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941. Climate Change and Biodiversity - A Case Study on Beldih Lake, Jamshedpur

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ABSTRACT

Climate change poses significant threats to freshwater biodiversity, particularly in vulnerable ecosystems like Beldih Lake, Jamshedpur. This study investigates the impact of climate change on freshwater biodiversity in Beldih Lake, analyzing water quality, aquatic life, and local community perceptions. The findings highlight the urgent need for conservation measures to protect the lake's ecosystem and biodiversity. Beldih Lake, a vital freshwater ecosystem in Jamshedpur, faces numerous environmental challenges due to climate change. Rising temperatures, altered precipitation patterns, and increased human activities threaten the lake's biodiversity. This study aims to understand the impact of climate change on freshwater biodiversity in Beldih Lake. Objectives of the study were. Objectives 1. To assess the impact of climate change on water quality and aquatic life in Beldih Lake. 2. To analyze local community perceptions regarding climate change and its effects on the lake's ecosystem. Methodology. Aquatic life surveys (fish,). Questionnaire-based surveys among local communities (n=100). Results 1. Reduced fish diversity (40%) .2. Local communities reported changes in lake level, water quality, and fishing practices. Conclusion Climate change significantly impacts freshwater biodiversity in Beldih Lake, Jamshedpur. Urgent conservation measures are necessary to protect the lake's ecosystem, including: 1. Water quality monitoring and management. 2. Habitat restoration and aquatic life conservation. 3. Community engagement and education. 4. Climate-resilient management strategies. This study contributes to the understanding of climate change's effects on freshwater biodiversity and informs evidence-based conservation efforts for vulnerable ecosystems like Beldih Lake.

Keywords: Climate change, Beldih Lake, Bio-Diversity, Aquatic Life, Conservation

Introduction

Climate change, driven primarily by human activities such as deforestation, industrialization, and the burning of fossil fuels, is the most significant environmental challenge of the 21st century. The rapid increase in greenhouse gases (GHGs) like carbon dioxide, methane, and nitrous oxide has led to global warming, resulting in rising global temperatures, altered weather patterns, and an increase in the frequency and intensity of extreme weather events. The consequences of climate change are multifaceted, affecting not only the physical environment but also the biological systems that depend on it. Among the most pressing concerns is the impact of climate change on biodiversity. Biodiversity,

the variety of life on Earth, including species diversity, genetic diversity, and ecosystem diversity under unprecedented threat. As climate change alters habitats, temperature regimes, precipitat patterns, and the availability of resources, species and ecosystems are increasingly challenged to ad or face extinction. According to the Intergovernmental Panel on Climate Change (IPCC), if curr trends continue, up to one million species may be at risk of extinction in the coming decades. This l of biodiversity is not just a conservation issue but also a critical problem for ecosystem services t human societies rely upon, such as food security, water purification, and disease regulation. One a of particular concern is freshwater biodiversity. Freshwater ecosystems, which include rivers, lak wetlands, and streams, cover only about 1% of the Earth's surface but support roughly 10% of known species. These ecosystems are especially vulnerable to the impacts of climate change, as th depend on precise hydrological and temperature conditions. Rising temperatures, altered precipitati patterns, and increased evaporation can reduce water levels, change water chemistry, and degra habitat quality, leading to significant biodiversity loss. Freshwater species are also often high specialized, meaning they are less adaptable to environmental changes. In the Indian subcontinent, t effects of climate change on freshwater ecosystems have become increasingly evident, with lakes a rivers showing signs of stress due to fluctuating water levels, rising temperatures, and increas pollution. One such ecosystem facing these challenges is Beldih Lake, located in Jamshedp Jharkhand. Beldih Lake, a significant freshwater body in the region, is not only a recreational hub the city but also an essential ecosystem supporting a variety of species. Over the years, the lake witnessed a decline in its ecological health, exacerbated by both climate change and human-indu stressors.

Introduction to Beldih Lake, Jamshedpur

Beldih Lake is one of Jamshedpur's most prominent freshwater ecosystems, located in the indust heart of Jharkhand. The city, known for being home to Tata Steel, has grown rapidly over the p century, and with it, the demand for freshwater resources has increased. Beldih Lake, origina created for recreational purposes, has since become a multi-use water body serving nea communities, including irrigation for the adjoining Beldih Golf Course. The lake also supports a ra of biodiversity, including fish species such as Rohu, Katla, and Tilapia, as well as aquatic plants, bi and other organisms that rely on its waters for survival.

However, like many urban lakes, Beldih Lake faces numerous threats. The industrial activities Jamshedpur, coupled with the expansion of residential areas, have led to increased pollution level the lake. Additionally, the extraction of water for irrigation and recreational use has led to fluctuati

in water levels, affecting the health of the lake's ecosystem. Despite these challenges, the lake remains a vital ecological and social asset to the region, making its conservation an urgent priority. In recent years, the effects of climate change have become increasingly apparent in Beldih Lake. Rising temperatures, altered rainfall patterns, and increased evaporation have combined to create a challenging environment for the species that inhabit the lake. This makes Beldih Lake a valuable case study for understanding the broader impacts of climate change on freshwater biodiversity in India.

Climate Change and Freshwater Biodiversity: Impacts on Beldih Lake

The biodiversity of Beldih Lake, like other freshwater ecosystems, is highly sensitive to changes in temperature, water levels, and water quality. The effects of climate change on the lake are already visible, manifesting in several ways:

- Rising Water Temperatures: One of the most direct effects of climate change on freshwater ecosystems is the increase in water temperatures. Higher temperatures reduce the dissolved oxygen content in the water, leading to hypoxia, which can stress or kill aquatic organisms. Fish species that are sensitive to temperature changes, such as Rohu and Katla, are particularly vulnerable, as their metabolic rates and reproductive cycles are closely tied to water temperature. Prolonged exposure to higher temperatures can lead to reduced growth rates, lower reproductive success, and even population declines.
- Altered Precipitation Patterns: Climate change has led to more erratic rainfall patterns in the Jharkhand region, with periods of intense rainfall followed by prolonged dry spells. This variability has disrupted the natural hydrological cycle of Beldih Lake, leading to fluctuating water levels. During periods of heavy rainfall, increased runoff from the surrounding areas brings pollutants and sediments into the lake, degrading water quality. Conversely, during dry spells, the lake's water levels drop, concentrating pollutants and reducing habitat availability for aquatic species.
- Increased Evaporation: Rising temperatures also increase the rate of evaporation, further lowering water levels in the lake. This not only reduces the volume of water available for aquatic organisms but also concentrates pollutants and nutrients, leading to eutrophication. Eutrophication, a process in excess nutrients stimulate the growth of algae, can create "dead zones" in the lake where oxygen levels are too low to support most life forms. Algal blooms can also produce toxins that are harmful to both aquatic organisms and humans.

- Pollution and Human Activity: While climate change plays a significant role in the degradation Beldih Lake, human activities exacerbate these effects. Industrial pollution from nearby factori along with runoff from residential areas and agricultural lands, has increased the concentration heavy metals, pesticides, and other harmful chemicals in the lake. Additionally, the use of the la for recreational activities such as boating and water extraction for irrigation further stresses t ecosystem.
- Invasive Species: Another indirect effect of climate change is the spread of invasive speci Warmer water temperatures and altered habitat conditions have allowed non-native species, su as Tilapia, to thrive in Beldih Lake. These invasive species compete with native fish for food a habitat, often outcompeting and displacing them. The introduction of invasive species disrupts t natural balance of the lake's ecosystem and can lead to the decline or extinction of native species

Rationale of Studying Beldih Lake

Beldih Lake offers a unique opportunity to study the intersection of climate change and biodiversi loss in a freshwater ecosystem. As climate change continues to accelerate, understanding its speci impacts on local ecosystems like Beldih Lake is crucial for developing effective conservati strategies. Moreover, the lake serves as a microcosm for the broader challenges faced by freshwa ecosystems in urban and industrial regions across India and the world.

Studying Beldih Lake also highlights the role of human activity in exacerbating the effects of clim change. By examining the combined impacts of industrial pollution, water extraction, and recreatio use, alongside climate-induced changes, researchers can gain a holistic understanding of the pressu facing freshwater biodiversity. This knowledge is essential for informing policy decisions a conservation efforts aimed at mitigating the impacts of climate change and preserving biodiversity f future generations.

Objectives of the study

1. To assess the impact of climate change on water quality and aquatic life in Beldih Lake.
2. To analyse local community perceptions regarding climate change and its effects on the lak ecosystem.

Methodology

This study was conducted using structured interviews, questionnaires, and focus group discussio Data was collected from a sample size of 100 participants to collect the data. The questions cove topics such as changes in fish populations, water quality, perceptions of climate change, and its imp

on Beldih lake. The collected data were analysed to identify trends and patterns over the five-year period.

Population - All residents of Jamshedpur

Sample- 100 people of Jamshedpur city living within a radius of 3 km of the Beldih Lake

Data collection- Self- made questionnaire and telephonic interviews were conducted for JUSCO officers, local people and also used online information for this study.

Interpretation and Discussion of the Result

1st objective - To assess the impact of climate change on water quality and aquatic life in Beldih Lake

Here is a comparative analysis of the availability of key fish species in Beldih Lake, Jamshedpur, over the past five years (2018–2023). The data highlights trends in fish population dynamics, showing which species have increased, decreased, or remained stable during this period.

