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Chapter 11. Climate Change and the Environment: With Special Sections on Energy and Water

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Introduction

Climate change is a global phenomenon accelerating rapidly and causing environmental as well as socioeconomic consequences, leading to water and energy insecurity all over the world (Maas et al., 2012). In recent times, most continents have been facing water scarcity; it is predicted that by 2030, nearly half of the world's population will experience severe water stress conditions, likely impacting energy security (Halstead et al., 2014). Unfortunately, while climate change will continue to significantly impact the water and energy sectors, most of our communities have little or no resilience to climate change implications.

Climate extreme events are made worse by the fact that the average global surface temperature has already risen by about 1.1 degree Celsius (°C) from the pre-industrial period of 1850–1900. Extreme weather events such as heat waves, wildfires, droughts, flooding, and severe storms are expected to increase in frequency and cause climate-related disasters if the global mean temperature rises by 4°C over the next century (IPCC

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reports 2007, 2014, 2019, 2021; Berstein et al., 2008; Sharma and Rabindranath, 2019; Legg, 2021). According to recent studies, global warming is predicted to reach 4°C to 6°C by 2100 if greenhouse gas (GHG) emissions continue on their current projected trajectory. This is an unprecedented shift with a high likelihood of larger and irreversible natural environmental changes and damages that have not been seen in millions of years and that threaten to destroy the natural ecosystem that currently exists. Although 189 countries have already pledged to cut GHG emissions by 2030, global CO_2 emissions still continue to increase. In 2021, 36.3 billion metric tons were recorded in the atmosphere, the highest level in history. Climate change will affect the developmental progress and growth made over the past decades. It will also increase migrations on a large scale which will lead to unstable conditions, civil social unrest, and further degradation of the environment. To limit global warming to 1.5°C above pre-industrial levels, emissions must be reduced by almost half by 2030, which is just 6 years away to reach the targets. It requires a paradigm shift towards climate-resilient progress while outlining a clear path to achieve the target of net-zero emissions. For a sustainable future, preventive actions and workable solutions are urgently required to avert disastrous outcomes.

Environmental Extremes and Climate Change

1. *Severe Heat Events*: With the current rise of 1.2°C, the likelihood of extreme heat waves occurring is almost five times higher. The frequency will increase to 14 times if global warming hits 2°C. Heat waves are becoming more intense; if the world temperature rises by 2°C, the hottest temperatures will rise by over 3°C above those of earlier heat waves, making matters worse. The climate of India is already warming, with temperatures rising in certain areas. It is

predicted that hot weather will become more frequent and unexpected in the years to come. If temperatures increase by 4°C beyond their current levels, the west coast and southern India are expected to move into new, high-temperature climatic clusters in the coming days.

2. *Sea Level Increase*: As sea levels rise, high tide floods become more severe, and storm surges occur all across the world. Even if global warming stays below 2°C, sea levels are expected to increase by 2 to 3 metres by 2300 and by 5 to 7 metres with accelerated global warming. Expecting that global warming stays below 2°C, by 2100, catastrophic coastal floods will occur once every 100 years, leading to the inundation of more than half of the world's coastlines at least once a year. Sea level rise may be substantially higher in the Indian subcontinent than in higher latitudes because of its closeness to the equator. Saltwater intrusion in coastal areas due to rising sea levels and frequent storm surges will impact agriculture and other sectors and degrade groundwater quality, all of which will ultimately negatively impact human survival.
3. *Widespread Flooding*: The likelihood of both floods and droughts occurring is increasing due to climate change. Warmer air can result in extreme rains, but more intensive evaporation will cause more droughts. The frequency of intense downpours has started to rise by roughly 30% on average. India is experiencing unexpected droughts and floods in several places.
4. *Changing Rainfall Patterns*: In recent years, there has also been an increase in the frequency of periods of high rainfall. If the average global temperature rises by 2°C, the summer monsoons in our country will become considerably more unpredictable. By the end of this century, a 4°C increase in temperature might make an extraordinarily rainy monsoon, which usually happens only once every 100 years, possible every 10 years.
5. *Severe Droughts*: Severe droughts will occur two to three times

more frequently than they do now if global temperatures rise by 2°C above the preindustrial norm. Certain regions, including Jharkhand, Orissa, Chhattisgarh, and Northwest India, are more likely to experience droughts. By the 2040s, excessive heat is predicted to cause crop yields to drop dramatically, which might impact the country's economy and generate food insecurity.

