India's coastline can be used to produce wind energy, which can then generate green hydrogen that can have a transformative effect on the nation. Offshore wind farms, North Sea.

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6. Innovating Technologies or Climate Change Solutions

The most poignant phenomenon that humanity is witnessing due to the rise in global temperature is climate change, which leads to changes in the cryosphere, weather, climatic patterns, and oceanic circulations, among others. The recent IPCC AR6 Report shows that the average global temperatures have risen by 1.1°C compared to pre-industrial levels. There are various implications of this rise on diverse ecosystems. The urgency and uncertainty attached to the phenomenon require climate solutions encompassing different domains. This chapter highlights innovative technologies employed or likely to be employed in the energy sector, assessment of hydrological and oceanic resources, solutions regarding climate-based disasters, and the challenges and opportunities to redress these concerns.

6.1 Introduction

The impact of climate change on ice and the cryosphere is alarming. According to the IPCC AR6 assessment and special report, anthropogenic factors influence the climate. Recent findings indicate that the temperature in 2022 was approximately 1.1 degrees warmer than the pre-industrial climate due to greenhouse gases (Krishnan, 2023). Gases, such as CO_2, methane, nitrous oxide, and HCFCs, trap heat, leading to an accelerated rate of warming. However, there is variability in the spatial warming pattern, resulting in a non-uniform surface temperature increase. As mentioned in the report, the Polar Arctic has experienced the most significant warming. Similarly, the Indian Ocean has witnessed the highest levels of sea level rise compared to other regions (Swapna, 2023).

Climatic solutions are necessary to address climatic concerns and facilitate a sustainable transition for global economies. It entails implementing measures in energy alternatives, sustainable utilisation of oceanic and hydrological resources, and identification of new resources. These advancements can enhance observations, data aggregation, modelling, and prediction.

