lower long-term energy expenses. In 2022, the International Renewable Energy Agency (IRENA) reported that over 12 million individuals were employed in the renewable energy sector, indicating a growing need for skilled workers in areas such as solar panel installation and wind turbine maintenance.

To expedite decarbonisation, robust policy frameworks and international collaboration are essential. Governments are implementing ambitious climate initiatives, including carbon pricing, incentives for renewable energy, and emission reduction goals to stimulate clean energy investments and innovation. Significant efforts, like the EU's Green Deal and India's National Action Plan on Climate Change, exemplify the pursuit of low-carbon transitions. Additionally, international partnerships through climate summits and agreements bolster global commitments by sharing resources, technologies, and best practices.

Nevertheless, challenges persist. The variable nature of solar and wind energy underscores the necessity for enhanced energy storage solutions. Effective decarbonisation also requires considerable financial investments, infrastructure development, and strategic policies. Workforce training is crucial to fulfil the increasing demand in renewable energy fields, and it's essential to support communities reliant on fossil fuels to ensure an equitable and stable transition. Attaining a decarbonized future involves integrating renewable energy, electrification, and sustainable practices. By weaving together renewable energy strategies, electrification, and sustainable practices while promoting policies and global cooperation, we can reach a cleaner, more resilient future that benefits public health, ecosystems, and economies alike.

GREEN HYDROGEN AS A CLEAN ENERGY SOURCE FOR SUSTAINABLE FARMING

Sneha Mistri

Green hydrogen, produced by splitting water into hydrogen and oxygen using renewable Energy sources like solar and wind, is rapidly emerging as a game-changer for sustainable farming. Traditional agriculture relies on fossil fuels for machinery, irrigation, and heating, contributing to environmental harm and emissions. By embracing green hydrogen, farmers can significantly cut down their carbon footprints, using clean energy to power tractors, pumps, and greenhouses. As this technology continues to evolve, it holds the potential to boost energy efficiency and lower pollution levels, leading to more sustainable and resilient farming practices. This shift can help agriculture tackle the challenges posed by climate change while also reducing its environmental impact.

Hydrogen can store excess energy generated from renewable sources like solar and wind. This stored energy can be converted back into electricity when needed, providing a reliable power supply for agricultural operations, even in off-grid or remote locations. Hydrogen-powered fuel cells can replace traditional fossil fuels in farm machinery such as tractors, harvesters, and irrigation pumps, reducing greenhouse gas emissions and operational costs. This shift not only contributes to a cleaner environment but also lowers long-term costs associated with fuel and machinery maintenance. Hydrogen is a key component in the Haber-Bosch process, which synthesizes ammonia from nitrogen. Ammonia is then used to produce nitrogen-based fertilizers. Green

hydrogen enables the production of ammonia without the associated carbon emissions of conventional methods, making fertilizer production more sustainable. Farms could potentially produce their green hydrogen and ammonia, reducing dependence on external fertilizer supplies and enhancing self-sufficiency. By generating these essential inputs on-site, farmers can gain greater control over their supply chains and reduce transportation costs.



Figure: Hydrogen Energy (Kain, 2023)

Hydrogen fuel cells can provide a reliable and clean energy source for powering irrigation pumps, especially in areas where grid electricity is unavailable or unreliable. This ensures that crops receive adequate water without the carbon footprint of diesel generators. With hydrogen fuel cells, irrigation systems can operate efficiently, supporting optimal crop growth and water management for a sustainable agriculture approach. Hydrogen can be used to generate electricity for post-harvest processing facilities, such as grain dryers and cold storage units, ensuring that crops are preserved efficiently and sustainably. This reduces post-harvest losses and maintains food quality. By utilizing green hydrogen, farms can enhance their food preservation practices while minimizing their environmental impact.

Green hydrogen offers a sustainable, emissions-free energy source for farming, reducing reliance on fossil fuels and minimizing environmental impact. As technology advances, it has the potential to revolutionize agricultural practices, contributing significantly to cleaner, more resilient food production systems.

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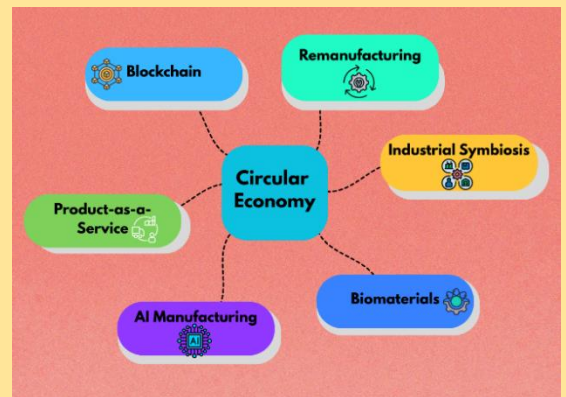
CIRCULAR ECONOMY STRATEGIES: PAVING THE WAY TO A SUSTAINABLE FUTURE

Soheli Saha

"The greatest threat to our planet is the belief that someone else will save it" ~ Robert Swan, Environmentalist

In a world increasingly affected by resource depletion and climate change, the traditional “take-make-dispose” model of consumption is no longer sustainable. The circular economy offers a smarter alternative—an economic model that minimizes waste, continuously repurposes resources, and prioritizes efficiency within industries. This concept goes beyond mere recycling; it aims to create a regenerative loop where materials, energy, and products are constantly cycled back into the economy. By leveraging advanced technology, rethinking production systems, and promoting collaboration, businesses and governments can reduce their environmental impact while remaining economically competitive.

The question “*Why buy when you can lease?*” introduces the “*Product-as-a-Service*” model, which emphasizes access over ownership. Companies like Philips and Rolls-Royce are pioneers in this approach, providing lighting and jet engines as services instead of selling them as physical products. This shift holds manufacturers accountable for the longevity and maintenance of their products, which helps reduce the demand for raw materials. It also encourages companies to focus on durability and upgradability instead of planned obsolescence. Additionally, demand-driven rental and subscription models, such as Rent the Runway and Grover, allow consumers to access high-end products without contributing to overproduction. Furthermore, car-sharing platforms like Zipcar and BlaBlaCar are making significant advancements in this area.



“*What if one industry’s waste became another’s raw material?*” The future of manufacturing is shifting toward zero-waste production models, in which every byproduct is transformed into a new resource. Through industrial symbiosis, businesses can trade their byproducts, turning waste streams into valuable resources. Denmark’s Kalundborg stands as a pioneering eco-industrial zone, where leftover fly ash reinforces cement and steam from power plants provides heat for nearby homes. This innovative approach encourages communities worldwide to rethink their waste management practices. Imagine a world where a closed-loop, cross-industry ecosystem flourishes, with algae farms producing biofuels using carbon dioxide emissions from breweries.

Advanced economies are leveraging AI-driven predictive analytics in manufacturing to minimize waste and energy consumption. By optimizing supply chain logistics, AI ensures that only essential resources are utilized. Pioneering companies like ZenRobotics and AMP Robotics are at the forefront of this movement, preventing valuable materials from ending up in landfills due to sorting errors. Retail leaders such as IKEA are employing AI to forecast customer demand, thereby reducing waste in both production and distribution processes.

Nature has mastered the art of circularity over billions of years, and now we are beginning to follow suit. Breakthroughs in biomaterials are transforming industries that have historically relied on plastics and toxic chemicals. Companies like Ecovative are pioneering mushroom-based packaging solutions, including biofabricated leather made from mycelium to replace Styrofoam. Pangaia, on the other hand, produces clothing using seaweed fibers and peppermint oil, significantly reducing the need for harmful dyes and synthetic materials. Additionally, as the construction industry evolves, bio-concrete infused with microorganisms can heal cracks, extending its lifespan while also mitigating the substantial carbon footprint associated with cement production.

Have you ever thought about the question, “*Why discard when you can reinvent?*” Remanufacturing is evolving from mere refurbishment to innovative reinvention. Companies like Tesla are setting an example by recycling electric vehicle batteries and extracting valuable metals for use in new ones. The true innovation lies in scaling this practice to include electronics, appliances, and even medical equipment.

Customers and corporations are prioritizing responsibility. Blockchain technology enables tracking of materials, ensuring ethical sourcing and disposal. Companies like Stella McCartney use it to maintain sustainable fashion supply chains. Understanding a product’s journey from origin to recycling makes you a changemaker.

Embracing the circular economy goes beyond simply adopting new technologies or business strategies; it requires a fundamental reevaluation of our relationship with the planet. Each of us has the potential to be a changemaker. By choosing to lease instead of buy, supporting eco-friendly products, and promoting innovative waste management practices, we can collectively reduce our environmental impact. Let us commit to rethinking, reusing, and reinventing our approach to create a prosperous, circular world. The time for action is now; *Are we prepared to close the loop?*

WASTE-TO-ENERGY SOLUTIONS: TACKLING EMISSIONS AND POLLUTION

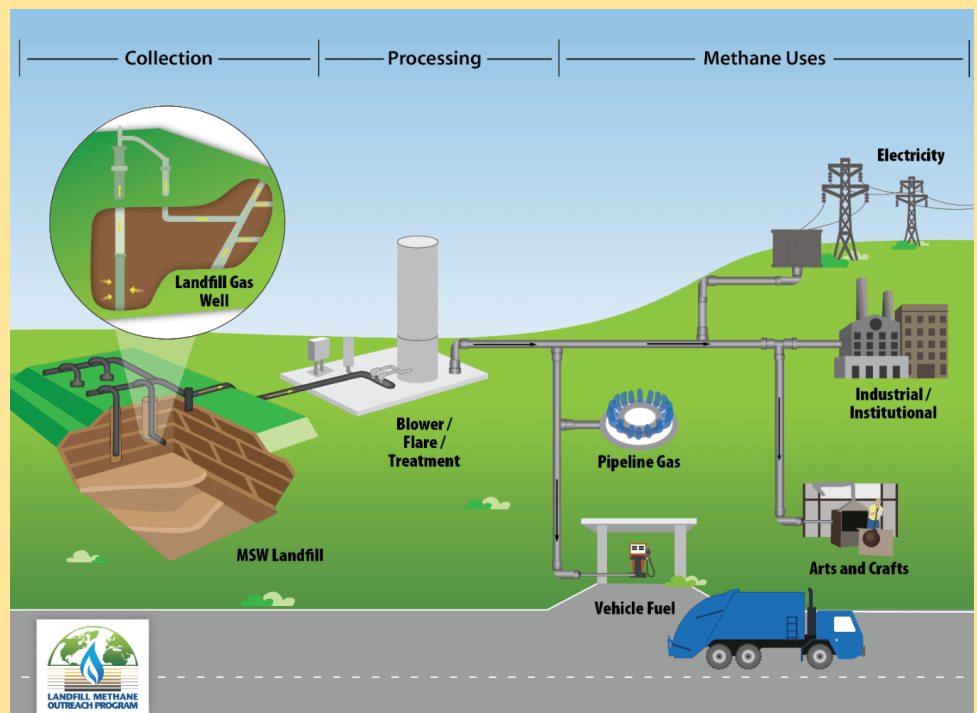
Sravana Chanda

With the increase in waste generation globally, waste-to-energy (WTE) solutions are becoming necessary for sustainable waste management as well as fighting environmental issues. Billions of tons of waste are produced by the world every year, with most of it finding its way to landfills or contaminating natural habitats. Waste decomposition in landfills produces methane, a potent greenhouse gas that is one of the causes of climate change, while its improper disposal results in serious air, soil, and water contamination. Waste-to-energy technologies offer a solution through the conversion of municipal solid waste (MSW) into energy forms that are useful, including electricity, heat, or biofuels. Some of these technologies involve incineration, where waste is combusted at high temperatures to produce steam for power generation, and gasification, where waste is transformed into synthetic gas to be used as fuel. Anaerobic digestion treats organic waste using microorganisms to produce biogas for energy, while pyrolysis decomposes waste thermally into bio-oil and syngas, providing a substitute for fossil fuels. Contemporary WTE plants use cutting-edge filtration technology and emission reduction systems, keeping the level of harmful pollutants significantly lower while also supplying a renewable energy source continuously.

Waste-to-energy technology provides lots of environmental as well as economic advantages. Waste-to-energy technology diverts waste away from landfill spaces, which reduces methane emissions and saves land. Greenhouse gas emissions are also reduced in comparison to traditional methods of waste disposal by WTE technologies because they keep the release of hazardous gases from waste decomposition under check. Recovering valuable metals and materials from waste also supports the principles of the circular economy and reduces dependence on raw materials. In addition, WTE contributes to energy security by supplementing traditional power sources with a renewable and consistent source of energy. However, with all these benefits, WTE still has a number of disadvantages, including a high initial cost, public opposition due to concerns over air pollution, and inefficient segregation of wastes. WTE critics argue that it releases toxic emissions, but emission control technologies have improved significantly, and contemporary WTE plants are much cleaner than other forms of waste combustion.