6. *Weather Whiplash*: In addition to making extreme weather events more severe and frequent, climate change is also disrupting natural phenomena and causing "weather whiplash"—wild fluctuations between destructive floods in 1 year and severe droughts in another year caused by dry and wet extremes (IPCC, 2021).
7. *Ground Water*: Rain-fed agriculture accounts for more than 60% of India's agricultural output, and groundwater is crucial to many areas of the country. Even in the absence of climate change, 15% of India's groundwater supplies are often overexploited. The implications of climate change are making the issue worse. Climate change is estimated to have a significant impact on groundwater supplies.
8. *Glacier Melt*: The stability of the Himalayas is predicted to be jeopardised by a warming of 2.5°C, which will cause the glaciers to melt. Additionally, the snow cover and dependability of northern India's rivers, which are predominantly fed by glaciers, especially the Indus and the Brahmaputra, will be lost. It is anticipated that after the snow melts in the spring, the rivers will have higher flows, which will then decline in the late spring and summer. Rivers swell as a result of the abrupt snowmelt. Millions of people's lives and the food produced in the basins could be significantly impacted by the shifting flows of the Indus, Ganges, and Brahmaputra rivers, which could also have a significant impact on irrigation and hydropower supplies. These changes will harm the agriculture sector.
9. *Agriculture and Food Security*: The yields of staple crops like wheat and rice are severely impacted by high temperatures

above 34°C in northern and southern India. Seasonal water scarcity, salt intrusion, rising temperatures, and seawater intrusion are risks to the nation's food security.

10. *Water and Climate Change*: There is an inseparable connection between water and climate change. Water is essential for the delivery of energy, and vice versa. In the coming years, the interdependency between energy and water will grow, with important implications for the security of both. Water around the world is impacted by climate change in several intricate ways. Climate change affects rainfall and tampers with the hydrological cycle, resulting in erratic patterns of precipitation, glacier melting, sea level rise, floods, and droughts (UN Water). Due to the disruption of precipitation patterns and the water cycle caused by rising temperatures, climate change is having a significant impact on the availability of water and causing water-related risks such as floods and droughts (UNICEF).
11. *Energy Security*: Climate-related effects are having an impact on India's thermal and hydropower output as both require sufficient water resources to develop and operate efficiently. Unpredictable river flows can pose serious challenges for hydropower facilities, while thermal power plants need a consistent supply of cool, fresh water to maintain optimal cooling system efficiency. The production of thermal power will be severely hampered by the lack of water and temperature increases. Recently, in October 2023, a glacial lake outburst flood (GLOF) in Sikkim state led to the collapse of the Teesta Hydroelectric Dam and the power plant, besides causing death of more than 100 people and affecting thousands of others. The commercial, residential, industrial, and other sectors will all be disrupted by the energy sector's instability.
12. *Health*: Since climate change has an impact on the agriculture industry, the main health effects linked to it include malnutrition and illnesses like stunting in children. Communities that are less fortunate are probably going to be

most negatively impacted. As a result of the heavy rains, consequent flooding, and water stagnation, vector-borne illnesses would spread. Child mortality is seriously threatened by diarrhoeal infections, malaria, and other vector-borne illnesses. High temperatures and heat waves are predicted to cause a high death rate as well as other illnesses in the coming years.

13. *Migration and Conflict*: In quest of food and a means of subsistence, people migrate from degraded or disaster-affected areas to other countries and regions in South Asia. These migrations in large numbers lead to a significant impact on agriculture and livelihoods due to the increased number of climate refugees and civil unrest.

Organisations and Policies

To prevent and stabilise the GHG concentrations in the atmosphere, it was decided to adopt the United Nations Framework Convention on Climate Change (UNFCCC). Over the past 20 years, GHG emission concentrations have reached historic highs and are still far from levelling down. The atmospheric concentration of carbon dioxide (CO_2), the main GHG, increased from 358 parts per million (ppm) in 1994 to 412 ppm in 2018 and 424 ppm in 2023. The global mean temperature has likewise gradually increased, rising from 0.25°C above the pre-industrial era in the early 1990s to 1.1°C in 2018. The temperature is expected to increase by 1.5°C over the next few years. As a precaution against the catastrophic consequences of climate change, the Intergovernmental Panel on Climate Change (IPCC) has released a declaration.