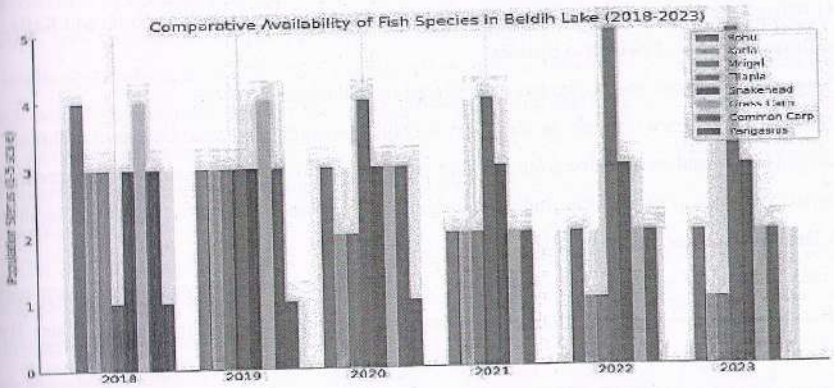

Fig1. Comparative Availability of Fish Species in Beldih Lake (2018–2023)

Key Observations (2018–2023)

1. **Native Species Decline**

Rohu, Katla, and Mrigal, three commercially important native fish species, have seen a steady decline in population. In 2018, these species were either abundant or moderately available, but by 2023, their populations had drastically decreased.

Reasons: The decline is primarily due to increasing water temperatures, low dissolved oxygen levels, pollution from nearby industrial and urban areas, and competition with invasive species.

Impact: These species are crucial for local fishers and play an important role in the lake's ecosystem.

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Fishermen

2019: Fishermen reported a 30% decrease in their daily catch due to the declining fish populati during 2019 but now they reported a 50% decline in fish catch. They are struggling to maintain the livelihoods and have started seeking alternative income sources, such as small-scale farming or labou

4. Community Perceptions of Climate Change

Changes in Rainfall Patterns

2019: 50% of respondents noticed erratic rainfall patterns, which they believed were affecting t lake's water levels.

2024: 75% now report that the rainfall has become more irregular, with heavy rains followed l extended dry periods, causing both flooding and drought conditions around the lake.

Temperature Increases

2019: 40% of respondents believed that the summers had become hotter in recent years.

2024: 70% now feel that temperatures, especially during summer, are consistently higher, causin more evaporation from the lake and affecting the fish population.

Suggestions

1. Pollution Control

Immediate steps must be taken to monitor and reduce pollutant entering the lake. The installation filtration systems and strict pollution control regulations are necessary.

2. Restoration of Fish Populations:

Efforts to restock native fish species and regulate fishing practices should be introduced to restore th ecological balance of the lake.

3. Climate-Resilient Water Management:

The construction of rainwater harvesting systems and check dams could help manage water during dr periods and prevent excessive evaporation.

4. Community Involvement in Conservation:

Continued awareness programs on climate change and environmental conservation should b implemented to engage the local population in sustainable practices that protect the lake's ecosystem.

Conclusion

The data collected from local residents highlights the growing awareness of climate change among th local community and their recognition of its impacts on Beldih Lake. The decrease in fish population lower water levels, and deteriorating water quality are consistent with global trends observed freshwater ecosystems affected by climate change. Furthermore, pollution and invasive species a

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exacerbating these challenges. Livelihoods dependent on the lake, especially fishing have been significantly affected, pushing the community to adapt through alternative means. The data collected from local residents underscores a significant shift in awareness regarding climate change and its direct impacts on Beldih Lake. Residents have noted a troubling decline in fish populations, which is not only a local concern but also reflects broader global trends seen in freshwater ecosystems experiencing the effects of climate change. The observed decrease in water levels and the deterioration of water quality further illustrate the lake's declining health, making it increasingly challenging for local fisheries to sustain their yields.

In addition to climate-related changes, the presence of pollution and invasive species has compounded these environmental challenges. Pollution—whether from agricultural runoff, industrial discharges, or waste management issues—has contributed to the degradation of water quality, making it less hospitable for aquatic life. Invasive species disrupt the local ecosystem, outcompeting native species and altering habitat conditions, which can lead to further declines in biodiversity and fish populations. The implications of these environmental changes extend beyond ecological concerns; they have a profound impact on the livelihoods of local residents. Many community members rely on the lake for fishing and household work , both of which are increasingly jeopardized by the declining health of the ecosystem. As fish stocks dwindle and water quality worsens, those dependent on fishing face diminished catches, while agricultural practices suffer from reduced water availability and quality. In response to these challenges, the community is being pushed to adapt. Many residents are exploring alternative means of livelihood, such as diversifying income sources, pursuing ecotourism, or engaging in sustainable farming practices that require less water and are more resilient to changing environmental conditions. These adaptations are crucial for the community's resilience, allowing them to navigate the economic pressures imposed by a changing climate and its effects on Beldih Lake. Overall, the situation at Beldih Lake exemplifies the intricate interplay between climate change, local ecosystems, and community livelihoods. It highlights the urgent need for concerted efforts—both locally and globally—to address these challenges through sustainable management practices, pollution control, and the promotion of biodiversity to safeguard the lake's future and the well-being of its surrounding communities.

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951. Exploring India's Sustainable Water Management Practices

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ABSTRACT

The article explores India's traditional sustainable water management practices, emphasizing their historical significance and contemporary relevance. Utilizing a historical research method, we examine ancient techniques such as step wells, rainwater harvesting, and community-managed irrigation systems that have sustained local populations for centuries. As India grapples with an escalating water crisis, characterized by depleting groundwater resources and erratic rainfall patterns, reviving these time-tested practices offers a viable solution to enhance water security and promote ecological balance. The research highlights successful case studies where traditional methods have been reintroduced, leading to improved water availability and community resilience. By bridging the gap between past wisdom and modern challenges, this study advocates for integrating traditional practices into current water management policies. The findings suggest that a renewed focus on sustainable techniques can not only mitigate the ongoing water crisis but also foster a deeper appreciation for cultural heritage and community engagement in resource management.

Keywords: Sustainable water management, traditional practices, water crisis, rainwater harvesting, temple ponds

Introduction

Water is the essence of life, serving as the building block for all living organisms. It covers about 70% of the Earth's surface and makes up around 60% of the human body, underscoring its critical role in sustaining life. Every biological process, from cellular functions to digestion, requires water. It helps regulate body temperature, transports nutrients and oxygen, and flushes out toxins. Water is also essential for the survival of ecosystems, supporting plants, animals, and aquatic life. Without it, ecosystems would collapse, food production would cease, and life as we know it would be impossible. Life without water is unimaginable. Civilizations have historically flourished near water sources, recognizing it as vital for agriculture, industry, and everyday survival. Lack of access to clean water still causes widespread suffering, leading to health crises and conflicts. Its abundance ensures life continues, while its scarcity spells disaster. As climate change threatens global water supplies, preserving and managing this resource is increasingly critical for human and environmental well-being.

The global water crisis in 2024 has escalated to unprecedented levels, driven by pollution, climate change, and unsustainable water management. This crisis is evident in key metrics comparing the past and present conditions, showing a stark deterioration in water availability, quality, and the stability of ecosystems. The rapid melting of glaciers, rising sea levels, erratic rainfall, and the modification of river flows by dams and reservoirs are further straining water resources. Extreme weather conditions, including longer summers and harsher winters, reflect the disruption of natural water cycles, with severe consequences for populations worldwide. According to the World Health Organization, 3 billion people lacked access to safe drinking water in 2018, but by 2024, this number has surged to 2.6 billion, primarily due to increased industrial waste, untreated sewage, and agricultural runoff contaminating freshwater sources. Glaciers in the Himalayas are melting at nearly double the rate compared to the 20th century. Between 2000 and 2024, glaciers have lost more than 40% of their ice mass, accelerating the depletion of freshwater reserves. Global sea levels have risen by about 3.6 mm per year since 2010, but by 2024, the rate has accelerated to 4.8 mm per year, affecting coastal freshwater aquifers with saltwater intrusion.

India has historically faced water challenges, but recent developments show a drastic worsening of the situation. According to the NITI Aayog, 600 million people in India already faced water stress in 2019. By 2024, this number has ballooned to over 850 million, driven by over-extraction of groundwater, erratic rainfall, and widespread water pollution. Example of Delhi the capital city's water demand in 2015 was around 3.6 billion liters per day (MLD). By 2024, it has surged to over 4.5 billion liters per day, far outstripping supply. In 2015, groundwater in Delhi dropped at an average rate of 1-2 meters per year. By 2024, this rate has increased to 3-4 meters per year in many parts of the city, leading to acute water shortages. The Yamuna River, which provided 60% of Delhi's water in 2010, now faces 90% pollution levels. Untreated sewage and industrial waste continue to flow into the river, making much of its water unsafe for use. Bangalore the IT hub of India which has been in news for shortage of drinking water had 262 lakes in 1960s but by 2024, only 17 lakes remains because of rapid urbanisation. In 2010, the water table in Bangalore was at 10-12 meters below ground. By 2024, it has dropped to 200-300 meters, making water extraction extremely expensive and unsustainable.

In 2024, India faces a paradox where regions are experiencing both devastating floods and severe droughts simultaneously. Assam, Kerala, Bihar, West Bengal, Himachal Pradesh have experienced more intense and unpredictable monsoon rains, with average rainfall increasing by 12% since 2010, leading to severe floods. On the other hand, states like Rajasthan and Tamil Nadu have seen 40% less rainfall than the average, creating drought-like conditions.