Though WTE cannot be used on its own, when combined with rigorous recycling practices and curbs on waste generation, it provides an all-embracing solution to sustainable waste management. Sweden and Japan, among other nations, have managed to integrate WTE into their waste management policies, with major success in decreasing landfill dependency and generating energy at high efficiency.

The future of waste-to-energy technology is bright as governments and industries continue to invest more in research



and development to enhance WTE efficiency and sustainability. Enhanced emission control technologies, better waste separation methods, and advancements in waste conversion technologies continue to render WTE more viable and sustainable. As the world shifts towards renewable energy and sustainable waste management, WTE plays a main role in bridging the gap between waste reduction and energy production. However, a balanced approach combining waste minimization, recycling, and efficient energy recovery is essential for long-term environmental health. Policymakers, businesses, and communities must work together to adopt and optimize WTE solutions and help ensure a clean and sustainable future.

NET-ZERO STRATEGIES FOR REDUCING GREENHOUSE GAS EMISSIONS GLOBALLY

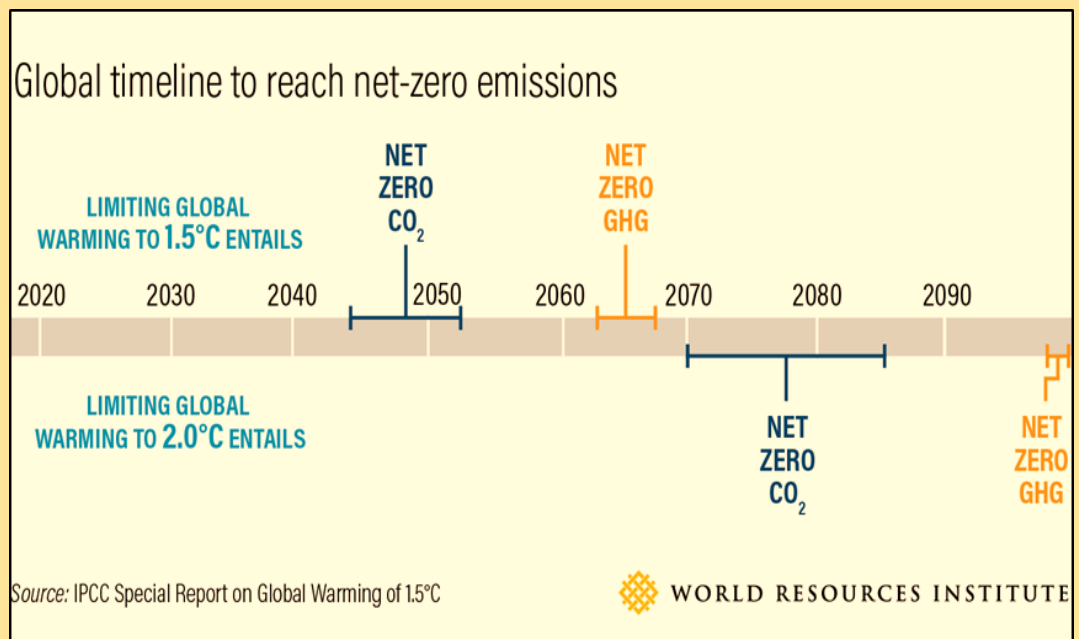
Tazmin Sultana

Achieving net-zero greenhouse gas (GHG) emissions is a vital goal in the battle against climate change. This involves striking a balance between the amount of GHGs released into the atmosphere and the amount removed. Reaching this goal requires a multifaceted approach that encompasses policy reforms, technological advancements, and collaborative efforts across various sectors and nations.

A straightforward strategy for attaining net-zero emissions is to transition from fossil fuels to renewable energy sources such as solar, wind, and hydroelectric power. This shift not only contributes to a reduction in CO₂ emissions but also enhances global energy security by diversifying energy options, as highlighted in energy trilemma reports. Companies like Amazon and Google are investing in next-generation nuclear technologies, providing environmentally friendly energy to their data centers while demonstrating a strong commitment to sustainability throughout their operations.

Countries such as China, the USA, India, and the European Union are quickly advancing their commitments to achieving net-zero emissions, creating a significant global movement toward this goal. Bhutan made history in 2015 by becoming the first country to declare a net-zero target. Currently, over 90 countries have established net-zero objectives, collectively representing approximately 80% of global emissions.

Carbon capture, utilization, and storage (CCS) technologies are essential for reducing emissions in hard-to-abate sectors such as steel and cement production. The UK government has already allocated substantial funding to support CCS initiatives, highlighting its importance in reaching net-zero targets. Additionally, carbon pricing policies, including carbon taxes and cap-and-trade systems, provide businesses with financial



incentives to reduce emissions while encouraging innovation in clean technologies. Effective strategies also include promoting low- or zero-emission solutions in urban areas and enhancing afforestation and reforestation efforts. These actions play a crucial role in increasing CO₂ sequestration and support technological and policy-driven mechanisms for carbon absorption.

Climate change is an issue that transcends national borders, necessitating international cooperation. Agreements like the Paris Accord set forth targets for emissions reductions and promote global collaboration. The UN's 'race to net-zero' initiative encompasses nearly 3,000 entities, accounting for around 25% of global CO₂ emissions and over 50% of the world's GDP. While transitioning to net-zero may require an annual investment of approximately €8.2 trillion, an increasing number of companies are recognizing the importance of sustainability and are committing to science-based targets for emission reduction. Nevertheless, current emission levels remain alarmingly high, with projections suggesting a potential temperature increase of 3.1 degrees Celsius by the end of the century, highlighting the urgent need for more ambitious global strategies.

In conclusion, achieving net-zero greenhouse gas emissions will require a comprehensive approach that involves a combination of renewable energy, energy efficiency, carbon capture and storage technologies, effective policy measures, and reforestation efforts. It is imperative for governments, industries, and individuals to unite in order to secure a sustainable and resilient future for our planet.

Aveek Roy

The Energy Crisis in Disasters

When disaster strikes, darkness follows. Hospitals experience power outages at the same time communication networks fail while communities lose access to emergency support. A major obstacle that hinders relief operations continues to be the problem of obtaining trustworthy energy access. Power grids as well as diesel generator supply and fuel delivery systems routinely break down during emergencies. Diesel generators remain widespread although they create major problems such as fuel challenges, cost issues and environmental pollution. The benefits of solar energy become apparent through its unique characteristic of offering both renewable energy solutions together with a clean operation, that is, operates without fuel consumption while releasing zero pollutants.

Solar Solutions in Action: Real-World Impact

Portable Solar Kits for Immediate Relief

The use of lightweight modular solar kits has become vital equipment during emergency responses. UNICEF together with the Red Cross implemented solar-powered charging systems which include portable lights and water filtration units in disaster struck regions of the Philippines following Typhoon Haiyan, 2013.

Solar Microgrids for Long-Term Recovery

The post-Hurricane Maria situation in Puerto Rico, 2017, led to the essential development of solar microgrids that functioned as vital power backup for communities. The installation of rooftop solar panels along with battery storage systems made communities develop their own energy hubs which provided continuous power to schools, clinics and shelters.

Solar-Powered Medical Facilities

Solar energy maintains operational status for hospitals located in conflict regions such as South Sudan along with Yemen. Solar arrays provide power to Cold storage equipment for vaccines and operate surgical tools as well as neonatal care systems. Solar-powered ventilator systems together with vaccine cold chain distribution enabled medical teams to save numerous lives across distant places where electricity was not accessible during COVID-19.

Advantages of Solar in Emergency Response

Installation of solar panels takes place in a matter of hours.

Solar technologies stretch from lightweight cell phone chargers to power multi-megawatt microgrids according to different necessity levels.

Benefit from complete cost-neutral operations.

Solar power operations help countries lower their consumption of fossil fuels, supporting the global push for climate goals.

Challenges

Solar power technology transforms energy consumption yet several challenges exist during operation:

- High upfront investment for equipment like batteries.
- Battery systems need to be highly developed because cloudy days and nighttime restrict power storage capabilities.
- Passing knowledge to local workers regarding maintenance operations demands technical expertise for proper execution.

Solutions

- **Innovative Financing:** The World Bank along with other organizations provide grant funding through innovative financing approaches that support pay-as-you-go solar energy solutions.
- **Improved Battery Tech:** Modern production of Lithium-ion and solid-state batteries is making these technologies more economical while improving their operational efficiency.
- **Community Training:** NGOs like We Care Solar trains local personnels to sustain equipment after disasters strike.

DESIGNING ECO-FRIENDLY WIND AND SOLAR FARMS TO MINIMIZE WILDLIFE IMPACT

Biplab Pal

The world's move towards the use of renewable energy sources such as wind and sun power is based on the desire to fight climate change and shift towards a sustainable future. The technologies emit fewer greenhouse gases and help in ensuring a healthier world. Their application, however, comes with the involvement of wildlife that is causing a challenge. Scientists, energy developers, and conservation groups are collaboratively seeking out new solutions that balance clean energy development with avoiding harm to wildlife, creating a future where ecosystems and clean energy coexist.

Wind farms are a major hazard to bird species, especially migratory songbirds and raptors, through direct collision with the blades of turbines. Wind farms have the potential to cause habitat loss, displacement, and disturbance of feeding or roosting areas. Bats are also affected, suffering from barotrauma, a lung damage resulting from sudden changes in air pressure around the rotating blades. Solar farms occupy large areas of land, causing loss of habitat, fragmentation and ecosystem disruption. The "lake effect", where the large, reflective surfaces of solar panels can attract waterbirds that mistake the panels for bodies of water, causing collisions and failure to lift off from the parched panels.

Wind and solar farms can significantly reduce their environmental footprint by minimizing their impact on wildlife

. Wind farms and solar parks can greatly reduce their environmental footprints by opting for proper sites, undertaking meticulous surveys, mapping bird and bat flight patterns, and giving more preference to degraded or disturbed areas over intact natural environments and lands with high indigenous biodiversity and vulnerable ecosystems. Well-integrated ecological evaluations, ranging from biodiversity baseline surveys to proper impact assessments, are important determinants of sensible siting practices.



Fig: Wind Farms and Biodiversity (Source: windcycle.energy)

Over the past two decades, wind turbine design has significantly reduced their impact on birds. Modern land-based turbines are larger and spaced farther apart, reducing the need for multiple turbines. Painting one of the blades black can increase visibility, reducing collision fatalities by up to 70% for some species.



Fig: Solar Plants and Sunflower (Source: solarpowerportal)

Solar farms with design features consist of raising panels to provide native vegetation cover and animal movement corridors, preserving connectivity of habitats. To reduce the "lake effect," developers may increase panel spacings and use non-reflective surfaces or specialized coatings.

Beyond careful design, the way wind and solar farms are operated can significantly influence their impact on wildlife. Advanced systems employ "real-time data" on temperature, wind speed and bat activity to selectively shut down turbines when the risk is maximum. Ultrasonic and acoustic deterrent devices are also used to deter bats and some bird species from approaching turbines. Solar farms can enhance biodiversity by sowing native grasses and wildflowers, providing habitats for wildlife and pollinators. This enhances soil health, and minimizes maintenance. The "agrivoltaics" idea integrates solar energy production with agriculture, including grazing livestock that can control vegetation, offer extra benefits to the land and potentially generate economic returns. Designing environmentally friendly wind and solar farms to reduce their footprint on wildlife is a viable objective. The continued partnership among researchers, developers, conservationists and regulatory agencies offers a positive vision for a future in which our energy requirements and the preservation of our planet's wildlife coexist.

HARNESSING BARREN LANDS FOR LARGE-SCALE RENEWABLE ENERGY PROJECTS

Disha Roy

“A strong renewable energy industry is good for our environment and our economy.”

—Roy Cooper

Barren lands, often underutilized due to poor soil quality, extreme climates, or geological factors, are a crucial resource for sustainable development and economic growth. Areas such as deserts, mountains, strip mines, and regions with less than 15% vegetation cover can be effectively used for large-scale renewable energy projects. This approach can help minimize conflicts over land use and promote sustainability. The growing global demand for renewable energy, combined with the finite nature of fossil fuels, makes transitioning to renewable sources essential. Deserts, for example, are ideal for harnessing solar energy due to their high solar irradiance. The Sahara Desert receives more than 3,000 hours of sunshine annually and already hosts significant solar operations, such as those in the Mojave Desert and the Bhadla Solar Park in India. Mountainous regions, characterized by rugged terrains, also have high wind speeds, making them suitable for wind energy generation. Additionally, degraded forest lands of low ecological value can be transformed into wind farms, provided careful planning is undertaken to minimize impacts on pristine forest ecosystems. Other forms of barren land, including abandoned mines and salt flats, may also be viable locations for renewable energy projects, depending on specific technologies and environmental conditions.