Almost every country in the world, including wealthy ones that have pledged to reduce emissions, is seeing an increase in emissions. It is evident from the IPCC's special report on the 1.5°C temperature rise that the Paris Agreement cannot accept warming to even 2°C. Between 2030 and 2052, the GHG effect is

predicted to reach 1.5°C. To achieve net zero by 2050, limiting global warming to 1.5°C is crucial, and to do so, CO_2 emissions must be cut by 45% from 2010 levels by 2030.

UNFCCC Enhanced Implementation

India had a strong desire to cooperate internationally under the United Nations Framework Convention on Climate Change (UNFCCC). In general, future global climate change collaborations will focus on the following goals:

- Implementation of appropriate adaptation and mitigation strategies to reduce the adverse effects of climate change.
- Make sure that all activities and measures are equitable and fair.
- Make sure that technology is accessible on reasonable terms.
- Creation of a worldwide framework for climate change action, based on the Paris Agreement.

To combat climate change, the developed countries that are responsible for the major emissions of GHGs must take the lead in climate actions and also extend support to developing countries by providing financial, technological, and capacity-building support on topics such as mitigation and adaptation measures in accordance with the Paris Agreement. Development priorities like the eradication of poverty, food security, energy access, etc. are being suggested in the multilateral framework post-2020.

With climate change being recognised as a global challenge, India will continue to engage actively in multilateral negotiations in the UNFCCC and also focus on climate resilience at the same time.

Sustainable Development Goals

Despite the global adoption of the 17 UN Sustainable Development Goals (SDGs) and 169 associated targets, each country is liberal in framing indicators that are appropriate for sustainable development based on the country's needs. The NITI Aayog has been delegated the role of supervising the implementation of SDGs at the central level and has carried out a detailed mapping of the 17 goals with nodal Central Ministries under the Government of India for the implementation of SDGs. The Ministry of Statistics and Programme Implementation (MoSPI), Government of India, is developing the related national indicators.

UN SDG 13: Climate Action

The main objective of Goal 13 of the SDGs are:

- Strengthening each country's capacity to adapt and be resilient to natural catastrophes and climate-related risks is essential.
- Climate change measures should be incorporated into national planning, policies, and programmes.
- Improvements should be made in education, awareness-building, and institutional and human capacity for early warning, adaptation, mitigation, and impact reduction.
- The commitment made by wealthy countries to pool US$100 billion annually by 2020 from all sources to address the needs of developing countries and operationalise the Green Climate Fund through its capitalisation will be implemented by the UNFCCC.
- Developing the ability to support improved planning and control of climate change for developing nations, with a focus on underserved communities.

Figure1: UN SDG 13: Climate Action

Andhra Pradesh State Action Plan on Climate Change

The aim of inclusiveness and sustainable state development is to shield society's most vulnerable groups from the negative consequences of climate change. The main goals are as follows:

- Enhanced environmental sustainability;
- Establish a framework for taking steps that will mitigate and adapt to climate change while promoting growth and development;
- Determine funding sources and give the state's adaptation and mitigation strategies top priority;
- Engineering new and innovative policies and mechanisms to promote sustainable development.

Effects of Climate Change on Water Resources

Climate change has substantial consequences on the global hydrological cycle, influencing patterns of precipitation, evaporation, and water storage. These changes have cascading effects on ecosystems, agriculture, water management, human health, energy sector, and ultimately the economy on a large scale.

1. *Changes in Precipitation Patterns*: One of the most significant implications of climate change is the regional variations in rainfall patterns, causing extreme weather events, like storms, cyclones, and heavy rainfall, to become common across the country. These calamities lead to flooding, including urban flooding, soil erosion, and damage to ecosystems and human settlements. For example, in mid-latitude regions, high precipitation can lead to more frequent, recurring, and severe flooding, while subtropical areas may experience prolonged dry spells and droughts, accelerating water scarcity.
2. *Increased Evaporation Rates*: Rising global temperatures lead to higher evaporation rates from water bodies and soil. This increase in evaporation reduces water availability, particularly in regions already experiencing water stress, leading to decreased crop yields and food security concerns. High temperatures also lead to the accumulation of more water vapour in the atmosphere, which can enhance the greenhouse effect, causing a feedback loop that further increases global mean temperatures.
3. *Changes in River Flows and Freshwater Availability*: Climate change causes variations in rainfall and snowmelt patterns that can lead to major changes in river flows. These changes affect existing ecosystems, water usage, and agricultural practices. Over-extraction of groundwater can deplete aquifers, resulting in severe long-term implications. Sometimes this over-exploitation of the groundwater table

leads to salinity intrusion. This over-reliance on groundwater can intensify water scarcity, particularly in areas where surface water supplies are becoming more unpredictable and scarce.