India has long faced the challenge of water imbalances due to its erratic monsoon seasons, which often result in either droughts or floods. To mitigate these extremes, dams have been constructed across the country, serving as reservoirs to store excess rainwater for times of scarcity. However, dams alone are not sufficient to address the increasing demand for water, especially with a growing population and rapid urbanization. India is transforming into a concrete jungle, leaving little space for rainwater to percolate into the ground, further intensifying the water crisis.

Water harvesting techniques are not new to India. These sustainable practices date back to the Indus Valley Civilization, where elaborate systems for managing water were already in place. Unfortunately, modern infrastructure has overshadowed these ancient methods, even though they are more relevant than ever in addressing today's water challenges. The degradation of natural water bodies and the neglect of traditional techniques have only aggravated the issue. In this paper we will study a few traditional water conservation methods in India used by our illiterate yet successful water managers in India.

Objectives

1. To study the various traditional, sustainable water conservation techniques used in India.
2. To explore examples where ancient water sources have been revived to tackle contemporary water issues.

Methodology

The methodology for this research involved a historical descriptive analysis based exclusively on secondary data to comprehensively explore the topic. A significant amount of information was gathered through an extensive review of research articles, academic journals, historical records, books, and reputable online sources related to ancient water conservation practices in India. These sources provided a broad and varied perspective, enabling a thorough examination of historical practices and cultural contexts without the use of primary data.

Findings and Analysis

Objective 1: Ancient Sustainable Water Conservation Techniques

To trace the earliest examples of water management and usage by humans, we can look back to the Indus Valley Civilization. This ancient society is notable for large-scale constructions related to water management, from well systems to massive reservoirs. Cities like Harappa and Mohenjo-Daro provide significant evidence, especially Mohenjo-Daro, where more than 800 wells were constructed with trapezoidal bricks (instead of rectangular) to prevent inward collapse.

Dholavira, one of the five largest Indus Valley cities, offers a particularly sophisticated example of water management. It features a meticulously planned network of reservoirs located on the eastern and southern sides of the citadel. The inhabitants channelled water into these reservoirs by damming a nearby river flowing south of the settlement, and excess water was later released through gated channels. Evidence of dam structures, constructed from interlocked wooden logs and stone blocks, has been discovered here. While small by modern standards, this dam effectively diverted water into channels and reservoirs, showcasing resourceful engineering with available materials.

Other examples of ancient water management are seen in Baluchistan's "gabarbands" or small dams built along rivers and streams, as well as in mentions from the Arthashastra on irrigation technology, water taxes, and maintenance of water systems. The water supply systems were meticulously managed under strict regulations. Cultivators paid different types of taxes based on the irrigation method used. A tax rate of 25% of the produce applied for water drawn from natural sources, such as rivers, tanks and springs. For water from storage facilities constructed by the King, tax rates varied depending on the method of water extraction: 20% for manual drawing, 25% when drawn by bullocks, and 33% for water diverted through channels. Exemptions were granted to those developing or enhancing irrigation facilities, with a five-year exemption for new tanks and bunds, four years for renovating old structures and three years for clearing weed-infested works.

The Ahar-Pyne system exemplifies advanced rainwater harvesting from the Mauryan era, where a sophisticated network of reservoirs (Ahar) and irrigation channels (Pyne) managed water efficiently. A notable find by the Archaeological Survey of India between 1951 and 1955 at Kumhrar revealed a canal from this era, measuring 45 feet in width, 10 feet in depth, and 450 feet in length, highlighting the technical prowess of the period. Additionally, Chandragupta Maurya, commissioned the Sudarsana Dam near Girnar in Gujarat as written in Junagarh rock inscription of Rudradaman.

The Satavahanas (1st century B.C. - 2nd century A.D.) pioneered the use of brick and ring wells. During the Pandya, Chera, and Chola dynasties in South India (1st - 3rd century A.D.), lake and well irrigation expanded significantly, with large structures built across the Cauvery and Vaigai rivers. Many irrigation tanks were created by developing large natural depressions. Extensive water resource development also took place during the Gupta era (300 - 500 A.D.). In the south, the Pallavas further expanded irrigation in the 7th century A.D., including the construction of the famous Cauvery anicut. Large-scale tank construction, known as *tataka*, was also undertaken in Tamil Nadu to capture rainwater. The Chola period (985 - 1205 A.D.) saw the introduction of advanced irrigation systems which fostered prosperity in the Deccan region. This included not only anicuts across rivers and

streams but also chain-tanks—multiple tanks connected by channels—providing more reliable water availability and flexibility in distribution. The Grand Anicut (Kalnai) by the Chola dynasty, and gravity-aided systems in Aurangabad, exemplify continued advancement.

In the 11th century A.D., King Bhoja of Bhopal directed the creation of India's largest artificial lake, covering an impressive area exceeding 65,000 hectares. This extraordinary accomplishment was made possible by diverting water from 365 streams and springs to sustain the vast lake.

In the 16th century, under the rule of Kempegowda, the founder of Bangalore, an extensive network of artificial lakes was developed to address the water needs of the growing population and support agriculture. Kempegowda's vision led to the creation of nearly a thousand interconnected lakes across the Bangalore region, designed to capture and store monsoon rains. For example, the Kempambudhi Lake, originally constructed in the 16th century, covered around 300 acres, while the Doddabommasandra Lake spanned over 100 acres. This extensive lake network not only served as a water source but also helped replenish the city's groundwater.

The Rajputs of Rajasthan developed innovative water harvesting techniques to ensure a steady water supply within their desert castles, taking advantage of limited rainfall, terrain, and natural water sources. They built stepwells (Baolis or Bawdis), which are intricately designed wells with descending steps, were built within or around castles to collect and store rainwater. These structures allowed easy access to water, even as water levels fluctuated. Famous examples include the Toorji Ka Jhalra in Jodhpur , Raniji ki baori and Chand Baori in Abhaneri. Castles often had large water tanks or reservoirs (talabs) to capture rainwater. These tanks were strategically positioned at higher elevations to collect runoff from castle rooftops and surrounding areas. For example, the Amer Fort near Jaipur has the Maota Lake, a reservoir fed by channels that direct rainwater from nearby hills. Kunds (small, often circular catchments) and tankas (underground storage tanks), jhalaras, Johads were used to capture and store rainwater.

Feroze Shah Tughlaq (1351-1388 A.D.), constructed the Western Yamuna Canal in 1355 to enhance irrigation in present-day Haryana and Rajasthan. Emperor Shahjahan(1628-1658) developed several canals, notably the Bari Doab or Hasli Canal, while Rangila Muhammad Shah oversaw the creation of the Eastern Yamuna Canal for irrigation in Uttar Pradesh.In southern India, the Vijayanagar Kingdom (1336-1546 A.D.) focused on building both large and small storage tanks, such as the Anantraj Sagar tank, which featured a 1.37 km earthen dam across the Maldevi River. The renowned Korangal dam was constructed under King Krishnadevaraya. The Bahamani rulers (1388-1422 A.D.) were pioneers of canal irrigation in the eastern Deccan. Sultan Zain Uddin (1420-1470 A.D.) introduced an extensive

canal network in Kashmir.In 1615, during Mughal rule, Abdul Rahim Khan established a unique wa supply system for Burhanpur (Madhya Pradesh), which included long underground tunnels wi vertical shafts to harness groundwater from the nearby Satpura hill ranges to the Tapi River. Th system continues to efficiently meet the town's water needs.

Indian temples have historically incorporated water conservation into their design, often built ne rivers or with large ponds known as *kalyanis* or *pushkarinis*. These ponds hold both religio significance and serve as essential water resources for surrounding communities. By collecti rainwater, temple ponds help replenish groundwater, benefiting nearby wells and ensuring wat availability during droughts. The Virupaksha Temple in Hampi, for instance, has a *pushkarini* pon that collects monsoon rains, providing water throughout the year. Additionally, some ponds are fed b hot springs, like those at the Surya Kund in Gujarat's Modhera Sun Temple, believed to have healin properties for skin ailments. North Indian temples often depict Ganga and Yamuna at their entrances symbolizing the cleansing of worshippers with holy water. This emphasis on water conservatio within temple architecture reflects a unique blend of spirituality and environmental stewardship ensuring sustainable water use for generations.

Objective 2: Reviving Ancient Water Bodies

Reviving ancient water bodies in India has become a critical step to combat water scarcity and climat change. Traditional water bodies like tanks, step-wells, and ponds, once the backbone of India's wate supply, have been neglected over the years, leading to pollution, encroachment, and drying up. These ancient structures, historically used for irrigation and drinking water, now need restoration to suppor millions of people who face acute water shortages.

Stepwell restoration has "the potential to solve a lot of water availability issues at the village level, by really going back to the basics," said conservation architect Ratish Nanda, CEO of the Aga Khan Trust for Culture (AKTC), a philanthropic foundation working to preserve heritage sites across the world.

In Maharashtra, the NGO All World Gayatri Pariwar is revitalizing 52 ancient kundas, or wate reservoirs, in Alandi. In Chennai, the City of 1000 Tanks initiative focuses on repairing existing tanks and constructing new ones, incorporating treatment stations to store clean water for dry periods. Rajasthan has enabled locals to construct 10,000 johads, which enhance underground water storage and revive dry rivers.