Renewable energy developments on arid lands provide many advantages, such as economic benefits from land leasing, manufacturing, construction, operation, and maintenance jobs, and tax contributions to the local community for vital public services. From an environmental perspective, these lands reduce conflicts with agriculture and possibly high-value ecological zones. Desert utility-scale solar PV facilities have the ability to improve surface soil quality and cover vegetation, which can reduce climate change. A strategy of renewable energy ensures energy security and self-sufficiency through abundant resources. Technical issues, solar and wind power variability, logistics and engineering challenges, and environmental risks must be addressed in order to deploy successfully at large scale. Mass developments can disrupt sensitive ecosystems, endanger bird and bat populations, and require significant front-end investment and specialized personnel and equipment. Social and logistical concerns are remoteness, complex construction and labour logistics, and potential social acceptability issues and land use conflicts, even in supposedly unpopulated landscapes.

Advances in technology are increasing the viability of installing renewable energy on barren lands. Solar energy has high-efficiency modules, self-cleaning systems, and sophisticated tracking systems, and wind energy has taller and more massive turbines with larger rotors. Better technologies for wind resource assessment help with optimal placement of turbines. Storage technologies in batteries increase the feasibility of grid-scale storage for stand-alone projects. Smart grids and high-voltage direct current transmission lines enable power transfer from distant locations with low losses. Remote maintenance and monitoring through drones and robotics are becoming more advanced. Government policies and action plans promoting the realization of potential for renewable energy on desert lands are needed. Land use planning strategically, environmental impact assessment holistically, grid infrastructure investment, and local community participation are the success factors. Strategically locating solar and wind technology on unused land can generate clean power, replace fossil fuel reliance, and mitigate climate change.

Barren Land Type	Suitable Renewable Technology	Primary Advantages	Key Challenges
Deserts	Solar PV, CSP	High solar irradiance, ample space	High temperatures reduce efficiency, dust accumulation, water scarcity for cleaning, and remote locations
Rocky terrains (mountains)	Wind	Strong and consistent winds	Terrain variability, accessibility for construction and maintenance, potential impact on mountain ecosystems
Degraded forests	Wind	Utilizing low ecological value land	Potential deforestation, habitat fragmentation, impacts on birds and bats
Other (salt flats, mines)	Solar, wind (depending on location)	Utilizing otherwise unproductive land, potential for repurposing disturbed sites	Specific environmental conditions may pose challenges, and infrastructure requirements

TURNING ENVIRONMENTAL AWARENESS INTO IMPACTFUL CLIMATE ACTION

Falguni Murmu

Today, environmental awareness is an important ability because ecological degradation and climate change threaten human survival. Awareness of sustainability is not just about education toward nature, but action toward preserving it as well. Through conscious but small changes in their daily lives, individuals can contribute toward an environmentally sustainable future.

Natural resources such as water, air, and soil form the basis for human survival, but these resources are becoming increasingly threatened through overexploitation and pollution. Environmental awareness educates people about the necessity of conservation and motivates them to adopt sustainable practices such as conservation of water, minimization of energy consumption, and waste reduction. The conservation of natural resources ensures their continued existence for posterity, thereby avoiding the catastrophes arising from their non-consumption and environmentally unsound management. Pollution is yet another area of concern calling for environmental awareness. Air, water, and soil pollution arising from urbanization and industrialization pose serious threats to human health. Environmental awareness campaigns encourage individuals to embrace cleaner habits that incorporate the use of green products, reduction of plastic waste, and eco-friendly transportation in the form of cycling or public transport. These results translate into cleaner environments and healthier populations with diminished pollution-related diseases, adding to their well-being.

Climate change remains one of the most significant global challenges, with rising temperatures, extreme weather events, and sea-level rise threatening ecosystems and human settlements. Raising awareness about climate change empowers individuals to take action in reducing their carbon footprint. Small steps, such as switching to renewable energy, using energy-efficient appliances, and supporting climate-friendly policies, can collectively lead to substantial change. When people understand the causes and consequences of climate change, they are more inclined to support and participate in sustainability initiatives. The preservation of biodiversity intimately relates to environmental awareness as this is the balance of such life forms within ecosystems that is dependent upon the different species' plant and animal variable. Raising awareness about biodiversity will instil a sense of responsibility for conservation; these will support wildlife conservation, engage in afforestation, protect natural habitats, and hinder poaching and deforestation.

Conferences indeed have a huge role to play in enhancing environmental consciousness. It brings together experts with policymakers, activists, and sometimes the general public at times to discuss sustainable solutions. These events also offer learning, knowledge sharing, and opportunities for collaboration. They also provide an opportunity to listen to and exchange different perspectives on some of the world-recent most pressing issues, including but not limited to pollution control, energy sustainable production and conservation efforts. But, perhaps most importantly, this knowledge will become instrumental in founding new, local initiatives; lobbying for policy changes; and inspire community action toward environmental protection. Technology will also play a very important role when it comes to climate action. AI, blockchain, IoT, all invented in the recent years, have now completely changed the way environmental monitoring and sustainability actions are being carried out. Through these, it is possible to track one's carbon footprint, improve energy efficiency, and also make disaster preparedness better. Increased environmental communication has escalated through digital platforms and social media mobilizing people to take actions and put pressure to account to the corporations and governments for their environmental footprint.

Letting people know environmental issues was necessary but not enough, it requires something more as concrete to mitigate the effects of climate change and environmental degradation. It has to translate itself into concrete actions for sustainability at every level. Education, innovation, policy intervention and participation of all sectors of the society would be instrumental in turning environmental consciousness into reality. By creating a sense of urgency and stewardship within human kind, much can be achieved in mitigating climate change, conserving resources, and ensuring a better world for the generations to come.

CHALLENGES AND OPPORTUNITIES OF MEETING THE GLOBAL TARGET OF TRIPLING SOLAR ENERGY

Joyeta Basu

Transitioning to renewable energy is essential for mitigating climate change and promoting sustainable development. Solar energy stands out as a key renewable energy option due to its widespread availability and technological advancements. On a global scale, nations and international organizations have committed to tripling solar energy capacity by 2030. Although this goal presents numerous opportunities, it also brings forth challenges that must be addressed for successful implementation.

Challenges

1. Infrastructure and Grid Integration: A significant hurdle in expanding solar energy is the need for substantial infrastructure investments. Most existing power grids are not designed to handle the variability and decentralized nature of solar power. Upgrading these systems requires considerable financial resources and technical expertise to support increased solar production.

2. Energy Storage Limitations: As solar power generation relies on sunlight, it tends to be intermittent. This necessitates efficient energy storage solutions to ensure a steady power supply. However, current battery storage technologies remain expensive, and large-scale deployment is constrained by supply chain challenges, including limited availability of crucial materials like lithium and cobalt.

3. Land and Environmental Considerations: Large-scale solar farms require vast tracts of land, which may conflict with agricultural, conservation, and urban development needs. Poor land-use planning can lead to biodiversity loss and habitat disruption.

4. Supply Chain and Raw Material Constraints: The production of solar panels and their components is contingent on critical raw materials such as silicon, silver, and rare earth metals. Disruptions in supply chains, trade barriers, and geopolitical tensions can hinder the rapid rollout of photovoltaic energy systems.

5. Financing and Investment Barriers: Despite the significant decline in photovoltaic energy costs, the initial capital investment remains a challenge, particularly for developing countries. Many regions struggle to access affordable financing options and incentives necessary for widespread solar energy adoption.

6. Policy and Regulatory Challenges: Effective policies and regulations are vital for increasing solar energy capacity. Many nations still face bureaucratic obstacles, prolonged permitting processes, and inadequate incentives for private investment in solar infrastructure.

Opportunities

1. Technological Advancements: Progress in photovoltaic efficiency, energy storage, and grid management is enhancing the viability of solar energy. Innovations like perovskite solar cells and bifacial panels can potentially increase energy output while lowering costs.

2. Economic Growth and Cost Reductions: The decreasing costs of solar photovoltaics (PV) make it one of the most affordable energy options. Widespread adoption of solar energy could create jobs, stimulate economic growth, and enhance energy security.

3. Decentralized and Off-Grid Solutions: Expanding solar energy creates opportunities for decentralized and off-grid solutions, particularly in remote or underserved areas. Solar mini-grids and home solar systems can provide electricity access to millions who currently lack reliable power.

4. International Cooperation and Investment: Collaborative efforts to expand solar capacity can lead to increased international investments, technology transfers, and partnerships. Initiatives like the International Solar Alliance (ISA) foster cooperation to accelerate solar energy adoption worldwide.

5. Sustainable Land Use and Agrivoltaics: Innovative approaches such as agrivoltaics, where solar panels coexist with agricultural practices, can optimize land use, enhance food security, and boost energy production without compromising environmental sustainability.

6. Government Incentives and Policy Support: Supportive policies, including tax credits, subsidies, and feed-in tariffs, can encourage solar energy adoption. Enhancing regulatory frameworks to facilitate investments and simplify permitting processes will be crucial to achieving the tripling target and tripling goal.

EMPOWERING WOMEN IN THE GREEN ECONOMY FOR A SUSTAINABLE WORLD

Lopamudra Mukherjee

Upholding an economy that goes green is no longer optional but rather a need stemming from the climate crisis and environmental degradation. To achieve a green economy, all stakeholders and parties must work as one toward making this economy low-carbon, resource-efficient, and socially inclusive. The inclusion of women is necessary for the change since they actually account for almost half of global persons. In addition to promoting gender equality, women empowerment in the green economy catalyses innovation, better sustainability, and strong economic resilience.

Women's grassroots activism has seen them removed from exclusive pioneering establishment space in environmental conservation. Today, their responsibilities tend to include renewable energy, climate policy, sustainable agriculture, and greener entrepreneurship. They work in waste management, renewable energy development, and environmentally friendly businesses to cut carbon footprints and promote circular economies. Women refer to a significant proportion of the workforce in agriculture in developing countries, for instance. They can gain access to modern technologies with sustainable farming methods and financial resources to increase productivity while conserving natural resources. Similarly, women-led businesses in the renewable energy sector are showing that even environmentally sustainable solutions could also be profitable and thereby assist in realizing economic growth and, at the same time, acting as climate change combatants.

Women still meet many roadblocks both in society and institutions for achieving the best possible entry points into the economy for which they are most suited- a green economy. These challenges come with socio-economic limitations to mobility and decision-making caps, unequal access to the finance system, gender bias in policymaking, and limited access to STEM (science, technology, engineering, and mathematics) education and training.

Strategies to Empower Women in the Green Economy

Education and Skills Development: Women should be invested into education in schools that could be beyond STEM and emplace them with the knowledge and skills to develop green jobs. Training in renewable energy, sustainable farming, and climate science should augment the participation of women in such employment sectors.

Finance inclusion: Women entrepreneurs are deprived access to the capital required to start or expand their green businesses: therefore, Governments, banks, and impact investors should develop gender-responsive financial instruments like micro-loans, grants, and green bonds for women-owned businesses in the area of sustainability.



Policy and Leadership Representation: Policies to implement by the government and organizations should promote gender inclusion in environment governance.

Support Women in Sustainable Agriculture: Access to land, technology, and markets for women farmers will enable food security through sustainable agriculture. Women's cooperatives and women-led initiatives gain momentum in such a case.

Encouraging Green Entrepreneurship: Green start-ups led by women in clean energy, eco-tourism, sustainable fashion, and recycling should benefit from mentorship, incubation programs, and access to business networks.

Sustainability in the green economy depends on empowering women. This can create a robust and inclusive future by advocating for gender equality, offering financial assistance, and guaranteeing representation. In the green economy, women's leadership will spur innovation and make the earth healthier for coming generations.