4. *Impacts on Water Quality*: Climate change has adverse effects on water quality. Increased runoff from heavy rains can carry pollutants into rivers, lakes, and other water bodies, degrading water quality and disrupting aquatic ecosystems. Higher temperatures can favour algal bloom formation, which can produce toxins which are harmful to aquatic life and humans.
5. *Ecosystem Changes*: Ecosystems are particularly vulnerable to changes in the water and weather cycles. The wetlands, which are vital for biodiversity, water purification, and flood control, can be severely impacted by changes in water availability. Reduced water flow can degrade these habitats and ecological niches, causing loss of biodiversity and hindering ecosystem services, which causes disturbance in ecosystem dynamics and equilibrium.

Effects of Climate Change on Energy Resources

1. *Coal and Lignite*: India has the richest deposits of coal in the world. The total estimated reserves of coal as of April 1,2022, were 361.41 billion tonnes. The top two states with the highest coal reserves in India are Odisha and Jharkhand, having approximately 69% of the total coal reserves in the country. Lignite reserves, primarily found in Tamil Nadu, stood at 46.20 billion tonnes as of April 2022. The extraction and use of lignite may be significantly influenced by changes in weather patterns, affecting both the supply chain and the efficiency of lignite-based power generation.
2. *Natural Gas and Crude Oil*: In 2022, India's projected crude oil

reserves were 651.77 million tonnes. The western offshore has the largest percentage of crude oil reserves (33%), followed by Assam (23%). In 2022, natural gas reserves were predicted to be 1,138.67 billion cubic metres. The western offshore had the largest natural gas reserves (29.6%), followed by the eastern offshore (23.6%). Climate change can badly affect offshore drilling operations through increased storm frequency and severity, potentially disrupting supply chains and increasing operational risks.

3. *Solar and Wind Power*: India's vast solar potential, estimated at 748,990 MW, could be affected by increased temperatures reducing the efficiency of solar panels. However, areas with increased sunlight due to climate change might benefit from enhanced solar energy generation.
4. *Wind Power*: With a potential of 695,509 MW at a 120 m hub height, wind power in India could be influenced by changing wind patterns. Regions may experience variations in wind speeds, affecting the reliability and feasibility of wind farm operations.
5. *Small-Hydro, Biomass, and Waste-to-Energy*: Small hydro power is estimated with a potential of 21,134 MW; however, small hydro projects can face challenges from changes in river flows and an increased frequency of droughts.
6. *Biomass Power*: With a potential of 17,538 MW, biomass energy depends on agricultural residues, which could be impacted by changes in crop yields due to climate variations. Livestock is also affected by climate extremities.
7. *Waste-to-Energy*: This sector, with a potential of 2,556 MW, may see fluctuations in waste generation patterns due to demographics and lifestyle changes induced by climate change (Ministry of Statistics and Programme Implementation, Energy Statistics, 2023).

Renewable Energy Situation

More than 150 GW of renewable energy sources have been established, and as of May 2024, the total installed capacity of renewable energy sources, including major hydropower, is 193.57 GW. The installed capacity for renewables is as follows:

- Solar power: 84.27 GW;
- Large hydro: 46.92 GW;
- Wind power: 46.42 GW;
- Biomass and co-generation: 10.35 GW;
- Small hydro power: 5 GW;
- Waste to energy: 0.59 GW.

By 2030, India envisions producing 5 million tons of renewable hydrogen. This will be made possible by 125 GW of renewable energy capacity. Fifty solar farms with a combined capacity of 37.49 GW have been approved in India. Likewise, India is targeting to produce 30 GW of offshore wind energy, and possible locations have been found for this.

Union Budget Highlights

2023–2024 Highlights

- One of the thematic areas of the Saptarishi (seven priorities) is green growth;
- An additional US$36 million has been budgeted for the National Hydrogen Mission, which has been allocated US$2.4 billion to generate 5 MMT by 2030;
- The viability gap funding for 4 GWh battery energy storage systems;
- Support for interstate transmission system infrastructure for 13 GW renewable energy for Ladakh.