In Karnataka, the rejuvenation of tanks through the "Jal Samvardhane Yojana" project has revived more than 12,000 water bodies, providing water to thousands of villages. Mr Anand Malligavad also referred to as lake man of India successfully transformed 35 lakes of Bangalore, previously polluted

by sewage, into freshwater ponds through cost-effective initiatives.In Tamil Nadu, traditional "Eri" (tank) systems, which could once sustain agriculture in semi-arid regions, are being revived under the Tamil Nadu Irrigated Agriculture Modernisation Project. Furthermore, Delhi's Neela Hauz lake, revived with support from Delhi Development Authority, has restored biodiversity and improved the local micro-climate.

The "Waterman of India," Rajendra Singh, has led transformative efforts to revive traditional water systems in Rajasthan, rejuvenating over 11,000 water bodies. Through traditional water harvesting techniques, his work has replenished groundwater, restored rivers, and improved agriculture, bringing water security to thousands and earning him the Stockholm Water Prize.

Traditional **kundi** systems in Madhya Pradesh (underground water tanks) were restored, alongside **check dams** and **farm ponds**, which helped increase water storage, recharge groundwater, and transform the area from water-scarce to water-sufficient. Revival of the **Suranga** system of Kerala (horizontal tunnel wells) for groundwater access led to water sustainability in remote hilly areas, benefiting agricultural and domestic water needs.

A recent report by the Centre for Science and Environment highlights that restoring water bodies not only enhances water availability but also recharges groundwater, boosts agriculture, and mitigates flood risks. With effective policies and community participation, reviving ancient water bodies can play a crucial role in sustainable water management across India.

Suggestions

1. Everyone should take steps to conserve water at a personal level by reducing wastage and adopting sustainable water-use practices.
2. Once individuals adopt water conservation habits, they should work together as a community to protect and manage local natural water resources effectively.
3. The government should implement and enforce strict policies focused on water conservation, ensuring responsible use and long-term sustainability of water resources.
4. The government must prioritize the conservation of ancient water bodies, as they are built with great precision and provide valuable lessons for modern water management.
5. These water bodies are not only functional but also archaeological marvels that symbolize the ingenuity of past generations. They should be preserved to instill pride in future generations.

Conclusion

The water crisis in 2024 is far worse than in previous decades, demanding immediate and coordinated efforts. India's example—where some cities face acute water scarcity while others are ravaged by

floods—highlights the complexity of the issue. Without improved water management practices, restoration of natural water bodies, and better preparedness for climate extremes, the situation is likely to worsen, putting millions more at risk of water insecurity.

Reviving ancient water management techniques is essential for sustainable water security, especially as India faces increasing water stress and climate challenges. These methods, such as step-wells, tanks, and rainwater harvesting systems, were ingeniously adapted to local climates, landscapes, and communities. Unlike modern, large-scale water projects, these traditional techniques minimize environmental disruption and are cost-effective, using natural contours and gravity to manage water sustainably. They also recharge groundwater, support agriculture, and foster biodiversity, making them invaluable assets for rural resilience.

Rehabilitating these structures not only helps address immediate water shortages but also builds a resilient future. By integrating modern science with ancient wisdom, India can protect its water heritage, adapt to climate change, and secure resources for future generations. Reviving these techniques is not just an environmental necessity but a pathway to social, economic, and cultural revitalization.

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Fostering Education for Sustainable Development (ESD) in India: A Broad Review

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ABSTRACT

While the global community faces environmental, social, and economic problems, it is education that has been hailed as the linchpin for sustainable development. In India, this notion has taken hold and has led to the emergence of "Education for Sustainable Development" (ESD). ESD is the tool—with both the state's policy frameworks and the education system itself as key stakeholders—that can potentially address India's mountainous and diverse sustainability issues, not least of which are climate change, environmental degradation, social inequality, and economic disparity. This research paper delves into the dynamic relationship between education and sustainability, exploring how education can foster a sustainable society and nation. This study investigates the impact of education for sustainability (efs) on promoting environmental stewardship, social responsibility, and economic viability. Education is the backbone for the citizens to develop a country and also a very important tool for achieving sustainability. It has been recognized by all individual across the world that the current economic development trends are not sustainable and public awareness, education and training, are key to moving society towards sustainability. Sustainable development is a demanding concept to define. One of the original illustration of sustainable development is credited to the Brundtland commission: "sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development is generally thought to have three units: 1) environment (planet), 2) society (people), and 3) economy (profit). ESD is a vision of education that seeks to balance human and economic well-being with cultural traditions and respect for the earth's natural resources. ESD applies the transdisciplinary educational approaches and methods to develop moral principles for lifelong learning; fosters respect for human being needs that are compatible with sustainable use of resources and the needs of the planet; and encourages nurtures a sense of global solidarity problem-solving skills and critical thinking are essential for sustainable development. In the present paper an attempt has been made in education to elevate the major thrust which is required to begin the work of Indian education for sustainable development of society as well as nation. . This research paper identifies key components, including inclusive curriculum design, participatory pedagogy, and community engagement, and highlights the need for policy support and capacity building. The study's

recommendations offer insights for policymakers, educators, and stakeholders seeking to harness the transformative power of education for a sustainable tomorrow.

Keywords: Education, Sustainable Development, Environmental Awareness, Social Responsibility, Economic Growth, Nation.

Introduction

One of the most effective tools for molding the character and skills of individuals is widely considered to be education. When it comes to sustainable development, it is vital that we prepare young people for a life in a world that we expect to be sustainable and equitable. Education for Sustainable Development (ESD) is working to make this happen. ESD takes the principles of sustainable development and integrates them into the different forms and levels of education that we have in the societies where we live. ESD seeks not only to inform young people about the principles of a sustainable world but also to involve them in a much more equitable world.

As a country in the midst of rapid development, with more than 1.4 billion people, India has some unique challenges related to sustainability. These troubles are compounded by environmental degradation, severe inequalities in economic opportunity, an unprecedented pace of urbanisation, and climate change.

The Foundational Concept of Sustainable Development

Environmental degradation, economic disparities, urbanisation, and climate change all increase the issues that India faces in terms of sustainable development. Integrating Education for Sustainable Development (ESD) into India's educational system is critical for promoting sustainable behaviors in all sectors of society. This article examines the current environment of ESD in India, examining its evolution, the regulations that shape it, the barriers to implementation, and potential opportunities for strengthening the Education for Sustainable Development.

ESD is a transformative approach for education that seeks to provide students with the information, skills, and values required to support sustainable development. ESD, which was first introduced at the 1992 Earth Summit in Rio de Janeiro, recognises the importance of education in accomplishing sustainable development goals .UNESCO(United Nations Educational, Scientific, and Cultural Organisation) has played a crucial role in advancing ESD around the world, calling for educational systems to incorporate sustainability into curricula and pedagogical methods.

ESD is more than just environmental education; it represents a comprehensive view of sustainability that incorporates economic development, social fairness, and environmental conservation. Climate change, biodiversity conservation, sustainable production and consumption, social justice, and civic

responsibility are among ESD's key topics. ESD also emphasizes on experiential learning, problem solving, critical thinking, participatory, decision-making and also allowing students to grapple with real-world sustainability issues.

In the Indian context, ESD can make a substantial contribution to tackling some of the country's most important issues, such as poverty reduction, environmental protection, and sustainable economic growth.

The Strategic Policy Framework

The country's policy frameworks and national development plans demonstrate its commitment to sustainable development. Several major legislation and programs highlight the necessity of incorporating sustainability into education, establishing the groundwork for ESD activities.

1. National Policy for Education (NPE)

National Policy on Education (NPE) has helped shape India's education system. The NPE, which was originally developed in 1968 and amended in 1986 and 1992, has changed to suit shifting educational priorities. While earlier versions of the NPE were primarily concerned with increasing access to education, following iterations included components of environmental education, recognizing the importance of education in raising environmental consciousness.

The NPE 1986 (updated in 1992) established environmental education as an integral part of the school curriculum, with the goal of raising knowledge concerning The National Policy on Environment 1986 (updated in 1992) established environmental education as a core component of an educational program of study, with the goal of raising student understanding regarding environmental conservation. This strategy provided the framework for following ESD projects, albeit with a concentration on environmental education rather than the broader notion of sustainable development.

2.The National Curriculum Guidelines (NCF)

National Curriculum Framework (NCF), designed by the National Council of Educational Research and Training (NCERT), serves as a framework for the creation of school curriculum in India. The National Curriculum Framework (NCF) of 2005 was an enormous leap forward in incorporating sustainability into the educational system, emphasizing the importance of environmental literacy and urging schools to take a holistic, multidisciplinary approach to acquiring knowledge.

The 2005 National Curriculum Framework emphasized the need of students understanding the interconnection of environmental systems and human activities. It advocated for the integration of environmental themes into all areas, encouraging students to investigate sustainability issues in science, social studies, and even literary arts. However, while the NCF 2005 established a solid

platform for ESD, its implementation has been patchy, with many schools considering environmental education as a separate subject rather than incorporating it into the overall curriculum.

3. The National Policy on Education 2020 (NEP)

The National Education Policy (NEP) 2020 is a watershed moment in India's educational reforms. The NEP 2020 acknowledges the significance of sustainability in education and argues for the incorporation of environmental awareness, climate change education, and sustainability practices at all levels of learning. It encourages interdisciplinary learning, experiential education, and the development of critical thinking and problem-solving abilities—all of which are essential components of ESD.

The NEP 2020 advocates for a more flexible curriculum that allows pupils to address sustainability concerns holistically. It promotes schools to involve students in practical environmental projects, community service, and experiential learning activities that promote sustainability. The strategy also emphasizes higher education institutions' role in fostering sustainability research and innovation, recognizing the importance of preparing a workforce to face the complex issues of sustainable development.