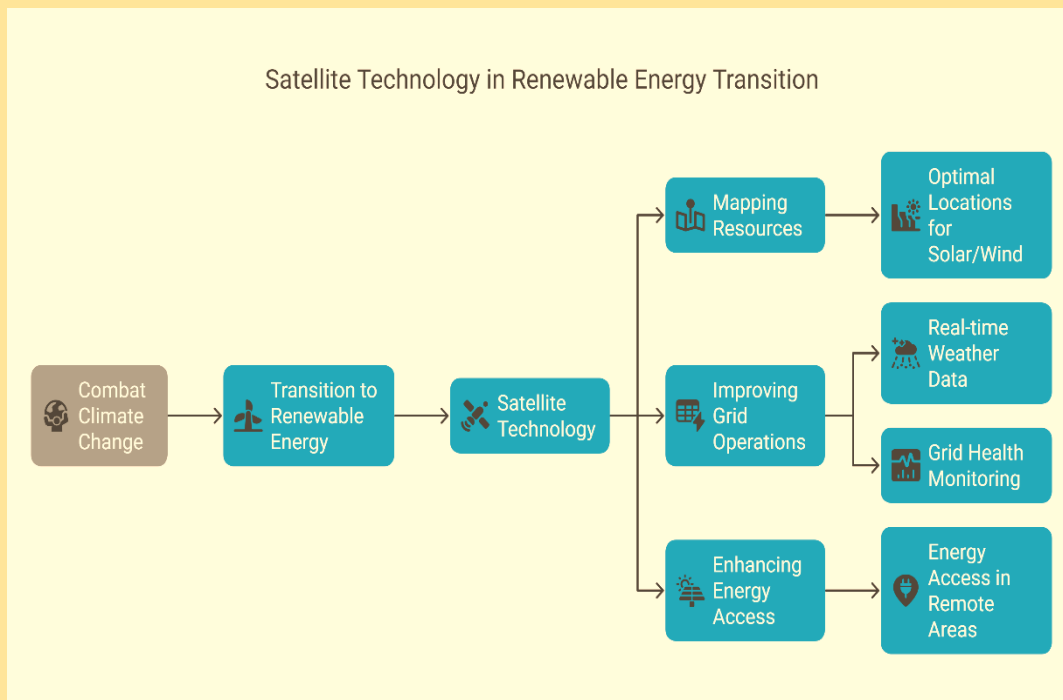
LEVERAGING SATELLITE TECHNOLOGY TO FAST-TRACK THE GLOBAL SHIFT TO RENEWABLE ENERGY

Maitreyee Biswas

As the world intensifies its efforts to combat climate change, transitioning to renewable energy stands as a cornerstone of a sustainable future. Solar, wind, and other renewable energy sources are essential for reducing our reliance on fossil fuels; however, the challenge lies in their effective deployment and integration on a large scale. This is where satellite technology comes into play: an incredibly powerful solution that is gaining momentum in facilitating the shift to clean energy. By providing real-time information, monitoring environmental metrics, and optimizing energy infrastructure, satellites play a crucial role in the pursuit of a more sustainable planet.

Mapping and Tracking Renewable Resources

One of the foremost challenges in the rollout of renewable energy is identifying the optimal locations for solar panels and wind turbines.



Satellites offer a promising solution by mapping solar and wind resources across extensive areas. With advanced sensors, satellites can accurately assess solar radiation levels and wind speeds, providing valuable insights into which regions are most suitable for renewable energy extraction. For solar power, satellite data can evaluate factors such as cloud cover, sunlight intensity, and atmospheric conditions to pinpoint the best sites for large-scale solar farms. Similarly,

satellite-based radar and LIDAR technologies can analyze wind patterns and identify areas with significant potential for wind energy generation.

Improving Grid Operation and Energy Predictions

Renewable resources such as wind and solar power are inherently intermittent, generating energy based on weather conditions. This variability creates challenges in aligning energy supply with demand. Satellites play a crucial role by providing real-time weather data, which helps grid operators improve forecasts of renewable energy output. With accurate predictions, energy grids can be adjusted to accommodate fluctuations in generation, enhancing load balancing and ensuring that supply meets demand. Additionally, satellites are capable of monitoring the health of energy grids and infrastructure, identifying vulnerabilities that could lead to power outages and enabling predictive maintenance to avert disruptions.

Energy Access in Remote Areas

One of the most promising applications of satellite technology is improving energy access in remote or underserved areas. Off-grid locations often lack reliable power infrastructure, but satellites can identify opportunities for economically viable and sustainable solar or wind energy use. Additionally, satellite imagery can aid in monitoring energy consumption patterns, ensuring that renewable energy systems are deployed promptly and precisely where they are most needed.

Satellite technology is transforming the renewable energy landscape by mapping resources, managing grids, monitoring emissions, and accelerating the global transition to clean energy. As advancements in satellite technology continue, its contribution to improving sustainability and optimizing energy systems will speed up the shift toward a renewable-powered future, effectively addressing the climate crisis.

CREATING A SUSTAINABLE FUTURE THROUGH WORLDWIDE COLLABORATION ON RENEWABLE ENERGY SOLUTIONS

Mir Wasif Ahammed

The world is now on the threshold of what is clearly a historic juncture wherein the switch from fossil fuels to renewable energy no longer remains an option but rather an imperative. The greenhouse gas emissions from coal, oil, and gas affect these ecosystems and economies, as well as human health. Reducing these risks can only be done by working together globally on the adoption of renewable energy. Sustainable alternatives that can add greenhouse gas emissions reductions for energy security are solar, wind, hydro, and geothermal power. Accomplishing this will require international collaboration in sharing technology, aligning policies, investing, and developing infrastructure. According to the international context, fossil fuel combustion produces more than three-quarters of the greenhouse gas emissions that accentuate climate change. Higher temperatures lead to extreme weather events, glacier melt, and rising sea levels, putting coastal communities at risk. Renewable energy disrupts little or no emissions and, therefore, plays an important role in **limiting global warming to 1.5°C**, as stated by the **Paris Agreement**.

International Agreements

- ***The Paris Agreement (2015)***: A landmark treaty where 196 countries committed to reducing emissions through renewable energy investments.
- ***The International Solar Alliance (ISA)***: Led by India and France, this alliance promotes solar energy adoption in sun-rich countries.

Technology and Knowledge Sharing

There, with an advanced level of renewable energy technology, are the developed nations that have very basic or completely lacking the necessary infrastructure and expertise in the developing countries. Joint projects as **Germany's support for African solar farms** or **China's investments in Latin America's wind energy**, show how this technology transfer would help bridge the divide between nations. Countries like **Denmark and Iceland** have managed to transition fully to their renewables and thus become energy-independent. The most significant barrier is related to solar and wind energy being intermittent. Continuous energy supply is possible through a combination of developments in storage batteries (**lithium-ion, solid-state**) as well as smart grid technology. Countries like **Australia** and the **U.S.** are developing large-scale battery storage systems to further support the steady distribution of electricity.

Financial Investments and Economic Equity

Massive investments are necessary for the transition to renewables. The **World Bank, IMF, and private investors** are funding massive projects through green bonds and climate funds. For example, the **Green Climate Fund (GCF)** provided billions of dollars to renewable energy projects in developing countries. **Public-private partnerships (PPPs)** are crucial for scaling up clean energy infrastructure. Developing countries often have high upfront costs that hinder implementation of renewable projects. International cooperation, low-interest loans, and microfinancing can help make these projects possible. The **Solar Sister program** operating in **Africa** helps promote **women's empowerment** by training women to sell solar products in rural settings and thus blends sustainability with economic development.

Nations must enhance cooperation through:

- **Joint research programs** on next-gen renewables (e.g., floating solar farms, green hydrogen).
- **Cross-border energy grids**, like the **North Sea Wind Power Hub**, which connects multiple countries to share wind energy.
- **Corporate commitments**, such as Google and Apple's pledges to use 100% renewable energy.

A sustainable future depends on collective action. By uniting governments, businesses, scientists, and citizens worldwide, we can accelerate the renewable energy transition. The technology exists—what we need now is global solidarity to implement it.

LEVERAGING SOIL CARBON SEQUESTRATION AS A KEY NATURAL CLIMATE SOLUTION

Priti Biswas

Carbon sequestration: Carbon sequestration is a process where carbon is captured naturally by the elements of our ecosystem which in turn reduces the amount of carbon dioxide in the atmosphere. This process of carbon sequestration helps in mitigating global climate change.

Soil carbon sequestration: Like that of carbon sequestration, soil carbon sequestration is a type of carbon sequestration where carbon is stored in the soil thereby helping to reduce atmospheric carbon.

Process of soil carbon sequestration: Photosynthesis is a process where plants absorb atmospheric CO₂ and convert it into organic compounds. These compounds are then transferred to the soil through root exudates, decaying plant matter, and soil organism activity. Microorganisms like bacteria and fungi decompose this organic matter, incorporating a significant portion of the carbon into stable soil organic carbon (SOC).

Importance of soil carbon sequestration: Soil carbon sequestration enhances soil health and fertility by increasing soil organic carbon (SOC), which improves soil structure, water infiltration, erosion reduction, and aeration. It also increases soil water-holding capacity, especially in arid and semi-arid regions. SOC boosts nutrient availability by providing food for soil microorganisms. This leads to increased agricultural productivity and food security, reducing the need for synthetic fertilizers and pesticides. It also reduces erosion, runoff, biodiversity, and water quality, offering a sustainable solution to climate change.

Role in combating climate change: Besides the above-mentioned benefits of soil carbon sequestration, it plays an important role in combating climate change. Soil carbon sequestration is a crucial process in combating climate change by reducing atmospheric CO₂ levels. It acts as a "carbon sink," absorbing and storing more CO₂ than it releases, thereby reducing the concentration of CO₂ in the atmosphere. This process occurs when plants absorb CO₂ during photosynthesis and convert it into organic compounds, which are then stored in the soil as soil organic carbon (SOC). Soil carbon sequestration also contributes to the global carbon cycle by restoring balance by transferring carbon from the atmosphere back into the terrestrial biosphere. Properly managed soil can store carbon for extended periods, effectively removing it from the active carbon cycle. It also enhances climate resilience by improving soil health, supporting diverse ecosystems, and supporting sustainable land management practices. Soil carbon sequestration promotes best practices such as no-till farming, cover cropping, crop rotation, and agroforestry.

Enhancing sequestration of carbon: Sustainable land management practices can enhance soil sequestration by minimizing soil disturbance, promoting cover cropping, diversifying crop rotations, integrating trees into agricultural landscapes, managing grazing systems, applying biochar to soil, and restoring degraded lands through reforestation or revegetation. These practices help preserve soil organic matter, increase biomass production, promote carbon accumulation, improve soil health, and enhance carbon storage in grasslands. Implementing these practices can also lead to improved soil fertility and carbon sequestration in grasslands.

Conclusion: Soil carbon sequestration is a potent natural climate solution that can be achieved through sustainable land management practices and investment in research and innovation, thereby mitigating climate change, enhancing agricultural productivity, and fostering a sustainable future.

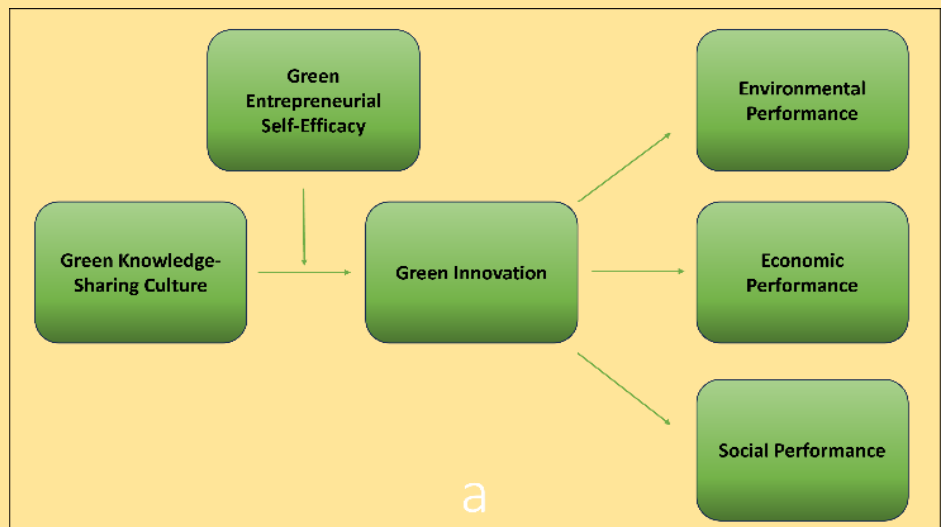
THE RISE OF GREEN ENTREPRENEURSHIP AND ITS ROLE IN SAFEGUARDING THE PLANET

Sanchita Saha

Green entrepreneurship is indeed a timely response to the most pressing environmental problems-such as climate change and depletion of resources-facing the world today. It creates profitable companies with a focus on improving the environment and saving it through ecologically sustainable practices as opposed to profit-oriented activities that have been enacted in the case of traditional entrepreneurship. Thus, environmental considerations would make it an important force for a balanced future, bringing prosperity in economic terms but also having its fair share of legacies for the well-being of the earth-expressive capitalism', decoupled from other social and environmental costs. Green entrepreneurship establishes innovative businesses for positive environmental impact and a sustainable society, valuing ecological sustainability alongside economic goals. It aims to transform the business landscape through resource efficiency, waste valorisation, and renewable alternatives, guided by the Triple Bottom Line. Motivations range from profit to a deep environmental commitment.