2024–2025 Highlights

- Climate finance given priority in the union budget for 2024–2025;
- The PM-Surya Ghar Muft Bijli Yojana project, which was introduced in February 2024 with an expenditure of ₹75,000 crores, has been allotted ₹6,250 crores, while the union government-sponsored solar power (grid) scheme has been given precedence with an allocation of ₹10,000 crores.

Effects of Climate Change on Energy Management

Climate change has major impacts on energy resources, affecting both the demand and supply of energy. These effects vary by region and type of energy source.

Effects on Energy Demand

Increased need for energy is one of the most direct impacts of climate change implications. One of the most direct impacts of climate change on energy demand is the increased need for cooling, especially in urban areas. As global temperatures continue to rise, the demand for air conditioning and other cooling systems increases proportionally, mainly during the hotter summer months. This surge in electricity consumption can exert stress on existing power grids, particularly in urban centres, where the phenomenon of urban heat islands is predominant and causes cities to be significantly warmer than their rural surroundings. This localised warming and microclimatic changes intensify the requirement for cooling, leading to high energy demand.

Effects on Energy Supply

1. *Hydropower*: Changes in precipitation patterns, glacial melt, and the frequency of droughts increasingly affect hydropower generation. Regions may experience either reduced or increased water flow, causing unstable and interrupted energy generation.
2. *Wind Power*: Shifting wind patterns can affect the reliability and geographical suitability of wind farms. Some areas may benefit from increased wind speeds, while others might see a decline, complicating the planning and development of wind energy projects.
3. *Thermal Power Plants*: Thermal power plants, including those powered by coal, natural gas, and nuclear energy, face severe problems in demand and supply, causing interruptions in supply chain management.
4. *Cooling Water Shortages*: These plants require large amounts of water for cooling purposes. Reduced water availability and higher water temperatures can affect plant operations, particularly during low water availability and peak temperatures.
5. *Bioenergy*: Variations in temperature, rainfall patterns, and the incidence of extreme weather events can impact the availability and cost of biomass feed stocks. Droughts and floods can devastate crops and livestock, while shifts in growing seasons can affect yields, posing challenges for bioenergy production and eventually affecting GHG emissions.

Infrastructure and Reliability

1. *Extreme Weather Events*: This can cause damage to Infrastructure and urban municipal services. Storms, cyclones, and flooding can damage critical energy infrastructure, such as power lines, substations, and

pipelines, leading to power outages and higher maintenance costs. These disruptions obstruct the civilian's day to day life causing economic and human loss.
2. *Resilience Challenges*: Building resilience in energy systems is important to withstand extreme weather events. This involves high investments in infrastructure hardening and other adaptation measures to ensure energy reliability even during climate related events.
3. *Sea Level Rise*: Rising sea levels can cause a substantial threat to coastal energy facilities, which are essential components of the energy supply chain. The Power plants, refineries, and liquefied natural gas (LNG) terminals located in coastal areas are at severe risk of flooding and erosion due to rising sea levels and severe storm surges. Protecting these facilities requires robust planning and investments in adaptive and mitigation measures are very needful, because already climate change implications are clearly visible in some regions.

Economic and Policy Implications

Energy Prices and Availability

Climate change introduces unpredictability in energy markets, affecting both prices and availability.

1. *Volatility*: Climate change-induced disruptions in energy supply and shifts in demand patterns can lead to increased volatility in energy prices. This volatility can result in an unstable economy and affect the affordability of energy for consumers.
2. *Investment Needs*: Adapting energy systems to climate change demands substantial investments in infrastructure, technology, and resilience measures to ensure a reliable

energy supply at a large scale.

Policy and Regulation

Strategic policies and regulatory frameworks are vital for addressing the impacts of climate change on energy resources, and some proactive measures are also needed in policymaking and regulations.

1. *Climate Policies*: Governments may implement policies aimed at reducing GHG emissions, such as carbon pricing, carbon credits, subsidies for renewable energy, and regulations on fossil fuel use. Climate finance can also be emphasised. These policies affect energy markets and influence investment decisions towards more sustainable options. These policies should address climate resilience.
2. *Adaptation Strategies*: Developing and implementing adaptation strategies is the need of the hour for enriching the strength of the existing energy systems. Focus can be given on "Green Energy." This includes diversifying energy sources, strengthening grid resilience, and capitalising on renewable energy technologies to mitigate the impacts of climate change. Strengthening and capacitating communities at grassroots levels are also important.