4. National Action Plan on Climate Change (NAPCC)

India's National Action Plan on Climate Change (NAPCC), which was released in 2008, describes the country's strategy for combating climate change through a variety of sectoral activities. The National Mission on Strategic Knowledge for Climate Change is one of the NAPCC's core missions, with an emphasis on developing human and institutional capacity to handle climate concerns. Education is an important part of our purpose because it promotes climate literacy and develops the scientific and technical skills required to mitigate and adapt to climate change.

While the NAPCC does not expressly address ESD, its emphasis on climate knowledge and capacity building is consistent with the goals of ESD. Climate education must be integrated into school curricula and higher education programs in order to provide future generations with the information and skills required to combat climate change and promote sustainable development.

Function of Non-Governmental Organisations (NGOs) in Promoting ESD

Non-governmental organisations (NGOs) have played a vital role in furthering ESD in India, in addition to government-led programs. Non-governmental organisations (NGOs) have also played a major role in designing creative programs, educating teachers, and increasing awareness about sustainability concerns in schools and communities.

1. The Centre for Environmental Education (CEE)

Centre for Environment Education (CEE), inaugurated in 1984, is one of the country's most prominent groups committed to both ecological education and sustainability The CEE has collaborated with schools, universities, and communities around the globe to create and execute ESD programs that provide students with hands-on learning experiences in biodiversity conservation, waste management, water conservation, and renewable energy.

The CEE's Environmental Education Programme (EEP) has been very effective in incorporating environmental education into school curriculum. The program offers teachers materials and training to help them incorporate sustainability topics into their teachings, as well as opportunities for students to participate in environmental initiatives and campaigns. The CEE's work has helped create awareness about the significance of sustainability and has aided in the formation of an environmentally conscientious generation.

2. The Energy and Resources Institute (TERI)

Energy and Resources Institute (TERI) is another well-known non-governmental organisation (NGO) that has helped promote ESD in India. TERI has created various educational initiatives to raise awareness about sustainable development, energy conservation, and climate change. The institution collaborates with schools, colleges, and communities to promote sustainability via research, capacity building, and outreach programs.

The Green Schools Programme, one of TERI's flagship initiatives, promotes schools to embrace sustainable practices such as decreasing energy use, saving water, and improving waste management. The initiative involves students in environmental audits of their schools and encourages them to take steps to lessen their environmental footprint. TERI's activities have been successful in promoting sustainability at the grassroots level and instilling a sense of environmental responsibility in students and instructors.

Operational Barriers of ESD in the Country

While India has made tremendous strides in promoting ESD, various obstacles prevent its full adoption. These obstacles originate from systemic flaws within the educational system, socioeconomic inequality, and a lack of resources and infrastructure to promote sustainability education.

1. Inadequate Teacher Preparation and Development

One of the most major barriers to adopting ESD in India is a lack of teacher training and capacity building. Many instructors have not had appropriate training in sustainability education, and as a result, they may lack the knowledge, skills, and confidence to properly teach ESD. Teacher education

programs in India have typically prioritized subject-specific knowledge, with minimal emphasis on interdisciplinary learning or sustainability teaching. To solve this difficulty, comprehensive ESD focused professional development programs for teachers must be developed. These programs should provide instructors with the information and teaching tools they need to incorporate sustainability into their teachings while also encouraging experiential learning, critical thinking, and problem solving.

2. Instructional Stability and Centred Around Tests Teaching

The Indian education system is frequently criticised for emphasising rote learning and exam-oriented instruction. This concentration on memorisation and standardised testing provides little room for introducing new subjects or implementing creative teaching approaches, such as those necessary for ESD. As a result, ESD is frequently viewed as an add-on rather than being completely incorporated into the curriculum. To address this difficulty, the curriculum must be revised to allow for greater flexibility and interdisciplinary learning. Schools should be encouraged to use project-based learning, which allows students to participate in hands-on sustainability initiatives that foster critical thinking and real-world problem solving.

3. Network and Shortages of Resources

Many Indian schools, particularly in rural regions, lack the necessary infrastructure to implement ESD. Schools, for example, may lack access to clean water, green areas, and labs, all of which are necessary for carrying out environmental projects and sustainability-related activities. Furthermore, schools may lack the financial resources required to adopt sustainability measures such as renewable energy installations or waste management programs. To overcome this issue, more investment in school infrastructure is required, especially in underprivileged regions. Government initiatives and public-private partnerships can help schools get the resources and assistance they need to successfully adopt ESD.

4. Economic and Demographic Imbalances

Socioeconomic gaps in India further complicate the implementation of ESD. While metropolitan schools with more resources are more likely to undertake sustainability education, schools in underserved or marginalized locations frequently fail to satisfy fundamental educational demands. This disparity in access to excellent education extends to ESD, with students in wealthier schools having more opportunity to participate in sustainability education than their peers in less affluent locations. Addressing this issue needs focused measures that priorities ensuring equal access to quality education for every child, despite of socioeconomic status. This may be accomplished by government

policies that priorities the needs of marginalised populations and increase funding for neglected schools.

Potential and Strategies for the Future for Enhancing ESD in India

Despite the limitations, there are various potential ways to expand ESD in India and guarantee that it plays an important part in attaining the country's long-term development goals. By using creative ideas and building on previous accomplishments, India can establish an education system that supports sustainability at all levels.

1. Boosting Education and Career Advancement

One of the most important initiatives towards enhancing ESD in India is to improve teacher training and professional development programs that emphasise sustainability education. These programs should provide instructors with the knowledge and abilities required to effectively teach ESD and promote transdisciplinary learning. Furthermore, teacher education programs should be reorganised to include sustainability education as a major component of the curriculum, so that all instructors are prepared to include ESD into their courses.

2. Educational Modernisation and Customisation

To encourage ESD, the curriculum must be revised to allow for more flexibility and interdisciplinary learning. Schools should be encouraged to use project-based learning, which allows students to participate in hands-on sustainability initiatives that foster critical thinking and real-world problem solving. Furthermore, sustainability should be included into all courses rather than regarded as a separate issue. Students, for example, should investigate sustainability concerns in science, social studies, and mathematics to have a better understanding of the interconnectivity of natural systems and human activity.

3. Utilizing Innovation for ESD

Digital platforms and online resources may play an important role in promoting ESD, especially in schools with limited physical infrastructure. For example, virtual workshops, online sustainability courses, and digital tools can assist instructors and students in engaging with sustainability concerns, especially in locations where traditional resources are limited. Furthermore, technology may help schools, non-governmental organisations, and communities collaborate, allowing pupils to participate in long-term sustainability initiatives.

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4. Neighbourhood and Guardianship Participation

ESD is most effective when it extends beyond the classroom and engages the larger community. Schools should include parents and communities in sustainability activities including trash management, water conservation, and renewable energy projects.

This can assist to foster a culture of sustainability that goes beyond the classroom and encourages students to use what they've learnt in their homes and communities.

5. Interaction among Organizations

Collaboration among governments, NGOs, educational institutions, and the commercial sector is critical for scaling up successful ESD models and integrating them into mainstream education. Public-private partnerships may give schools the resources and skills they need to execute sustainability programs, and non-governmental organisations (NGOs) can help design novel ESD projects. Furthermore, universities and research institutes may play an important role in furthering sustainability research and establishing novel instructional methods to ESD.

Conclusion

Education for Sustainable Development (ESD) is critical to tackling India's current complex environmental, social, and economic concerns. While the country has made substantial progress in promoting ESD through regulatory frameworks, NGO initiatives, and government programs, issues such as teacher readiness, curricular rigidity, infrastructural limits, and socioeconomic inequities continue to impede widespread adoption.

To fully realise ESD's potential in India, it is vital to invest in teacher training, revise the curriculum to allow for interdisciplinary learning, and guarantee that schools have the resources necessary to undertake sustainability education. India can construct an education system that encourages sustainability at all levels while also contributing to the country's wider dramatic effects by encouraging collaboration among governments, NGOs, and the business sector.

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Harnessing the Power of Education to Embrace Green Initiatives

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ABSTRACT

In the face of escalating environmental challenges such as climate change, biodiversity loss, pollution, and resource depletion, education emerges as a pivotal tool for fostering sustainable development. This essay examines the critical role of education in promoting and sustaining green initiatives, emphasizing its transformative potential in shaping values, attitudes, and behaviours essential for environmental stewardship. It explores the integration of environmental literacy into curricula, the cultivation of a sense of responsibility towards nature, and the implementation of sustainable practices within educational institutions. Innovative educational approaches, including outdoor and experiential learning, STEM education tailored to address sustainability issues, and the use of digital tools for environmental education, are discussed in detail. The essay also highlights the importance of policy support, teacher training, and institutional collaborations in achieving these educational objectives. Through the analysis of successful case studies, such as the Eco-Schools program and green university initiatives, the essay demonstrates practical examples of how education can lead to significant environmental change. The findings underscore that by prioritizing and investing in green education, we can empower future generations to act as proactive custodians of the environment, ultimately driving the global transition towards a more sustainable and resilient future.