The increased interest in green entrepreneurship is evident and has continued to increase as global awareness towards environmental issues continues to rise, making sustainable options and developing problems that call for stricter regulations as well as scientific developments. Such tendencies have led to the emergence of market environmentalism, which speaks of how eco-consciousness pays in value-laden environmentalism where it is most favoured by the green-aware consumers, thus making these parts of the practices an inspiration for business innovation and ultimately success with favorable conditions entered by policymakers as well as self-value-influencing aspiring green entrepreneurs.

Green entrepreneurship is all about conserving the environment by producing process-oriented but green



products and services that generate less waste and depend on renewable resources. It provides products and services meant to be sustainable in terms of climate change and stimulates green innovation in technologies and processes. Sustainability must be integrated into such operations so at least they will be generating new jobs in a growing economy while creating an environment less harmful to the outside.

Green Entrepreneurship has gained importance, but it has its own set of challenges which often become hurdles in establishing and nurturing these businesses. Acquiring proper funds and resources is challenging as investors consider an investment in green ventures riskier or having a longer time for return on investment. Another critical roadblock involves managing the complicated, and at times, ambiguous regulatory scenario, which results in a requirement of spending more than ample time for compliance. Although the market for green products is growing, it is nonetheless relatively small compared with the conventional alternatives; customers tend to shy away from using green products either because they are now expensive or they are not available at all. Building a sustainable and ethical supply chain is also a mammoth task, requiring time to have suppliers who share the same commitment to environmental and social responsibility. Building consumer trust is critical for them, avoiding charges of "greenwash" associated with such actions.

Future green entrepreneurship is likely to have abundant fortunes in solving future environmental problems. One of the most prominent trends is the increase in technology incorporation to develop new innovative sustainability solution businesses to take advantage of advancements designed for energy-saving, waste-reducing, and greening processes. Principles of circular economy waste reduction, through reusing, repairing, and recycling, are also gaining momentum. Moreover, the further development and adoption of renewable energy technologies such as solar and wind energy will continue to be a major green entrepreneurship area

Government regulations about establishing environmental norms are important to green entrepreneurship. Strategies, support systems, incubators, and public procurement are pathways directing green markets. Incentives and partnerships create an enabling environment for green entrepreneurship embracing Triple Bottom Line which is transforming business. There are great challenges ahead, but the future is promising because of demand from technology and sustainability.

Sneha Bhattacharyya

To reduce carbon emissions and combat climate change, the world seeks sustainable solutions where bioenergy is recognized as an important element which has the ability to shift to a low-carbon future. Bioenergy provides a sustainable and adaptable energy option that can substitute fossil fuels across different industries. It has a potential to reduce greenhouse gas (GHS) emissions, enhance energy security, and foster circular economies.

Bioenergy and Emission Reduction

Lower Carbon Footprint: The primary usage of bioenergy over fossil fuel is that it lowers carbon footprint. In contrast to coal, oil, and natural gas, bioenergy is viewed as carbon-neutral since the carbon dioxide emitted during burning is approximately equal to the quantity absorbed by plants throughout their growth period. If biomass is harvested in a sustainable manner and new plants are cultivated to replace those that have been utilized, bioenergy can reach nearly net-zero emissions.

Waste Utilization and Methane Reduction: Most impressive feature of bioenergy is its potential to transform waste into energy. Organic waste from agriculture, forestry, and municipal origins decomposes, producing methane which is a powerful greenhouse gas. By converting these materials into biofuels or biogas er can store methane and utilize its energy source, stopping it from escaping into the atmosphere. This approach lowers emissions as well as helps in tackling waste management issues.

Biofuels use in Transportation: Due to diesel and gasoline consumption, transportation sector holds a significant share in global emissions. Biofuels like ethanol and biodiesel provides a more environment friendly option by lowering the emission cycle compared to fuels made from petroleum. Innovative biofuels sourced from non-food materials, including algae or agricultural waste; enhance sustainability by preventing competition with food crops.

Bioenergy's Role in Sustainability

Bioenergy plays an essential role in the renewable energy portfolio, enhancing the reliability of variable sources such as solar and wind. In contrast to these fluctuating energy options, bioenergy offers a consistent and manageable power supply which maintains grid stability. Biomass power facilities can function continuously or act as supplemental energy sources during times when solar or wind production is low.

By reducing erosion, boosting soil organic matter, and carbon sequestration, sustainably managed bioenergy crops like switchgrass and miscanthus can improve soil health. Furthermore, biochar which is a byproduct of the generation of biomass energy can be applied as a soil amendment to increase soil fertility and seal carbon into the earth.

Apart from these, economic opportunities are created by increasing the production of bioenergy especially in rural areas. Bioenergy plants produce jobs in production, processing, and distribution, while farmers and landowners can make extra money by providing biomass feedstocks. This lessens dependency on imports of fossil fuels and promotes economic growth and energy independence.

Challenges of Bioenergy

Large scale bioenergy production must steer clear of land-use changes that result in biodiversity loss and deforestation. The utilization of waste residues, marginal lands, and sustainable forestry techniques should all be promoted by policy. When it comes to arable land, energy crops should not compete with food crops, rather priority should be given to advanced biofuels made from non-food sources.

It is important to thoroughly evaluate the entire environmental impact of bioenergy, taking into account emissions from the production, processing, and transportation of feedstock. Stricter environmental standards and cutting-edge technologies can guarantee significant carbon reductions. Investment and Technology Requirements, Research and innovation expenditures must be sustained in order to scale up bioenergy solutions.



COMBATTING AIR POLLUTION WITH GREEN TECHNOLOGIES FOR HEALTHIER CITIES

Souvik Dey

Air pollution is one of the greatest problems faced by people in cities. It is a major contributing factor to health-related problems and degradation of the environment. Currently, over 90% of the world's people are said to be breathing in polluted air; therefore, improvement in urban areas is necessary through adopting bold and innovative green technologies, which would reduce emission levels and lead to the creation of healthier living spaces. The adverse effects of atmospheric pollution, as caused by the emissions from vehicles, industry, and the production of energy, lead to various diseases like respiratory and cardiovascular diseases along with death before the expected due stage. Particulate matter sizes less than 2.5 micrometers ($PM_{2.5}$), nitrogen oxides (NO_x), and sulphur dioxide (SO_2) have specific health hazards, especially for populations that are already vulnerable. Direct intervention toward immediate action through clean technologies and policies focused on public health would be a remedy to this crisis. A few key green technologies for cleaner cities are mentioned below:



Electric and hybrid vehicles: Transportation is one of the chief contributors to urban pollution. The most effective way of ensuring a reduction in emissions is simply transferring traditional vehicles to electric vehicles (EVs) and hybrids, as well as hydrogen-powered buses. The electric public transport system in those city, Shenzhen, and Amsterdam has put them into practice. Installing facilities for EV charging also encourages people to adopt EVs. Some examples of policies that will help further promote this transition are tax relief and low-emission zones.

Renewable energy use: Electricity is produced largely by fossil fuels, which significantly contribute to air pollution. Among the cleanest power generation technologies, solar, wind, and hydropower stand out. They are assisted in sustainable energy transitions by improving efficiencies with rooftop solar panels, smart grids, and battery storage systems. Bring investment into renewable infrastructure by governments and businesses to entirely collapse the coal and gas facilities.

Green building innovations: A large number of urban pollution comes from buildings. Sustainable architecture energy efficient designs and green roofs using eco-friendly construction materials can reduce pollution, while green roofs absorb CO_2 and filter pollutants. Low-emission concrete and recycled materials minimize environmental impact. The LEED certification differs in promoting environmentally friendly building practices.

Air purification technologies: In highly polluted areas, advanced air-cleaning technologies immediately relieve suffering. Smog-free towers, applications of photocatalytic coatings on buildings, and indoor air purifiers all help to remove hazardous particulate matter. Although they do not eliminate the source, these technologies can significantly help in sustaining public health as long-term solutions are applied.

Smart urban planning: Perfect urban planning should minimize dependency on vehicles and maximize green areas to greatly reduce air pollution in cities. Cities that plan for walking and cycling through dedicated lanes and pedestrian infrastructure will encourage the populace to use these modes of transportation rather than dander-cleaning ones. The expansion of urban forests, parks, and green belts will absorb and filter out pollutants, contributing to improved air quality. Thus, environmental planning makes cities more sustainable by improving their liveability and habitability.

THE RISE OF CONSCIOUS CONSUMERISM AND MAKING SUSTAINABLE CHOICES MAINSTREAM

Srinjoy Roy

The emergence of conscious consumerism is reshaping the global marketplace, shifting purchasing choices to reflect not just price and quality but also social, environmental, and economic impacts. This evolution in consumer values is compelling businesses to embrace responsibility and transparency.

Conscious consumerism represents a thoughtful approach to acquiring goods and services, taking into account the broader repercussions of consumption. It emphasizes consuming less, favouring sustainable products, supporting ethical brands, and staying informed about purchasing decisions. This stands in stark contrast to mindless consumption, which is primarily driven by impulse or habit without considering the wider implications.



Everyday life increasingly reflects conscious consumerism, with individuals choosing reusable products, sustainable materials, fair trade initiatives, cruelty-free items, local vendors, boycotting unethical firms, repairing and repurposing goods, cutting back on unnecessary expenses, being informed in decision-making, evaluating the entire lifecycle of a product, avoiding single-use plastics, and backing brands that share their values. Certifications like Fair Trade and B Corp highlight this trend by promoting ethical labour practices, animal welfare, and community-focused economies.

Sustainable choices encompass social behaviours aimed at minimizing environmental damage while fostering equitable socio-economic progress and improving overall quality of life. These choices involve reducing negative impacts, emphasizing renewable resources, cutting waste, and championing ethical practices. They manifest across various daily life aspects, including food, fashion, transport, energy, and home and lifestyle choices. Examples include plant-based diets, eco-friendly clothing, public transportation, electric vehicles, and renewable energy sources. By integrating sustainable practices, we can secure a sustainable future for everyone.

The growth of conscious consumerism and sustainable choices stems from rising environmental concerns, social awareness, and technological advancements. Consumers are becoming more conscious of the adverse effects of overconsumption, like climate change, pollution, and resource depletion. This heightened awareness drives them towards informed decisions, reducing their ecological footprint, and contributing to a healthier, more sustainable world for present and future generations.

Advancements in technology have propelled conscious consumerism, giving consumers unprecedented access to information about products, companies, and their operations. Social media platforms raise sustainability awareness, while e-commerce sites make it easier to discover and buy sustainable products. Blockchain technology enhances supply chain transparency and traceability, while data analytics provide tailored recommendations for sustainable options. This technological empowerment enables consumers to make thoughtful purchasing decisions and encourages greater transparency in the marketplace.

Conscious consumerism and sustainable choices are poised to expand among all demographics, with an increased expectation for transparency and authenticity from brands. Circular economy principles will take precedence, with technology playing a vital role in offering personalized recommendations. Consumers are likely to pay a premium for products that align with their sustainability values, and regulatory initiatives will steer the focus toward sustainable practices and circular economy models.

Conscious consumerism and sustainable choices can greatly mitigate environmental degradation by lowering greenhouse gas emissions, conserving natural resources, and minimizing pollution. This transformation in consumption patterns concerning food, transport, and energy can also safeguard biodiversity and maintain ecosystem balance, ultimately lessening the overall impact of consumption.

Conscious consumerism and sustainable choices are reshaping the global marketplace. Consumers are demanding transparency, ethical practices, and sustainable products. Companies adjusting their product development, marketing strategies, and supply chain practices to resonate with these values can access new markets, foster brand loyalty, and enhance sustainability. Consumer insistence on transparency, ethical practices, and sustainable offerings is instigating a significant transformation across the global marketplace, pushing businesses to modify their strategies, marketing approaches, and supply chain processes.

Susmita Sarkar

As the world accelerates its transition towards cleaner and more sustainable energy systems, renewable sources like solar and wind have taken center stage. However, their intermittent nature poses a significant challenge: how to store excess energy generated during peak production times for use when demand is high or generation is low. This is where energy storage solutions become critical. Decoding the future of these technologies reveals a dynamic landscape filled with innovation, challenges, and immense potential.

Renewable energy sources are inherently variable. Without effective storage systems, this variability can lead to grid instability and energy shortfalls. Energy storage bridges the gap between generation and consumption, enabling excess energy to be saved and dispatched when needed. At present, lithium-ion (Li-ion) batteries dominate the energy storage market. Known for their high energy density, long cycle life, and relatively fast response times, these batteries are widely used in residential solar systems, electric vehicles (EVs), and utility-scale applications.

Companies like Tesla, LG Chem, and Panasonic have led the charge in scaling up production and reducing costs. However, Li-ion batteries are not without drawbacks. They rely on finite resources such as lithium and cobalt, raising concerns about supply chain sustainability, environmental impact, and geopolitical risk. Moreover, thermal runaway leading to overheating or even fires, remains a safety concern in large installations.