Attempts to Address Climate Change

In accordance with the Paris Agreement, India made its Nationally Determined Contribution (NDC) on a "best effort basis," accounting for the country's growth-related climate needs. By 2030, India aims to generate 40% of its installed electric power capacity from non-fossil fuels, reduce its GDP emission intensity by 33% to 35% below 2005 levels, and add a carbon sink of 2.5 to 3 billion tonnes of carbon dioxide

equivalent through increased forest and tree cover, according to its NDC. India has made progress towards achieving the Sustainable Development Goals for environmental protection by funding a number of projects in line with its NDC, including the Swachh Bharat Mission, National Smart Grid Mission, and Atal Mission for Rejuvenation and Urban Transformation (AMRUT). Notwithstanding economic constraints, India has placed a high priority on energy-efficiency improvements, resilient urban infrastructure—both green and blue—and clean and efficient energy systems (OSOWOG and floating solar panels), even to endure climate-related disasters.

1. *One Sun, One World, One Grid*: India highlighted the phrase "One Sun, One World, One Grid" (OSOWOG) to unite the world to gather solar power around the clock, and at the United Nations Climate Change Conference in Glasgow (COP 26) in 2021, the country committed to becoming net zero emitters of carbon by 2070 (MNRE, 2020). India is prepared to use this page to establish an ecosystem of linked renewable energy sources, a programme that is simple to spread for the good of all and long-term sustainability at all levels. Connecting solar energy sources globally, especially distributed systems like solar rooftop systems, is the main objective of this endeavour (IPCC report 2022 and ISA report 2021; Sharma and Rabindranath, 2019; Legg, 2021).
2. *Mission LiFE (Life Style for Environment) campaign*: It is a campaign initiated by the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, in 2021, with the objective to promote and encourage a sustainable and environmentally friendly way of living. This mission emphasises that people should embrace conservative and sustainable lifestyles. At COP 27, India highlighted concept of Mission "LiFE" and discussed the best practices for climate action. At COP 28, India launched the Green Credit Initiative with the aim of creating a participatory global exchange platform for innovative environmental programmes and instruments for climate

action, concentrating mostly on reforestation and water conservation.

3. *Decarbonising and the Built Environment*: This is a novel idea that is crucial for the globe to improve natural carbon sinks and lower GHG emissions in order to slow the rise in global temperatures (IPCC report 2018; Ghosh and Chawla, 2021; Pathak et al., 2022). A 2018 survey found that 40% of global GHG emissions are caused by the built environment (International Energy Agency and UN Environment Programme, 2018). By 2050, if nothing is done, 40%–50% of global GHG emissions will result in an intensified greenhouse effect. Buildings are essential to reaching the climate goals of the Paris Agreement and the shift to a low-carbon energy system. Nature-based solutions are given priority to handle the issue. "Green Building" is a new emerging concept in urban planning which helps in energy and water conservation, ultimately mitigating climate change impacts.
4. *The Oceans as Carbon Sink*: The IPCC estimates that 89% of global CO_2 emissions are caused by industries and fossil fuels. The world's seas operate as significant buffers and sinks against the effects of these CO_2 emissions in the atmosphere. They are sinks of atmospheric CO_2, which take up a substantial quantity of atmospheric carbon dioxide (Ibánhez et al., 2016). A carbon sink is an artificial or natural reservoir that absorbs and stores carbon from the atmosphere through biological and physical processes (Roobaert et al., 2019). When carbon dioxide is removed from ocean surface waters by photosynthesis, calcium carbonate is produced and precipitated, changing the balance between carbon dioxide, bicarbonate, and carbonate and thus creating an artificial carbon dioxide sink.

Future Prospects

To attain sustainable development in the mitigation of fossil fuel usage for a clean and green environment, one has to focus on three broad categories of action: (a) reducing emissions, (b) adapting to climate change impacts, and (c) financing advanced research and development. Inventing or discovering workable options for climate-smart agriculture, promoting innovative technologies for the generation of green hydrogen, and determining to reduce the usage of fossil fuels are essential. Nature-based solutions (NBS) can be encouraged while addressing climate actions. However, without state-of-the-art scientific and technical advancements and solutions, achieving these transformative consequences will be difficult in order to enhance adaptability and mitigation.