Keywords: Green Initiatives, STEM education, Environmental stewardship

Introduction

The 21st century presents humanity with a critical juncture as we face unprecedented environmental challenges such as climate change, biodiversity loss, pollution, and resource depletion. These issues threaten not only the health of our planet but also the well-being and survival of future generations. In response, there is a growing recognition of the need for a fundamental shift in how societies operate and interact with the natural world. Central to this shift is the role of education. Education is not merely about acquiring knowledge; it is a transformative force that shapes values, attitudes, and behaviours. When harnessed effectively, education can empower individuals and communities to embrace green initiatives and foster a culture of sustainability.

This paper explores the multifaceted role of education in promoting and sustaining green initiatives. It delves into how environmental literacy can be cultivated from an early age, the importance of instilling a sense of environmental stewardship, and the implementation of sustainable practices within

educational institutions themselves. Additionally, it examines innovative educational approaches, such as outdoor and experiential learning, STEM education for sustainability, and the integration of digital tools in environmental education.

Furthermore, the essay discusses the essential support mechanisms required to achieve these educational goals, including policy frameworks, teacher training, and institutional collaborations. Through an analysis of successful case studies, such as the Eco-Schools program and green university initiatives, the essay highlights practical examples of how education can lead to meaningful environmental change.

Ultimately, this essay argues that by prioritizing and investing in green education, we can cultivate a generation that is not only knowledgeable about environmental issues but also motivated to act as custodians of the Earth. The challenges are significant, but with a concerted effort, education can be a powerful catalyst for a sustainable and resilient future.

The Role of Education in Promoting Sustainability

1.Environmental Literacy

- **Definition and Importance**: Environmental literacy involves understanding ecological principles, the impact of human activities on the environment, and the interdependence between natural and human systems.
- **Curriculum Integration**: Incorporating environmental science into school curricula from an early age can help students develop a strong foundation in ecological knowledge. Subjects like biology, geography, and social studies can be tailored to include topics on sustainability.
- **Critical Thinking and Problem-Solving**: Educating students to analyse environmental issues critically and think about solutions encourages proactive engagement. Problem-based learning and case studies on local and global environmental problems can be effective in this regard.

2. Cultivating Environmental Stewardship

- **Values and Attitudes**: Education plays a crucial role in shaping values and attitudes towards the environment. Promoting respect for nature and a sense of responsibility towards environmental protection is essential.
- **Community Engagement**: Schools can partner with local organizations to involve students in community-based environmental projects. This hands-on approach helps students apply classroom knowledge to real-world situations, fostering a sense of stewardship.

3. Sustainable practices in educational institutions

- **Green Campus Initiatives**: Schools and universities can lead by example by adopting sustainable practices on their campuses. This includes energy-efficient buildings, waste reduction programs, and sustainable food services.
- **Student-Led Green Projects**: Encouraging students to initiate and lead green projects, such as recycling programs, organic gardens, or energy audits, empowers them to take ownership of sustainability efforts.

Innovative Educational Approaches for Sustainability

1. **Outdoor and Experiential Learning**

- **Nature-Based Learning**: Utilizing natural environments as learning spaces can enhance students' connection to nature. Field trips, nature walks, and outdoor classrooms provide experiential learning opportunities.
- **Service Learning**: Integrating community service with environmental education allows students to address local environmental issues while developing practical skills and civic responsibility.

2. **STEM Education for Sustainability**

- **Interdisciplinary Approach**: STEM (Science, Technology, Engineering, and Mathematics) education can be tailored to address environmental challenges. Projects that integrate these disciplines can provide innovative solutions to sustainability issues.
- **Green Technologies**: Educating students about renewable energy, sustainable agriculture, and eco-friendly technologies can inspire future careers in green industries.

3. **Digital Learning and Environmental Education**

- **Online Resources and Courses**: The internet offers a wealth of resources for environmental education, from online courses to interactive simulations. These can supplement traditional classroom instruction and provide flexible learning options.
- **Virtual Collaboration**: Digital platforms can facilitate collaboration between students and educators worldwide, fostering a global perspective on environmental issues and solutions.

Policy and Institutional Support for Green Education

1. **Government Policies and Funding**

- **National Curriculum Standards**: Governments can mandate the inclusion of environmental education in national curricula, ensuring that all students receive a comprehensive education on sustainability.

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- **Funding for Green Initiatives**: Financial support for schools to implement green initiatives, such as grants for energy-efficient infrastructure or funding for environmental projects, is crucial.

2. **Teacher Training and Professional Development**

- **Sustainability Education Training**: Providing teachers with training on how to integrate sustainability into their teaching practices is essential. Professional development programs can equip educators with the knowledge and tools they need to effectively teach environmental concepts.
- **Continuous Learning**: Encouraging teachers to stay updated with the latest research and developments in environmental science ensures that their teaching remains relevant and impactful.

3. **Partnerships and Collaborations**

- **Industry and Academia**: Collaborations between educational institutions and industries can provide students with practical insights into green careers and sustainable practices.
- **NGOs and Community Organizations**: Partnerships with non-governmental organizations and community groups can enhance environmental education by providing resources, expertise, and opportunities for student involvement.

Case Studies of Successful Green Education Initiatives

1. **Eco-Schools Program**

- **Global Reach and Impact**: The Eco-Schools program, operating in numerous countries, empowers students to lead environmental actions in their schools and communities. It provides a framework for integrating sustainability into all aspects of school life.
- **Student Empowerment**: Through activities like energy conservation, waste management, and biodiversity projects, students develop leadership skills and a sense of responsibility towards the environment.

2. **Green Universities**

- **Sustainable Campuses**: Many universities worldwide are adopting sustainable practices and becoming models of environmental stewardship. Initiatives include green building certifications, renewable energy projects, and sustainability-focused research.
- **Curriculum Integration**: Universities are also integrating sustainability into their curricula, offering courses and degree programs focused on environmental science, green technology, and sustainable development.

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3. **Community-Based Environmental Education Programs**

- **Local Impact**: Programs that involve local communities in environmental education can have a significant impact. For example, community gardens, clean-up campaigns, and conservation projects engage residents in sustainability efforts.
- **Lifelong Learning**: These programs often extend beyond the formal education system, providing lifelong learning opportunities for people of all ages.

Challenges and Opportunities

1. **Overcoming Barriers to Green Education**

- **Resource Constraints**: Many educational institutions, especially in developing countries, face financial and resource limitations that hinder the implementation of green initiatives.
- **Cultural and Societal Factors**: Societal attitudes towards environmental issues can vary, and cultural factors may influence the acceptance and effectiveness of sustainability education.

2. **Leveraging Technology and Innovation**

- **E-Learning Platforms**: Utilizing technology to provide accessible and scalable environmental education can overcome some resource constraints. Online courses, virtual labs, and digital libraries are valuable tools.
- **Innovation in Teaching Methods**: Innovative pedagogical approaches, such as gamification and project-based learning, can enhance student engagement and motivation in environmental education.

3. **Building a Global Movement**

- **International Collaboration**: Addressing global environmental challenges requires international cooperation. Educational institutions can participate in global networks and initiatives to share best practices and collaborate on sustainability projects.
- **Youth Empowerment**: Engaging young people as leaders in the sustainability movement is crucial. Empowering youth through education and providing platforms for their voices can drive significant environmental change.

Conclusion

Harnessing the power of education to embrace green initiatives is vital for creating a sustainable future. By promoting environmental literacy, cultivating stewardship, and adopting innovative educational approaches, we can empower the next generation to tackle environmental challenges

proactively. Institutional support, policy frameworks, and global collaborations are achieving this goal. Education is not just a tool for imparting knowledge; it is a catalyst capable of transforming societies and preserving the planet for future generations.

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ABSTRACT

This study examines the growing role of renewable energy in global electricity generation, drawing insights from the International Energy Agency's (IEA) "Renewables 2020" report. The analysis reveals significant expansion in solar, wind, and hydropower projects since 2016, with solar leading the projected 50% increase in renewable capacity between 2019 and 2024 (Folk, 2021). Estimates suggest that global solar capacity will reach 600 gigawatts (GW) by 2024, nearly double Japan's total electricity capacity (Folk, 2021). Overall, renewable energy is projected to increase by 1200 GW, nearing the US's electricity capacity (Folk, 2021). The data confirms a rising trend in renewable energy use. As of 2023, 30% of the world's electricity comes from renewable sources, a 10% increase from 2010. Solar and wind power are the primary drivers, reaching a record 13.4% of global electricity in 2023, compared to just 0.2% in 2000. This growth is associated with positive outcomes such as lower CO2 emissions. However, despite the rapid rise of renewables, fossil fuels still dominate energy production, accounting for over 80%. This research highlights the significant progress made in renewable energy while acknowledging the need for further development to achieve a sustainable future.

Keywords: Renewable energy, solar power, wind power, hydropower, CO2 emissions, fossil fuels, electricity, sustainable future.

Introduction

In 2002, the International Energy Agency defined renewable energy as "energy derived from natural processes that are replenished at a faster rate than they are consumed." Solar power, wind power, hydroelectricity, geothermal energy, biomass and ocean energy are widely agreed to be the main types of renewable energy. In contrast to fossil fuels, which are finite resources, renewable energy is virtually inexhaustible, making it a crucial component of the global energy transition. Given the worldwide energy transition, renewable energy is significant in several ways, as shown below.

- Energy Security: Nations that depend significantly on fossil fuels could be more vulnerable to price fluctuations and threats from other countries. By broadening their sources of energy and

boosting renewable energy, they can increase their energy security and decrease their dependency on imported gas and oil.