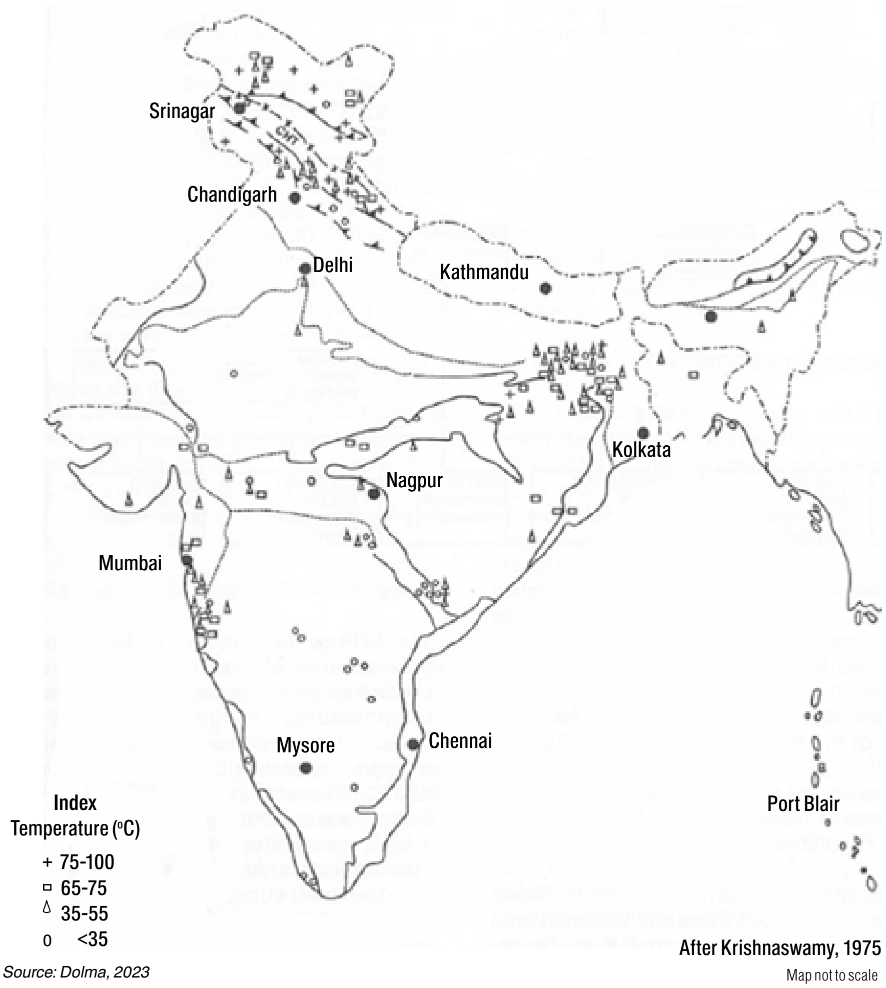
6.2 Clean Energy Solutions

6.2.1 Hydrogen Energy

Hydrogen, a high-density energy source, has the potential to emerge as a sustainable alternative to conventional energy sources. It is ten times more efficient than petrol or diesel (Singh, 2023a). Hydrogen can be extracted through electrolysis, splitting water into oxygen and hydrogen. The resulting hydrogen can be a high-density fuel, aligning with India's Net Zero 2070 vision. When renewable energy is used in electrolysis, the hydrogen is considered renewable.

Net Zero 2070 vision

Fig. 6.1: Geothermal in India



Source: Dolma, 2023

light fuel
liquefied
cost-effective

Hydrogen is a light fuel, eight times lighter than oxygen, increasing transportation costs. Therefore logistical challenges are associated with the supply chain of hydrogen energy. In order to transport the hydrogen from remote areas, it must be liquefied at -253°C and transferred to tankers (Singh, 2023a). Despite these challenges, there are economical ways to produce hydrogen. Scaling up hydrogen production is necessary to make it affordable and accessible. For example, caustic soda plants produce hydrogen as a byproduct (Atmanand, 2023). Situating a hydrogen plant near a caustic soda plant can provide a cost-effective option.

wind energy
production
fertilizer industry

India's extensive coastline of 7500 km offers opportunities for hydrogen production from oceanic water (Singh, 2023a). The coastline can also be utilized for wind energy production, further enhancing the potential for generating green hydrogen. Producing hydrogen can have a transformative effect on the fertilizer industry, as hydrogen is a crucial component in ammonia production for urea. The transportation sector can also transition to sustainable practices by adopting green hydrogen. With zero emissions and high energy density, 1kg of hydrogen can provide a mileage of 116 km using existing technologies, with the potential for further improvement (up to 150 km) with technological advancements.

6.2.2 Geothermal Energy

geothermal heat pump
hydrothermal

Geothermal energy, harvested from beneath the ground, is a significant source of energy (Dolma, 2023). Its resources can be classified into three categories: geothermal heat pump, hydrothermal, and enhanced geothermal systems. Based on temperature, geothermal energy can be divided into low-temperature fields (below 190°C) and high-temperature fields (above 190°C). In India, most fields fall under the low-temperature category ranging from 75 to 80°C (Ibid.).

Flash steam
plants
hydrothermal fluids

Various technologies are employed to extract geothermal energy, depending on the nature of the source. Flash steam plants, the most common type, utilize fluids exceeding 182°C (Dolma, 2023). These fluids are pumped from underground and undergo a pressure change, causing some fluid to transform into vapour rapidly. The vapour then drives a turbine, generating electricity. On the other hand, dry steam plants primarily utilize steam hydrothermal fluids, which are less common. The steam is directly sent to a turbine to generate electricity. Dry steam power plants have been in use since 1904, with the oldest plant located in Lardarello, Italy (Ibid). Steam technology is still used at northern California Geysers, the world's largest geothermal power source.

geothermal policy

Utilizing geothermal energy poses several challenges. In India, developing enhanced geothermal systems in low-temperature fields requires significant investment (Dolma, 2023). Moreover, the absence of a geothermal policy discourages foreign investment due to the need for stability and clarity in the sector.