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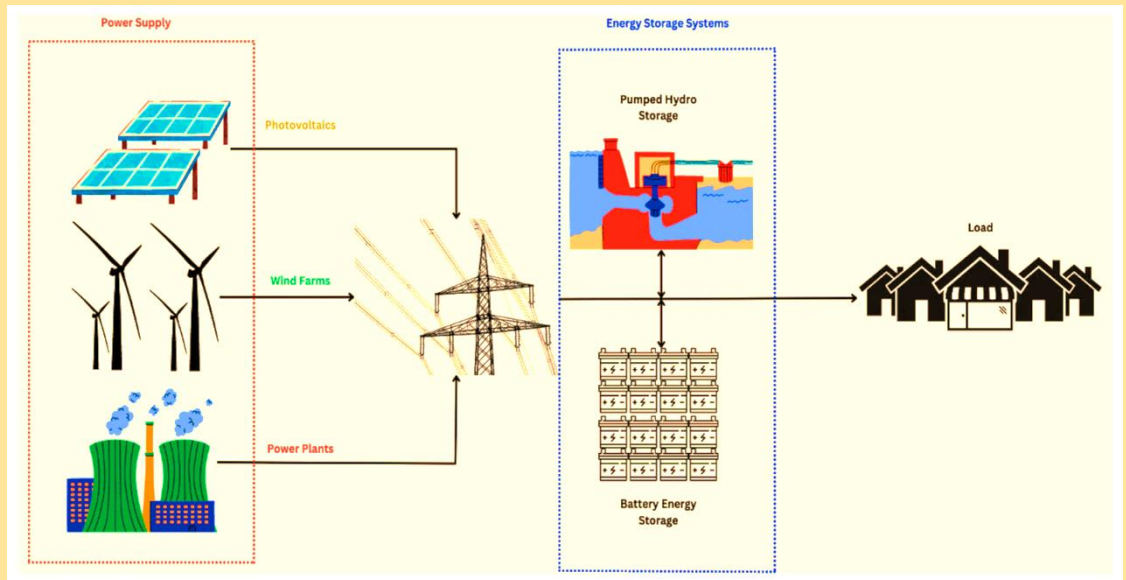


Fig: Schematic of hybrid wind/PV/thermal power plants integrated with different energy storage systems [source: Sayed et al., 2023]

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Emerging technologies on the horizon: To address the limitations of current technologies, researchers and innovators are exploring a wide array of alternatives. Some of the most promising emerging energy storage solutions include:

1. **Solid-state batteries:** By replacing the liquid electrolyte in Li-ion batteries with a solid material, solid-state batteries promise higher energy density, faster charging, and improved safety.
2. **Flow batteries:** Utilizing liquid electrolytes stored in external tanks, flow batteries offer scalable, long-duration energy storage ideal for grid-level applications. They are especially suited for renewable energy because they can be easily expanded to store hours, or even days of energy.
3. **Hydrogen energy storage:** Excess renewable energy can be used to produce green hydrogen through electrolysis. This hydrogen can then be stored and later used in fuel cells or combusted to generate electricity.
4. **Thermal and mechanical storage:** Technologies like molten salt storage, compressed air energy storage (CAES), and pumped hydro storage also offer viable solutions.

The future of energy storage isn't just about better batteries; it's also about smarter systems. Digital technologies like artificial intelligence (AI), machine learning, and Internet of Things (IoT) sensors are transforming how energy is stored and used. Smart grids that dynamically respond to real-time data can optimize when and how storage systems charge or discharge, thereby enhancing efficiency and reducing waste. Governments and private investors alike are recognizing the importance of energy storage. Policy incentives, research funding, and grid modernization initiatives are helping to accelerate deployment. The International Energy Agency (IEA) forecasts that global energy storage capacity could increase 15-fold by 2040 if current policies and commitments are sustained.

THE ROLE OF DIGITAL ACTIVISM IN PROMOTING ENVIRONMENTAL AWARENESS

Triparna Pal

The rise of the internet and the expansion of social media platforms have become powerful new tools for social activism, enabling significant grassroots change. Digital technologies have transformed the landscape of environmental activism, moving away from traditional campaigning methods typically conducted by lobbying groups, academics, or scientific institutions. These conventional methods often involved slow, labour-intensive processes like organizing protests, engaging in unconventional actions, and influencing public opinion through publications and news outlets.

In contrast, digital technologies facilitate faster communication among like-minded individuals who may be geographically distant, using emails, organizational websites, and social media platforms. Effective communication is vital for any form of activism, as it helps disseminate information, raise awareness, and coordinate mobilization efforts. The success of activist campaigns largely depends on this effective communication. Consequently, social media platforms and other online communication tools serve as powerful instruments for activist movements. They enable organizations to expand and accelerate the dissemination of information, gather resources, enhance awareness, encourage discussions, organize events, and generate public interest.

By leveraging digital technologies, the environmental movement has successfully connected and mobilized a broad and diverse audience of both existing and new supporters. Social media platforms like Facebook create "horizontal networks" that allow users to share campaigns, ideas, and information globally, thereby expanding the reach of any disseminated content. Furthermore, the user-friendly and adaptable forms of communication available on social media—including videos and event promotions—can attract larger audiences more effectively than traditional written content, which may be less accessible in mainstream media.

For instance, the global environmental organization Greenpeace has pointed out that tools like petitions and hashtags on social media enable individuals campaigning on similar issues to connect and participate in broader campaigns, which can lead to considerable societal change. The significant global attention garnered by the 'Fridays for Future' movement—an international initiative led by Greta Thunberg where youth strike weekly to protest climate change inaction—illustrates how digital technologies engage large audiences and attract considerable media coverage, especially through the widespread use of the hashtag #FridaysforFuture.

While the rise of digital technologies has made it possible to spread global messages more quickly and widely, it's important to note that the online audience primarily consists of individuals already interested in environmental issues. Additionally, online activism does not always translate into offline action. The extent to which digital technologies affect the environmental movement remains difficult to quantify. In a neoliberal economy, corporate news often dominates both traditional and online media, with algorithms favouring established organizations and limiting the independence of environmental groups. Neoliberal views of nature can obstruct environmental goals by prioritizing profit, which leads to overproduction and overconsumption.

To succeed, the environmental movement should focus on fostering open dialogue and creativity. This approach will help promote effective activism and contribute to a sustainable future.



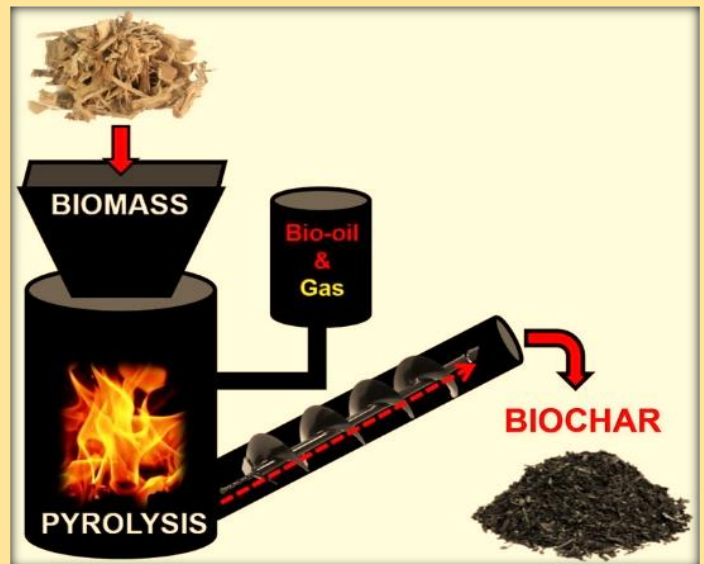
BIOCHAR AND SOIL RESTORATION CREATING A PATHWAY TO CARBON-NEGATIVE FARMING

Trisha Ghosh

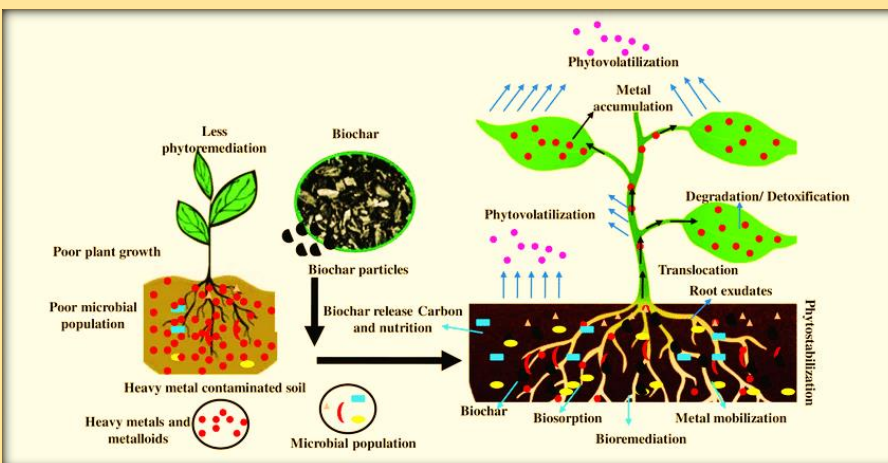
"Biochar has the potential to revolutionize agriculture by turning waste into a resource that improves soil health and sequesters carbon. It's a game-changer for sustainable farming." – Dr. David Laird.

Biochar is a carbon-rich material produced from organic waste that can be a sustainable solution against soil degradation and climate change. It enhanced soil fertility by carbon sequestration and enabled carbon-negative farming. Climate change and soil degradation are a threat to global food security and environmental sustainability.

Traditional farming practices generate greenhouse gases and degrade soil health. Biochar is in our ancient practice that improves soil fertility by carbon sequestration. In India, approximately 30% of its cultivable land is degraded due to the intensive use of chemicals in farming. Biochar adoption in India has limited spread due to the high cost of pyrolysis infrastructure and less awareness of people but research institutions and NGOs are promoting biochar as a solution for soil restoration and carbon sequestration.



Indian Council of Agricultural Research (ICAR) has conducted pilot projects that demonstrate biochar's effectiveness in improving crop yields and soil health in various regions like Maharashtra and Karnataka. Biochar is produced by heating organic materials like crop residues, wood chips, or manure in a low-oxygen environment at 300-to-700-degree Celsius temperature. This process converts biomass into a stable carbon-rich material that can be added to soil where it enhances water retention, nutrient availability, and microbial activity. Biochar's stability allows it to sequester carbon for centuries, this process makes it a powerful tool for climate mitigation.



Biochar is the solution for sustainable agriculture and climate change mitigation. It has the ability to restore degraded soils by storing carbon, which is a key component of carbon-negative farming. Biochar improves soil health cause biochar is a porous carbon-rich material that enhances soil structure, water retention, and nutrient availability. Its porous nature acts as a habitat for beneficial microbes that naturally improve soil quality and productivity, biochar stabilizes organic carbon which prevents the release of CO₂.

Furthermore, biochar reduces the need for chemical fertilizers and makes farming more sustainable and cost-effective while storing carbon in the soil. In India adoption is limited but pilot projects and research demonstrate its potential to address soil degradation improve crop yields and increase public awareness about carbon-negative farming. Challenges like high initial costs and lack of awareness can be managed through policy support, incentives, and education campaigns by the government.

The future of biochar lies in the improvement of pyrolysis technology and government incentives for carbon credit programs. In India integrating biochar into national agricultural policies and promoting community-based pyrolysis units can help us to shift towards natural farming. When the world seeks sustainable solutions to climate change, biochar is an ever-green initiative for a resilient agricultural future. By introducing biochar farmers can not only improve their livelihoods but also help our planet to create a sustainable green future.

PROMOTING SUSTAINABLE LIVING THROUGH EVERYDAY ECO-FRIENDLY CHOICES

Trisha Mondal

Climate change, deforestation, pollution, and depletion of natural resources pose significant threats to both ecosystems and human health. Living sustainably means making daily choices that reduce our environmental footprint and conserve resources for future generations. While individual efforts like conserving energy and minimizing waste can greatly impact a greener, healthier, and sustainable environment, they complement essential government policies, international agreements, and technological innovations.

Our daily actions, particularly regarding food and transportation, shape our environmental footprints, leading to carbon emissions and resource depletion. An increased ecological footprint results from fossil fuel use, consumption of non-local foods, and excessive energy consumption. Humanity's annual resource usage equates to the demands of 1.75 Earths, reflecting a rate of consumption that exceeds the planet's natural capacity for renewal. Adopting sustainable practices can effectively lower these environmental footprints. Sustainable living focuses on diminishing ecological footprints by minimizing waste, conserving energy, and making mindful consumption choices. It seeks to harmonize human development with the preservation of natural ecosystems, ensuring stability for future generations. Embracing sustainable living protects biodiversity, lowers pollution levels, and conserves finite resources such as water, soil, and energy. This approach benefits both individuals and the broader environment.