- Climate Change Mitigation: Greenhouse gas emissions from renewable energy sources are much lower than those from fossil fuels. Moving to an energy system based on renewable energy can curtail our carbon footprint and the effects of climate change.
- Environmental Sustainability: Renewable energy sources have less adverse environmental effects than fossil fuels. They don't cause land degradation, water pollution, or air pollution. Additionally, renewable energy can help preserve biodiversity and ecosystems.
- Technological Advancements: Renewable energy will play a more significant role in supplying the world's energy requirements as technology develops.
- Economic Benefits: Renewable energy projects can strengthen the local economy, boost GDP, and generate jobs.

Renewable energy, whose global capacity (MW) and production (GWh) are given below in Table 1, will be crucial in determining how the world moves towards a low-carbon future in terms of energy. It is expected that by 2035, more than 50% of the electricity production will be powered by renewable energy sources (Earth.org, Mar 10, 2021).

Table 1: Global Renewable Energy Capacity (MW) and Production (GWh)

Year	Global Capacity (MW)	Global Production (GWh)
2014	1698295	5304340
2015	1852496	5512471
2016	2015003	5869293
2017	2185712	6237087
2018	2360957	6633769
2019	2548686	6994086
2020	2819247	7458042
2021	3083431	7872657
2022	3391349	8439671
2023	3864522	

Source: Renewable Energy Statistics 2024 from IRENA (International Renewable Energy Agency)

An intergovernmental organisation called the International Energy Agency (IEA) works to guarantee clean, inexpensive, and dependable energy for all of its member nations and beyond. Established in

1974 during the 1973-1974 oil crisis, the IEA is based in Paris and comprises 29 industrialised countries under the Organization for Economic Development and Cooperation (OECD). The critical roles that IEA plays are:

- Examination of potential threats to the present and future oil supply and new issues with gas security.
- Promotion and recommendation of sound energy policies to enhance energy's reliability, affordability and sustainability.
- Fostering multinational energy technology cooperation through its Technology Collaboration Programs (TCPs).
- International collaboration with organisations such as the Group of 20 (G20), Group of Seven (G7), and Group of Eight (G8).
- Regional collaboration with the Asian Development Bank (ADB), the Association of Southeast Asian Nations (ASEAN), and the African Union (AU).
- Data collection - The IEA collects international data and is a founding partner of the Joint Organisations Data Initiative (JODI).

The "Renewable 2020" report from the International Energy Agency (IEA) lends credence to the idea that renewable energy is the way of the future.

In four years, the number of solar, wind, and hydropower projects has expanded quickly.

An abundance of renewable energy sources surrounds us as they come from natural resources that are made up faster than they are used. Wind and sunlight are well-known examples. On the contrary, resources like gas, coal, and oil, formed over hundreds of millions of years, are getting depleted. Carbon dioxide and other harmful greenhouse gases are released into the atmosphere by burning fossil fuels to produce energy. Burning fossil fuels produces far more emissions than producing energy from renewable sources. Renewable energy must replace fossil fuels, which currently make the majority of emissions, to address the climate crisis. Three times as many jobs are created by renewable energy sources as by fossil fuels in most of the world's economies.

Below, we discuss using five renewable energy sources, expanding the fastest globally.

Hydropower

Hydropower is a renewable energy source that generates electrical energy using the power of flowing water. It is among the most well-established and ancient renewable energy technologies, having been used by many civilisations for a long time. At 1295 gigawatts of energy production, hydropower is the most popular renewable energy source worldwide and ranks first in the list of the fastest-growing

renewable energy sources (Earth.org, March 10, 2021). This amounts to 54 per cent of the world's renewable energy generation capacity (Earth.org, March 10, 2021). Typically, hydropower plants consist of a dam, turbines and generators.

Types of Hydropower Plants

There are several types of hydropower plants, each with its unique characteristics:

- Conventional Hydropower: This type involves large-scale dams and reservoirs capable of generating significant amounts of electricity.
- Pumped Storage Hydropower: In this technology, pumped water stores energy uphill in a reservoir during off-peak hours and releases it back through the rotation of turbines to generate electricity during peak demand.
- Run-of-River Hydropower: Smaller facilities that use a river's natural flow without building sizable reservoirs.
- Tidal Power: In this case, the technology capitalises on the kinetic energy of flowing water by using turbines.

Advantages of Hydropower

- Reliability: It is a steady and dependable source of electricity, particularly in areas with an abundance of water.
- Efficiency: Hydropower plants are affordable for producing electricity due to their high energy conversion efficiency.
- Environmental Benefits: These plants emit fewer greenhouse gases and have a lesser environmental impact than fossil fuels.
- Storage Capabilities: Storage of surplus pumped hydropower during off-peak hours and release of the same during peak hours, which helps balance the supply and demand for electricity.

Disadvantages of Hydropower

- Environmental Impacts: Large-scale hydropower projects may harm the environment, including habitat destruction, a decline in biodiversity, and modifications to river ecosystems.
- Social Impacts: Building dams has the potential to uproot communities and disrupt local economies.
- Limited Suitability: Not all regions are suitable for hydropower, depending on certain geographical conditions.

Although hydropower has been essential in providing energy, its effects on the environment and society must be considered. Additionally, other renewable energy sources must be investigated to broaden the energy mix and solve hydropower development issues.

China is the world's largest producer, with the Three Gorges producing 22.5 GW hydroelectricity. China has made significant investments in hydropower and is now less reliant on coal. Hydropower accounts for 15% of the energy used there. Below are the global hydropower capacity (MW) and Production (GWh).

Table 2: Global Hydropower Capacity (MW) and Production (GWh)

Year	Global Capacity (MW)	Global Production (GWh)
2014	1176805	3986424
2015	1211410	3980023
2016	1247040	4153870
2017	1270901	4208719
2018	1294150	4333950
2019	1313093	4360547
2020	1335185	4449161
2021	1362416	4521122
2022	1394824	4671452
2023	1406863	

Source: Renewable Energy Statistics 2024 from IRENA (International Renewable Energy Agency)

Wind Energy

Wind power is a renewable energy source that exploits the wind's kinetic energy to generate electrical energy. It is the world's second most widely used renewable energy source, producing 563 GW, or 24 per cent of all renewable energy generation capacity (Earth.org, March 10, 2021). Wind turbines, tall structures with blades, convert the wind's energy into rotational motion, which drives generators and produces electricity. The different types of wind turbines are:

- Horizontal-axis wind Turbines (HAWTs): These are commonly used and mounted horizontally. The blades rotate perpendicular to the direction of the wind.
- Vertical-Axis Wind Turbines (VAWTs): These turbines have their axis of rotation aligned vertically, allowing them to capture wind from any direction.

Wind farms are clusters of wind turbines in areas with consistent and strong winds. The development involves several key steps: site selection, turbine selection, grid connection, and Environmental Impact Assessment (EIA).

Advantages of Wind Power

- Abundant Resource: Wind is a widely available and renewable energy source.
- Low Environmental Impact: There are no greenhouse gas emissions or air pollution from wind power.
- Scalability: Wind farms can be built in various sizes to meet energy demands.
- Economic Benefits: Wind power can stimulate local economies by creating jobs.

Challenges and Considerations

- Intermittency: Wind power is subject to fluctuations in wind speed, which can affect its reliability.
- Visual Impact: Wind turbines can visually impact the landscape.
- Noise Pollution: Wind turbines can generate noise, especially at close distances.
- Infrastructure Costs: Developing and connecting wind farms to the grid can require significant infrastructure investments.

To address these issues, efforts are being made to advance grid integration techniques, energy storage technologies, and wind turbine technology. With increasing efficiency and cost-effectiveness, wind power will play a more prominent role in the global switchover to clean energy.

Table 3: Global Wind Energy Capacity (MW) and Production (GWh)

Year	Global Capacity (MW)	Global Production (GWh)
2014	349458	712130
2015	416435	827886
2016	467241	952944
2017	514930	1131755
2018	563680	1258926
2019	622730	1412636
2020	733473	1588319
2021	824321	1840364
2022	902883	2098332
2023	1017390	

Source: Renewable Energy Statistics 2024 from IRENA (International Renewable Energy Agency)

Solar Power

Using the sun's radiant energy to create electricity, solar energy is a renewable energy source. Two primary types of solar power systems exist: photovoltaic (PV) and solar thermal.

Photovoltaic (PV) Solar Energy: The photovoltaic effect converts light energy into electricity. Silicon is a semiconductor material commonly used to make the cells. When sunlight strikes the cells, it dislodges electrons, creating an electrical current.

Types of PV Systems

- Grid-tied systems: These systems connect to the electrical grid, allowing excess energy to be sold back to the utility company.
- Off-grid systems: These systems are not connected to the grid and store excess energy in batteries during low sunlight or at night.
- Hybrid systems: A combination of grid-tied and off-grid systems.

Solar Thermal Energy: In solar thermal systems, mirrors or lenses focus sunlight and heat liquid or solid materials. Steam is subsequently produced from the heated fluid, and turbines generate electricity.

Types of Solar Thermal Systems

- Concentrated solar power (CSP): Uses large mirrors to concentrate sunlight onto a central receiver, heating a fluid to high temperatures.
- Solar water heating: Solar collectors heat water for domestic or industrial use.

Advantages of Solar Energy

- Abundant resource: Solar energy is freely available in most parts of the world.
- Clean and sustainable: Neither greenhouse gas emissions nor air pollution are caused by solar power.
- Decentralized: Solar systems can be installed at various scales, from small residential to large-scale utility-scale plants.
- Economic benefits: It can create jobs and stimulate local economies.