Understanding how scientific capacity may be used to combat climate change and improve cooperation amongst innovation groups in order to streamline industry and research in both developed and developing countries is crucial (Metz, 2001).

Research Needs

There is an immediate need to increase in-depth research efforts on the following:

1. The actions proposed in light of the IPCC assessments, the Kyoto Protocol, and the UN sustainable objectives are: (i) increasing energy efficiency; (ii) increasing renewable energy; (iii) preserving and improving carbon capture sinks; and (iv) encouraging sustainable agricultural practices.
2. Transitioning to a low-carbon energy system and buildings is necessary to meet the climate targets outlined in the Paris Agreement. Under the 1.5°C scenario, they are still insufficient to achieve the decarbonisation goals, nevertheless. Significant carbon reductions within the

anticipated range of the 2°C scenario are the outcome of decarbonisation scenarios.
3. Determine the extent of climate change vulnerability of locally accessible water resources, and then prioritise adaptation strategies tailored to the local context by identifying the primary risks and vulnerabilities.
4. Evaluate the efficacy and efficiency of various coping strategies or adaptation techniques that may reduce the vulnerability of local natural resources.

Green Initiatives

1. National Action Plan on Climate Change (NAPCC): To combat the implications of climate change, the Government of India has been taking proactive measures and initiatives for climate action. The NAPCC, which was launched in June 2008, consists of eight national missions: National Mission for Enhanced Energy Efficiency, National Water Mission, Jawaharlal Nehru National Solar Mission, Himalayan Ecosystem's Sustainability, Sustainable Habitat Mission, Sustainable Agriculture Mission, National Mission for a Green India, and Strategic Knowledge for Climate Change Mission. Every mission functions under a ministry, which has a leader in charge of execution, manages budgetary allotments, and sets priorities that are both actionable and implementable.
2. National Green Corridor Programme: The Green Energy Corridor Project is designed with the objective of harmonising the power produced from renewable sources, like solar and wind, with conventional power stations in the grid. The National Green Corridor Programme (NGCP) was launched by the Government of India to leverage the fluctuations and variability in the renewable power supply. This will improve the intra-state transmission infrastructure. This scheme is to be funded by 20% from state government

equity, 40% from the National Clean Energy and Environment Fund (NCEEF), and 40% from soft loan.

3. R&D for Clean Coal Technologies: In 2016, the Cabinet Committee on Economic Affairs has approved the R&D project for the development of advanced ultra-supercritical (USC) an innovative and advanced technology for thermal power plants on a mission mode, with an estimated cost of US$15.54 billion.
4. National Green Highways Mission: To develop green corridors along national highways for a sustainable environment and inclusive growth, in 2015 the Ministry of Road Transport and Highways (MoRTH) initiated the Green Highways (Plantations, Beautification, and Maintenance) Policy. Under this initiative, the development of green corridors like avenue and median plantations has been proposed along developed and upcoming national highways.
5. Accelerated Hybrid and Electric Vehicle Manufacturing and Adoption (FAME India): The government launched this programme in 2017 to incentivise people to buy eco-friendly cars. Up to US$0.14 million for cars and up to US$29,000 for bikes were offered. The programme was in pilot mode until February 2017. The Department of Heavy Industry has extended demand incentives of US$1.278 billion for the purchase of 111,897 electric/hybrid vehicles as part of the National Electric Mobility Mission Plan for 2020.
6. National Clean Energy and Environment Fund (NCEEF): The purpose of the National Clean Energy and Environment Fund (NCEEF) is to support and fund renewable energy research and projects. The Finance Bill 2010–2011 established the National Clean Energy Fund (NCEF), which was renamed the National Clean Energy and Environment Fund (NCEEF) in 2017. In this context, the "polluter pays" principle was emphasised. The coal cess, collected at US$50 per tonne of coal from June 22, 2010, was raised to US$400 per tonne in the union budget for 2016–2017 and changed its name to "Clean Environment Cess."

7. National Mission for Sustainable Agriculture: Agriculture is crucial for India's economy and the livelihoods of the people, accounting for 21% of the national GDP, 11% of all exports, employing 56.4% of the labour population, and providing direct or indirect assistance to 600 million people. Four sectors essential to agriculture and related fields will be the focus of the proposed national mission: climate change adaptation, specifically risk management, dryland agriculture, access to information, and use of biotechnology for advancements to handle the challenges.