Making a Difference: Simple Eco-Friendly Choices You Can Implement Today

The positive aspect of transitioning to a more sustainable lifestyle is that it doesn't call for drastic overnight changes. It involves integrating straightforward, eco-friendly habits into our everyday lives.

- Small actions like switching off lights, unplugging devices, using LED bulbs, maximizing natural daylight, adjusting thermostats, investing in energy-efficient appliances, enhancing insulation, and exploring renewable energy options like solar panels can significantly cut down energy usage, lower utility costs, and reduce greenhouse gas emissions.
- Water conservation is crucial for daily routines such as showering, brushing teeth, shaving, and operating dishwashers and washing machines. Implementing shorter showers, turning off taps, fixing leaks, only running full loads in machines, installing water-saving fixtures, and collecting rainwater can help conserve water and reduce expenses. High-efficiency appliances, like dishwashers and washing machines, can greatly save water, alleviating pressure on freshwater resources and helping maintain aquatic ecosystems.
- Opt for natural, plant-based, and non-toxic cleaning products to enhance both home health and the environment. Utilizing DIY cleaning solutions created from basic ingredients and reusable tools minimizes waste.
- The "3 Rs" approach—reduce, reuse, and recycle—promotes waste reduction by steering clear of single-use plastics, composting organic matter, recycling materials, and donating items instead of throwing them away.
- The food industry heavily impacts the environment, contributing to deforestation, greenhouse gas emissions, and water consumption. Sustainable food choices comprise eating locally sourced, seasonal foods, supporting farmers' markets, curbing meat and dairy intake, opting for plant-based meals, and preventing food waste. Sustainable agricultural methods such as organic farming, crop rotation, and reduced pesticide usage foster environmental well-being, while consumer preference for sustainably sourced foods meets the rising demand for eco-friendly farming practices.
- Adopting sustainable transportation habits—such as using public transit, carpooling, choosing active transportation like walking or cycling, investing in electric or hybrid cars, and fostering improvements in infrastructure like bike lanes and electric vehicle charging stations—can greatly reduce carbon emissions, promote cleaner air, and alleviate traffic congestion.

Ultimately, making eco-friendly choices in our daily lives supports sustainable living by minimizing waste, saving energy and water, and selecting sustainable food and transportation options. Every person's efforts contribute to preserving the planet's resources and fostering a healthier future.

EMPOWERING COMMUNITIES THROUGH SOLAR ENERGY-DRIVEN LIVELIHOODS

Abhijit Pal

Solar energy is the energy obtained from the sun's radiation. It is a renewable, abundant, and clean source of power that can be harnessed for various applications, such as generating electricity, heating water, and powering devices. Solar energy-driven livelihoods refer to the utilization of solar power to generate economic opportunities and enhance the socio-economic well-being of communities. This approach primarily focuses on integrating solar energy technologies into agriculture, small-scale enterprises, fisheries, and other rural activities, thereby reducing dependency on conventional energy sources and mitigating the adverse impacts of climate change. Solar-powered technologies such as solar irrigation pumps, solar dryers, solar-powered cold storage, and microgrids for rural electrification play a crucial role in enhancing productivity, income, and living standards. By reducing operational costs, minimizing environmental degradation, and ensuring reliable energy access, solar energy-driven livelihoods contribute to achieving the Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) (UNDP, 2021).

Significance:

Economic empowerment: Solar energy can reduce operational costs for small and medium enterprises, leading to increased profits and sustainable income generation. For example, in rural India, solar irrigation systems have lowered irrigation expenses by up to 90% (IRENA, 2022).

Gender inclusivity: Solar energy-driven livelihoods provide equitable access to economic opportunities, especially for women. Women-led solar enterprises have shown increased participation in community-level decision-making and financial independence (UN Women, 2020).

Renewable energy in developing countries: Developing nations have seen a significant increase in renewable energy capacity, with solar energy being a key contributor. Countries like China and India are rapidly expanding their solar markets, and off-grid solar technologies are providing sustainable and cost-effective alternatives in isolated rural areas.



Fig: Annual solar production globally from 2000-2023

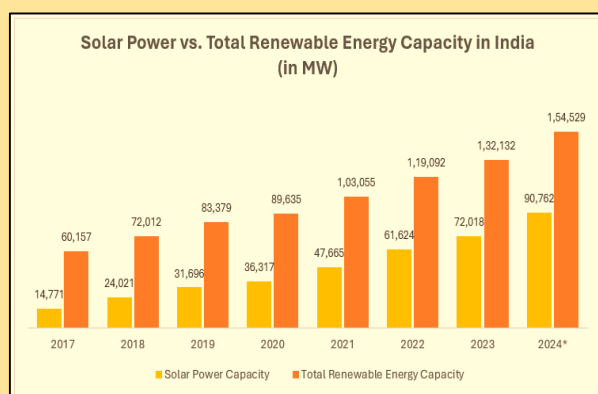


Fig: Solar Power and Total energy capacity in India from 2017-2024

FAO's initiatives in solar energy and sustainable agriculture:

Renewable energy integration in fisheries: FAO is exploring renewable energy solutions, including solar power, to modernize fisheries value chains. By integrating technologies like solar power, FAO aims to improve energy efficiency, reduce costs, and preserve fish freshness, all while minimizing the sector's carbon footprint.

Energy-smart food programme: FAO's Energy-Smart Food (ESF) Programme aims to increase access to sustainable energy in food systems through innovative, green energy solutions.

Climate change strategy (2022–2031): FAO's Climate Change Strategy envisions agrifood systems that are sustainable, inclusive, resilient, and adaptive to climate change. The strategy emphasizes the adoption of renewable energy sources, such as solar power, to contribute to low-emission economies while ensuring the provision of sufficient, safe, and nutritious foods for present and future generations.

In summary, solar energy-driven livelihoods represent a sustainable, inclusive, and economically viable solution to address pressing global challenges like energy poverty, climate change, and socio-economic disparities. The expansion of solar energy creates employment opportunities, promotes gender inclusivity, and strengthens local economies while reducing dependency on fossil fuels. Solar energy-driven livelihoods will play a crucial role in building resilient, sustainable, and empowered communities worldwide.

BUILDING ENERGY RESILIENT COMMUNITIES THROUGH CAPACITY DEVELOPMENT

Diksha Kar

Energy resilience refers to the ability of systems—ranging from individuals and communities to institutions and governments—to anticipate, prepare for, respond to, and recover from disruptions in a sustainable and adaptive manner. The National Renewable Energy Laboratory (NREL) describes it as a system’s capacity to rapidly bounce back from disturbances through holistic planning and technical solutions. In the context of communities, energy resilience is about empowering people at the local level to manage their energy systems effectively. This includes equipping them with the knowledge, skills, and resources necessary to adapt to climate change, withstand energy-related disruptions, and promote sustainable practices.

Why Capacity Development Matters: Capacity development is central to building energy resilience. It enhances a community’s ability to adapt to climate-related challenges and manage energy systems efficiently. This leads to several benefits:

Enhanced Adaptability: Equips communities with tools and knowledge to handle disruptions.

Sustainable Energy Systems: Encourages adoption of renewable energy and energy efficiency.

Reduced Vulnerability: Strengthens local capacities to withstand energy shocks.

Community Empowerment: Promotes inclusive participation and ownership of energy solutions.

Areas of Capacity Development:

Skills Development

Training programs for technicians and energy managers.

Localized education and vocational courses.

Certification programs for energy-related professions.

Knowledge and Information

Awareness campaigns on sustainable energy and climate resilience.

Access to up-to-date energy technologies and policies.

Platforms for community knowledge sharing and learning.

Resource Mobilization

Support for planning and implementing energy projects.

Access to funding and financial tools.

Building partnerships among communities, governments, and private sector actors.

Policy and Institutional Frameworks

Strengthening local governance and institutional capacity.

Creating enabling policies for energy sustainability and climate adaptation.

Integrating energy resilience into broader urban and development plans.

Some capacity building initiatives are CapaCITIES (India) which focuses on enhancing city capacities for climate resilience and greenhouse gas reduction. Resilient Cities Network which promotes global learning and collaboration on urban energy resilience. ELENA (EU) which offers grants for energy efficiency and renewable energy projects in urban areas. PCREEE supports renewable energy and energy efficiency capacity building in the Pacific.


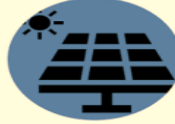








				
Energy Storage	Power Generation	Resilience Hubs	Network Infrastructure & Security	Electric Transportation
				
Emergency Services Support	Community Awareness & Education	Efficiency - Resilience Nexus	Green Infrastructure	Financial Support

Figure. Energy related resilience solutions at different

DRIVING DISASTER-RESILIENT INFRASTRUCTURE WITH RENEWABLE ENERGY POLICIES

Suchismita Roy, Research Scholar

The rise in both the frequency and intensity of disasters, caused largely by climate change and environmental degradation, is an imminent threat to the infrastructure systems around the globe. Disasters in the form of hurricanes and floods, earthquakes and wildfires can provide a blow to critical services, harm the economy and put human life at risk. Traditional infrastructure, which depends heavily upon centralized (and fossil-fuel-based) energy grids, is still very much susceptible to such disruptions. But it is coupling renewable energy policies with disaster risk reduction that provides a paradigm shift to improve climate-exacerbated disaster impacts and contribute to more sustainable recoveries. Clean energy needs to be prioritized so that governments can enforce infrastructure that is adaptable, self-sufficient, and able to withstand crises. Renewable energy policies to drive Disaster-resilient infrastructure for Sustainability: A New Perspective. Disaster-resilient infrastructure includes all types of permanent physical infrastructure, such as buildings, transport networks, energy systems and other lifeline and critical facilities that are planned, designed and constructed for resistance, recovery coping for probable extreme events. Every year, disasters cause billions of dollars of damage worldwide, rendering resilience not just a choice but a necessity. Disasters target traditional energy grids, which also rely on fossil fuels and large centralized power plants. When hurricanes or earthquakes hit, power lines are destroyed, and energy supply blackouts can take weeks to remedy. Policymaking on renewable energy allows us to decentralize power generation and create a system less dependent on fossil fuels, finally rethinking how to make infrastructure resilient.

The Role of Renewable Energy in Disaster-Resilient Infrastructure

Renewable energy sources provide many benefits for disaster mitigation, response, and recovery, particularly solar, wind, hydropower, and bioenergy. They can strengthen resilience when integrated into infrastructure systems. Many power grids are centralized, can more easily sustain damage during extreme weather events. Therefore, decentralized renewable energy systems such as microgrids or off-grid solar or wind systems will be able to provide electricity continuously even if there is devastation. The weather resilient future is made of climate mitigation, burning fossil fuels, which worsen climate change, and climate change, in turn, worsens disasters. Transitioning to renewable energy will go a long way to reducing carbon footprints, helping to prevent future disasters for years to come. Integrating renewable energy into infrastructure ensures sustainability. Increased resilience while decreased energy consumption through green buildings with in-built solar panels and wind turbines. Smart Grid Technologies help to optimize the use of energy and identify failures, ensuring that they do not turn into blackouts. Floating solar farms placed on reservoirs reduce evaporation and also produce electricity thus addressing the issue of energy security as well as water security.

Renewable Energy Policies for Disaster-Resilient Infrastructure

It will take strong policy frameworks to scale up the associated benefits of renewable energy in disaster resilience. Worldwide governments are adopting measures to facilitate clean power and resilient infrastructure. The key policy measures include: Community-based solar and wind projects should be encouraged by all governments. There are many different types of off-grid renewable energy incentives, including purchase incentives, tax credits, subsidies, and low-carbon loans that can speed up the adoption of off-grid renewable energy systems. Policies should require that new infrastructure incorporate renewable energy and resilient design. Disaster-proof designs should be enforced through building codes, requiring construction to stand against nature at its worst. Smart grid technologies facilitate real-time energy monitoring, predictive maintenance, and automated fault detection by investing in it. This unprecedented hardware AI-driven energy management can distribute load power when crises happen, preventing blackouts from lasting so long. Partnerships among governments, private firms, and research organizations facilitate the transition to renewables. They enable funding, technology innovation and large-scale deployment of resilient infrastructure projects through PPPs.

A Pathway to a Resilient and Sustainable Future

Disaster-resilient infrastructure is vital to limit the horrendous results of disasters. Governments and city planners can do this by placing weight on sustainable development and renewable energy policies to ensure that our urban and rural spaces are not as prone to the disastrous effects of increasingly volatile weather events. Making the shift to renewable energy enhances infrastructure resilience as well as climate change mitigation and sustainable development. When disasters strike, we must have reliable, uninterrupted services during crisis time; this means we need to invest in decentralized solutions, clean energy ones. Innovative solutions such as renewable energy incentives, resilient city planning, and climate-smart policies are critical to empowering communities to better withstand and rebound from disaster, and policymakers must act now. If we get our act together, renewable energy will not only run our cities but shield them from disaster, turning infrastructure that can withstand disaster from a future imperative into a present-day reality.