Challenges and Considerations

- Intermittency: Sunlight is a necessary but erratic component of solar power generation, particularly in overcast or twilight conditions.
- Initial investment: The upfront costs of installing solar systems can be substantial.

- Storage requirements: Batteries and other energy storage devices are essential for off-grid systems and storing extra energy during peak generation.
- Grid integration: Integrating large-scale solar power plants into existing electricity grids requires careful planning and management.

Despite these obstacles, the use of solar energy has grown significantly in recent years thanks to technological developments, declining costs, and increasing government support. Solar power is positioned to be a prominent player in the global changeover to clean energy as it becomes more cost-effective and efficient. Table 4 below shows the international capacity and production of solar power.

Table 4: Global Solar Energy Capacity (MW) and Production (GWh)

Year	Global Capacity (MW)	Global Production (GWh)
2014	179639	192602
2015	228081	252269
2016	300146	324797
2017	395854	437515
2018	491988	560036
2019	595027	689902
2020	726229	835685
2021	870643	1030571
2022	1070851	1294481
2023	1418016	

Source: Renewable Energy Statistics 2024 from IRENA (International Renewable Energy Agency)

The cost of solar PV-based power dropped by 13% in 2018, and according to Carbon Tracker, 72% of coal-based power is predicted to become globally unprofitable by 2040 (Folk, 2021). According to the IEA report, solar energy is expected to contribute 60% of the growth in renewable energy due to its accessibility (Folk, 2021). In the past six years, solar energy growth has more than doubled. Costs for solar power are predicted to fall by 15% to 35% in 2024, which will spur further expansion in the second half of the decade (Folk, 2021). Spain is the world's leading solar energy producer, accounting for 75% of global concentrated solar power production.

The United Arab Emirates is home to Earth's largest solar power plant. The 1.17 GW of electricity produced by the Noor Abu Dhabi solar project could provide power to ninety thousand people (Earth.org, Mar 10, 2021). Its yearly carbon footprint will be reduced by one million metric tonnes,

which is the same as taking two hundred thousand cars off the road. This indicates that, despite its continued reliance on oil, the United Arab Emirates is making headway in the fight against climate change.

Bio-Energy

Bioenergy is a renewable energy source from organic materials, or biomass that were recently alive. It can create heat, electricity, transportation fuels, and other products.

Types of Bioenergy

- Biomass: The organic material used to produce bioenergy. It can be classified into:
- Solid biomass: Wood, agricultural residues, and municipal solid waste.
- Liquid biofuels: Ethanol, biodiesel, and bioethanol.
- Gaseous biofuels: Biogas (produced through anaerobic digestion of organic matter).
- Biopower: The electricity generation from biomass through combustion, gasification, or anaerobic digestion.
- Bioheat: Using biomass to produce heat for heating buildings or industrial processes.
- Biofuels: Biodiesel and ethanol are examples of liquid fuels made from biomass that can be combined with fossil fuels or utilised as alternatives in transportation.

Technologies for Bioenergy Conversion

- Combustion is the direct burning of biomass to generate energy and heat.
- Gasification is turning biomass into a gas, such as syngas, electricity, or liquid fuels can be produced.
- Anaerobic digestion breaks down organic matter in the absence of oxygen to create biogas, a mixture of methane and carbon dioxide.

Advantages of Bioenergy

- Renewable resource: Biomass can be continuously replenished.
- Reduced greenhouse gas emissions: Biomass derived from sustainable sources will help reduce greenhouse gas emissions compared to fossil fuels.
- Energy security: It can reduce dependency on fossil fuels, improving energy security.
- Economic benefits: Local economies can be boosted, and jobs can be created with bioenergy.

Challenges and Considerations

- Competition with food production: Food production may face competition from producing bioenergy from agricultural residues.

- Environmental impacts: The production and use of bioenergy may have environmental effects such as altered land use, contaminated water, and air pollution.
- Efficiency and cost: The efficiency and cost-effectiveness of bioenergy technologies can vary based on the type of biomass used and the conversion process.

To meet these challenges, sustainable bioenergy practices that maximise benefits and minimise adverse environmental effects are crucial. In the shift to clean energy, bioenergy can be valuable if its biomass source, conversion methods, and overall sustainability are carefully considered.

Table 5: Global Bioenergy Capacity (MW) and Production (GWh)

Year	Global Capacity (MW)	Global Production (GWh)
2014	90101	428096
2015	96110	455088
2016	104874	469808
2017	110589	492012
2018	117821	515837
2019	124098	545168
2020	132017	568554
2021	138338	609546
2022	144286	618916
2023	148840	

Source: Renewable Energy Statistics 2024 from IRENA (International Renewable Energy Agency)

Geothermal

Geothermal energy is a clean energy source derived from the heat trapped in the Earth's crust. The remaining heat from the Earth's formation and the decay of radioactive elements generate this heat. Geothermal energy can create heat or electricity for a variety of applications.

Types of Geothermal Energy

- By boring deep wells into heated rock formations, conventional geothermal energy produces steam or hot water that powers turbines to produce electricity.
- Enhanced geothermal systems (EGS) generate electricity and extract heat by injecting water into hot rock formations to create man-made geothermal reservoirs.

- Ground-source heat pumps (GSHPs): These systems use the Earth's relatively constant temperature to generate energy for heating or cooling buildings. In the winter, they take heat out of the earth, and in the summer, they return it to it.

Advantages of Geothermal Energy

- Reliability: Geothermal energy is unaffected by daylight fluctuations or weather, making it a baseload and dependable energy source.
- Minimal environmental impact: Geothermal power plants' ecological footprint and greenhouse gas emissions are negligible.
- Constant availability: Geothermal energy is a dependable source of energy that can be accessed round-the-clock.
- Versatile: Geothermal energy is a resource that can be used for heating, cooling, and electricity generation.

Challenges and Considerations

- Geographic location: Areas with high geothermal gradients, such as those affected by recent tectonic activity or volcanic eruptions, are best suited for geothermal energy.
- Investment: The initial outlay for developing geothermal power plants may be substantial.
- Environmental impacts: While geothermal energy poses fewer environmental risks than fossil fuels, it can result in specific side effects, such as water pollution and induced seismicity.
- Technological advancements: Geothermal energy technologies require more R&D to increase efficiency and lower costs.

As technology advances and costs decrease, geothermal energy is expected to play a growing role in meeting global energy needs while reducing greenhouse gas emissions. Table 6 depicts the international capacity and production of geothermal energy.

Table 6: Global Geothermal Energy Capacity (MW) and Production (GWh)

Year	Global Capacity (MW)	Global Production (GWh)
2014	11249	77344
2015	11847	81229
2016	12173	83241
2017	12754	87052
2018	13157	89464
2019	13824	92001

2020	14157	95445
2021	14432	94654
2022	14653	96878
2023	15026	

Source: Renewable Energy Statistics 2024 from IRENA (International Renewable Energy Agency)

With 87% of its natural hot water needs coming from underground sources and 26.5% of its electricity from geothermal energy, Iceland is among the world's leading geothermal power producers.

Conclusion

According to the International Energy Agency (IEA) and as published in Renewables, 2023, renewable energy will be the most extensive channel for global electricity generation between 2025 and 2027 (Gini, 2022). The rise of renewable energy has led to several positive outcomes, including lower CO2 emissions and a rapid growth of renewable energy with the simultaneous decline of fossil fuels.

- ***Lower CO2 emissions***

  The CO2 intensity of global power generation reached a record low in 2023, 12% lower than its peak in 2007.

- ***A turning point***

  The rapid growth of renewable energy has likely brought the world to a turning point when fossil fuel generation declines globally.

  Despite the encouraging growth of these fastest-growing renewable energy sources, more work is still needed. To have the best chance of achieving the goals outlined in the Paris Agreement, governments everywhere must switch to utilising renewable energy sources to power their nations.

  According to UNEP Emissions Gap Report 2023, the top five emitters—China, the United States, India, the European Union, and the Russian Federation—were responsible for nearly 60% of greenhouse gas emissions in 2021. Approximately 76% of the world's greenhouse gas emissions are attributable to the Group of 20 countries, which includes Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the UK, the US, and the European Union. In comparison, 3.8% of global emissions come from the least developed nations.

Adopted in 2015, the Paris Agreement is an international, legally binding agreement that aims to lower greenhouse gas emissions to combat climate change. The primary goals of the agreement are:

- Limit global temperature increase: We should aim to keep the rise in the average global temperature to 1.5°C over pre-industrial levels and well below 2°C.
- Reduce greenhouse gas emissions: As soon as feasible, reach a global peak in greenhouse gas emission levels and keep them below what the earth, trees, and oceans can naturally absorb between 2050 and 2100.
- Provide climate finance: Assist under-developed countries in transitioning to renewable energy sources and adapting to climate change.
- Review contributions: Evaluate every five years how much each country has contributed to reducing emissions and ensure that each new contribution is more ambitious than the last.
- Enhance capacity: Bolster developing nations' ability to implement the agreement.

The Paris Agreement established a groundwork for countries to give their Nationally Determined Contributions (NDCs), or national climate plans, to meet these objectives. These NDCs outline each nation's pledges to cut greenhouse gas emissions and prepare for climate change. Countries must also update their NDCs regularly to reflect their growing ambition.

Although the Paris Agreement is a historic step forward for global climate cooperation, much work will be done worldwide to meet its lofty objectives. Collaboration among nations can facilitate shifting to a low-carbon economy and building a more sustainable future for future generations.

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