The Earth's climate is changing remarkably which has become a matter of concern, and it has emerged as one of the most complex issues at the global level. Carbon dioxide (CO_2) is the major pollutant that traps heat and remains in the atmosphere for thousands of years, leading to global warming. The three main approaches to address this issue are mitigation, adaptation, and resilience:

1. *Mitigation*: An intervention made by humans in order to reduce the GHG-emitting sources or enhance the sinks to absorb GHGs (Metz, 2001).
2. *Adaptation:* An adjustment made in natural or human systems to climate change or its effects, which decreases harm and explores advantageous opportunities (Metz, 2001).
3. *Resilience*: Mitigation and adaptation together refer to resilience. Community resilience is highly required in this current scenario.

Climate Change Adaptation (CCA) Actions

Adaptation to climate change is the most important and possible solution for the nation. Prioritising this, the Government of India placed prime importance on adaptation. Under the National Adaptation Fund, a central scheme worth US$3.50

billion for the years 2015–2016 and 2016–2017 was created. The adaptation activities that are not covered under any government schemes are given concrete support. The main objective of the fund is to reduce the adverse impact of climate change on sectors, states, and communities.

Surya Ghar Scheme: In order to increase the proportion of solar rooftop capacity and enable homes to produce their own electricity, the Indian government introduced the PM Surya Ghar: Muft Bijli Yojana on February 29, 2024. The outlay of the scheme is ₹75,021 crore and is going to be implemented for FY 2026–2027, expecting to provide benefits to over 1 crore (10 million) households in India. Moreover, 300 units of free power will be provided to households each month as part of the union government's plan. Additionally, the recipient will get financial support in the form of a subsidy to fit solar panels on their rooftops.

Conclusion

The natural phenomenon of climate change is being induced by human activities, causing a substantial threat to life on planet Earth at various levels. Increased GHG emissions have led to extreme weather patterns and rising sea levels, causing global warming to reach 1.5°C above pre-industrial levels which requires a reduction in emissions by almost half by 2030.

The effects of climate change are expected to rise in several regions of the country. Changes in precipitation will affect water resources planning and management in several ways, including the design of hydrological structures, flood and drought management, and urban planning and development. India's agrarian economy, which depends heavily on the monsoon and available water for agricultural production, is particularly vulnerable to the projected climate changes. India's agriculture and food security are at risk due to rising temperatures and lower rainfall. Climate-related impacts on water resources can

badly affect hydropower and thermal power generation, leading to water stress and increased water scarcity. Climate change is expected to pose major health impacts in India, especially on vulnerable communities, leading to an increase in malnutrition and other health disorders.

Therefore, it is essential to improve the assessment of climate change effects and to adapt technologies and proactive measures considering future scenarios. Existing water resource systems have major data collection gaps, including monitoring, processing, communication, dissemination, and storage networks, that are unable to meet the pressing challenges of a rapidly changing climate. Measures must be taken to ensure water resource and food security for future generations and also reduce the usage of fossil fuels, securing energy supply as well. Technology transfer can accelerate the modernisation process, and additional funds can assist the government in energy conservation. The concept of climate finance can be outlined in three layers of governance. At the same time, policies and frameworks for poverty alleviation must be given priority, considering the socio-economic aspects. The marginalised and vulnerable communities should be given priority as they are the worst sufferers of climate change.

Strategically designed climate change policies should be given utmost importance in sustainable development. A sustainable development path can reduce GHG emissions and reduce vulnerability to climate change. Hence, global mitigation efforts can facilitate sustainable development prospects in part by reducing the risk of adverse impacts on climate change. Mitigation can also provide co-benefits, such as improved health outcomes. Mainstreaming climate change mitigation is a key integral part of sustainable development. Socioeconomic development is given priority while considering climate actions.

The SDG 7 is to ensure access to affordable, reliable, sustainable, and modern energy for all around the globe. Priority is given to securing energy access because it is interconnected with various other socio-economic aspects such

as poverty alleviation, health, industrialisation, education, provision of communication infrastructure, and overall development of any nation.

India has declared her goal to achieve net zero emissions by 2070, with a target to transition to a net zero economy, balancing GHG emissions with their removal in a green and sustainable way for a better and more prosperous future.

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