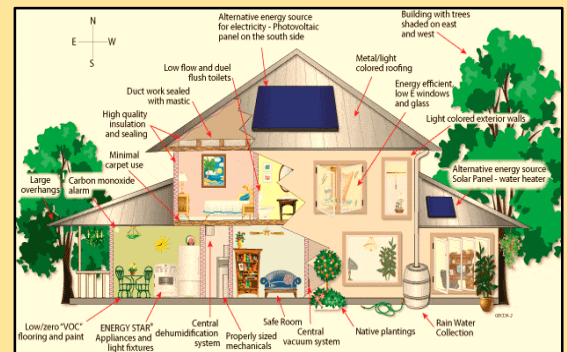
BOOSTING URBAN BIODIVERSITY THROUGH GREEN INFRASTRUCTURE AND CLEAN ENERGY SOLUTIONS

Sujan Mandal

The ongoing growth of cities presents a significant challenge for urban biodiversity conservation. This rapid urbanisation process creates substantial issues of habitat loss, fragmentation and environmental degradation, which strongly threaten the plant and animal species. However, they also offer opportunities for wildlife conservation through strategies such as green infrastructure and clean energy solutions. Urban biodiversity is the diversity of flora and fauna present in urban areas. In addition to these benefits, these ecosystems improve the quality of life for urban residents and provide vital services like air purification, temperature regulation, and water management. Various international organisations are increasingly viewing green infrastructure and clean energy solutions as synergistic pathways that can strengthen urban biodiversity while facilitating sustainable development.

The Role of Green Infrastructure in Biodiversity Enhancement

Green infrastructure is an interconnected network of natural and semi-natural systems that provides ecosystem services and contributes to the conservation of biodiversity. These include parks, urban forests, green roofs, wetlands, urban gardens and vegetated corridors that serve as oases for different species, providing food, shelter and breeding ground. In contrast to most grey infrastructure that purely centres on utility, green infrastructure tends to blend urban development with ecological processes. Urban forests and green roofs can also improve air quality, mitigate the urban heat island effect, and improve stormwater management, all of the key components of resilient urban systems. Singapore and Copenhagen are just two of the cities already proving the potential of green infrastructure to enhance biodiversity. Singapore's *"City in a Garden"* initiative has turned the metropolis into a lush urban habitat that is home to hundreds of native plant and animal species. Similarly, the green roofs policy also promotes biodiversity by offering habitat niches for various insect species, Copenhagen.



Clean Energy Solutions and Their Impact on Urban Biodiversity

Clean Energy, Climate Change, Primary—indirect benefits to urban biodiversity. The move from fossil fuels to renewable energy sources such as solar, wind, and hydropower has reduced greenhouse gas emissions and air pollution, two eroders of urban ecosystems. Solar parks can be engineered for biodiversity, using native plants under and within solar panels which improves soil quality and provides habitat for insects and small animals, however. Wind farms can be, in many cases, made biodiversity-stepping, and people concerned about the loss of avian species at wind mega sites but still want energy to power their home, we can be clever by replicating existing bird flocks that come together over some stable natural ecosystems like wetlands. Clean energy initiatives can also help mitigate the urban heat island effect, which is important for urban biodiversity. Lower air pollution levels and cooler temperatures offer favourable conditions for many species to thrive, even in the densely populated regions.

Integrating Green Infrastructure and Clean Energy for Enhanced Urban Biodiversity

Green infrastructure ideas work well with clean energy solutions, so combining the two can multiply the biodiversity benefits they provide. Urban planners could create solar parks that also serve as bee-friendly habitats, or green roofs that integrate renewable energy technologies. In addition, the integration of renewable energy systems into green buildings in a city will make it more sustainable and resilient. The idea of *"eco-districts"* — urban areas where sustainability and biodiversity are built into the design with the free movement of people, plants and animals in mind — is taking off globally. Focusing on energy efficiency, green infrastructure and habitat restoration, these districts are urban landscapes where nature and city life cohabitate harmoniously.

Challenges and Future Directions

Although they are advantageous, incorporating green infrastructure and renewable energy strategies into metropolitan settings comes with its own set of hurdles. In many cases, land scarcity, high costs and conflicting policies have deterred their broad uptake. The guidelines should focus on creating frameworks that promote biodiversity-friendly designs and approaches, like in the case of intergovernmental relations. To ensure success in implementation, collaboration between urban planners, ecologists, policymakers, and members of local communities is vital. Additionally, these initiatives must be regularly reviewed and monitored for their biodiversity outcomes as well as the effectiveness of green infrastructure and clean energy efforts. With an ever-increasing urban population worldwide, implementing these strategies will be crucial for developing cities that can accommodate humans and have flourishing ecosystems.

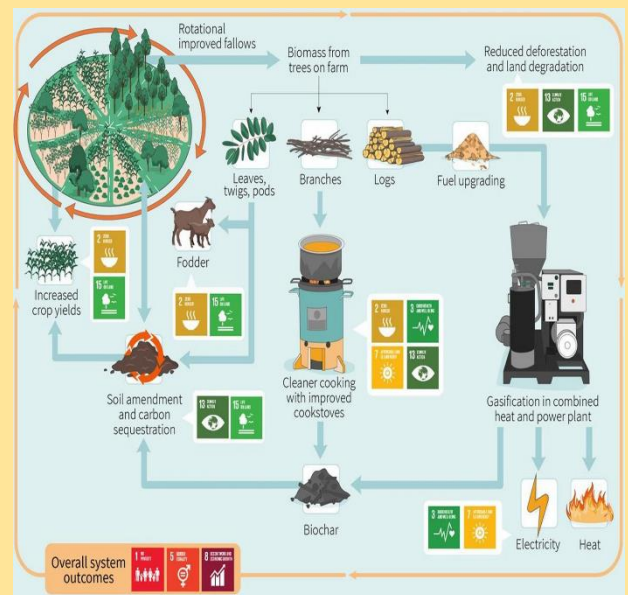
ENHANCING BIODIVERSITY, SOIL HEALTH AND ENERGY THROUGH SUSTAINABLE AGROFORESTRY

Br. Soumitra

Agroforestry systems contribute to improved energy, biodiversity, and soil health while fostering climate resilience. This system integrates trees, crops, and livestock into a balanced system that benefits energy efficiency, biodiversity, and soil health. Agroforestry has been identified as a tool to preserve rich species diversity around the world because agroforestry plays five major roles in biodiversity conservation. These include: (a) agroforestry provides habitat for species that can tolerate a certain level of disturbance; (b) agroforestry helps preserve germplasm of sensitive species; (c) agroforestry helps reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; (d) agroforestry provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (e) agroforestry helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitat.

Agroforestry systems have been linked to a 20% increase in the number of native plant and animal species in agricultural landscapes, supporting both food security and conservation efforts. Its can increase biodiversity by up to 50% compared to monoculture farming, with the diverse species supporting pollinators, wildlife, and a variety of plants. Its support natural pest control, reducing the reliance on chemical pesticides. Biodiversity provides many essential services to the society including material and non-material benefits and regulating environmental functions.

Agroforestry improves regulatory ecosystem services including erosion control, nutrient retention, water quality, soil health, air quality, pollination, pest control, and fire retardation as well as cultural services such as improvements in recreational, aesthetic, and cultural values. Soil degradation is a significant concern in India, with millions of hectares of agricultural land suffering from erosion, nutrient depletion, and loss of organic matter. Agroforestry offers a sustainable solution to restore soil health and the presence of trees improves soil structure, prevents erosion, and enhances water retention, which is critical in areas prone to droughts.



Agroforestry systems can reduce soil erosion by up to 50-70%, depending on the species and planting configuration and increased soil organic matter content by 15-30% compared to conventional farming systems. Trees, through their deep root systems, bind soil particles and prevent water runoff, reducing the risk of land degradation. The decaying leaves and organic matter from trees contribute to increasing soil organic carbon, which is vital for maintaining soil fertility. Moreover, agroforestry practices improve soil microbial activity, which further enriches soil health. In India, about 2.5 million hectares are currently under agroforestry, with increasing recognition of its role in sustainable land management, enhancing both agricultural productivity and environmental health. According to the Indian Council of Agricultural Research (ICAR), agroforestry can increase soil fertility by 30% and improve crop yields by up to 25%.

Sustainable agroforestry plays a pivotal role in enhancing energy efficiency in India by reducing dependence on conventional energy sources. Agroforestry systems, which integrate trees with crops, provide natural solutions for energy conservation, water management, and sustainable bioenergy production. Agroforestry provides an important renewable energy source for rural communities in India. Trees grown on farms can be used for fuel wood, biomass, and even bioenergy. Biomass from trees such as *Eucalyptus*, *Casuarina*, and *Poplar* can reduce reliance on fossil fuels, providing clean energy for cooking and heating (Indian Council of Agricultural Research). In India, agroforestry has been widely used to reduce energy demands in rural areas. Agroforestry systems could supply over 50 million tons of fuel wood annually, meeting the energy needs of millions of rural households (National Institute of Agroforestry). Agroforestry systems also reduce the need for heating and cooling in nearby buildings by providing natural wind barriers and shade, leading to energy savings in homes and agricultural structures. According to the Ministry of New and Renewable Energy (MNRE), bioenergy from agroforestry systems could meet up to 10% of India's energy needs in rural regions. The Indian Institute of Technology (IIT), Kharagpur, estimates that agroforestry could provide approximately 35,000 MW of energy through biomass, significantly reducing reliance on fossil fuels and contributing to sustainable energy solutions. Furthermore, by growing fast-growing trees on degraded or marginal land, agroforestry offers a sustainable solution to meet the demand for biomass and fuelwood. This reduces pressure on forest ecosystems, thus protecting natural forests and enhancing the sustainable energy supply for rural communities. The integration of trees enhances carbon sequestration, helping to mitigate climate change. In addition, the adoption of agroforestry helps in the production of biofuels and biogas, which can provide alternative energy sources.

BUILDING SUSTAINABLE AND ENERGY-SECURE COMMUNITIES: LESSONS LEARNED FROM THE PANDEMIC

Dr. Sourav Koley

The COVID-19 pandemic has brought unprecedented challenges to communities worldwide, highlighting the importance of sustainability and energy security. As we navigate the recovery phase, it's essential to reflect on the lessons learned and apply them to build more resilient, sustainable, and energy-secure communities.

Renewable Energy and Reduced Emissions

During the pandemic, many countries experienced reduced economic activity, leading to decreased energy consumption and lower greenhouse gas emissions. This unintentional experiment demonstrated the potential for renewable energy sources to play a more significant role in our energy mix. As we rebuild, we must prioritize investments in solar, wind, and other renewable energy sources to reduce our reliance on fossil fuels and mitigate climate change.

Energy Efficiency and Conservation

The pandemic also highlighted the importance of energy efficiency and conservation. With many people working from home, there was a significant increase in residential energy consumption. However, this also created opportunities for individuals to adopt energy-saving habits, such as using energy-efficient appliances, turning off lights, and adjusting thermostat settings. Governments and businesses can encourage these behaviors through incentives, education, and policy changes.

Community Resilience and Cooperation

The pandemic demonstrated the value of community resilience and cooperation in the face of adversity. Neighborhoods came together to support vulnerable members, and local businesses adapted to meet changing needs. As we build more sustainable and energy-secure communities, we must prioritize community engagement, social cohesion, and collective action.

Key Takeaways and Recommendations

- 1. Invest in renewable energy:** Prioritize investments in solar, wind, and other renewable energy sources to reduce reliance on fossil fuels.
- 2. Promote energy efficiency:** Encourage energy-saving habits through incentives, education, and policy changes.
- 3. Foster community resilience:** Support community engagement, social cohesion, and collective action to build more resilient communities.
- 4. Develop sustainable infrastructure:** Invest in sustainable infrastructure, such as green buildings, smart grids, and eco-friendly transportation systems.

As we emerge from the pandemic, we have a unique opportunity to rebuild and create more sustainable, energy-secure communities. By applying the lessons learned and prioritizing renewable energy, energy efficiency, community resilience, and sustainable infrastructure, we can create a brighter, more resilient future for all. We should remember

“No one is safe until everyone is safe.”- Dr. Tedros Adhanom Ghebreyesus, director general of the WHO:

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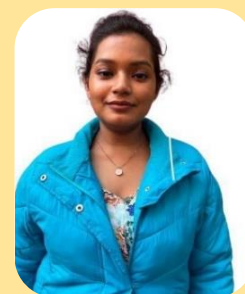
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