India has implemented a demonstration project in Puga, Ladakh, and other potential geothermal sites, including Manikaran in Himachal Pradesh, Sohna in Haryana, and

Demchok in Ladakh (Dolma, 2023) (Fig. 6.1). With the increasing costs of coal and oil, geothermal energy offers a clean alternative, reducing dependence on imports. Additionally, it can support remote households and contribute to the development of resource parks, benefiting small businesses and attracting tourists.

clean alternative

6.2.3 Ocean Thermal Energy Conservation

India's Intended Nationally Determined Contributions aim to achieve a 500 GW installed energy capacity from non-fossil fuel sources by 2030. One potential alternative to traditional clean energy resources is OTEC, Ocean Thermal Energy Conversion. The technology harnesses the temperature difference between the ocean's surface and depths (Atmanand, 2023), converting it to energy. However, it is crucial to consider scalability when considering OTEC as a viable energy source in order to make it cost-effective.

non-fossil fuel
OTEC

cost-effective

6.3 Innovative Technologies for Assessing Hydrological Resources

Groundwater is crucial for sustainable agriculture and livelihood in India and for recharging aquifers. However, there needs to be more understanding of the complex aquifer system in the country (Tiwari, 2023). Due to changing and dynamic factors, innovative technologies are necessary to assess and utilize hydrological resources (Ibid.).

A robust information and knowledge system for replenishing groundwater and mapping aquifers is urgently needed. Airborne and satellite-based models can provide a quality output based on input data from these technologies. India has recently adopted EVRI as a novel method for 3D subsurface mapping (Tiwari, 2023). Unlike conventional electrical imaging, EVRI measures voltage and current flow, making measurements possible in areas without electrodes. The wireless nature of this technology enables observations and notes in locations where traditional electric imaging techniques are not feasible. Using these techniques, a demonstration project in Hyderabad successfully mapped the flow of groundwater, which is essential for managing agricultural water resources (Ibid).

EVRI
electrical imaging

groundwater

Additionally, mapping groundwater flow will facilitate the placement of percolation tanks to recharge groundwater and aquifers. This method can also help identify the depth of groundwater flow, creating various opportunities. Another technique for aquifer mapping is the heli-borne geophysical mapping technique, which provides a 3D subsurface image up to a depth of 500 m (Tiwari, 2023). This technique covers large areas quickly and has led to the discovery of contaminated and uncontaminated aquifers in the Ganga Basin. Numerical simulations at the sub-basin level can assist in identifying groundwater possibilities in arid regions, addressing the nation's water issues.

percolation tanks
aquifers

heli-borne

contaminated

Space-based technologies are also employed for hydrological observations and modelling, such as estimating the rate of evapo-transpiration in the Ganga Basin, which is estimated to be 23 per cent (Tiwari, 2023). This knowledge aids in preparing water budgets for the region.

Space-based
evapo-transpiration

groundwater depletion
hard rock

The challenges in assessing hydrological resources in the country include a need for more understanding of subsurface precipitation and storage due to variability in subsurface hydrology. Water contamination is also a significant issue, along with groundwater depletion and rugged terrains of hard rock and heterogeneous formations–a challenge for groundwater flow and transportation modelling (Tiwari, 2023).

water security
food security
spatial resolutions

Addressing these requires linking science with local scientific problems related to water security, food security, and environmental flow to develop sustainable solutions for the earth system. Given that over 70 per cent of India's subsurface conditions are heterogeneous, innovative technologies for mapping the subsurface, aquifers, and their depths with high spatial resolutions are necessary (Tiwari, 2023).

6.4 Innovative Technologies to Harness Oceanic Resources

Blue Economy
sustainability

India has recently released its draft policy framework on the Blue Economy, a model of economic development based on the ocean economy with a focus on sustainability (Kumar, 2023b). Understanding the scientific drivers of ocean dynamics and the interaction between climate and oceans is essential in this context.

underwater instruments
deep-sea mining
underwater imaging

To conserve and preserve oceans and implement the Blue Economy policy, India has launched the Deep Ocean Mission worth INR 4800 crores (Murthy, 2023). This Mission aims to develop innovative technologies for underwater instruments, deep-sea mining remotely operated vehicles, underwater imaging, autonomous scoring systems, manned submersible vehicles, and underwater mining systems to harness resources sustainably.

Matsya 6000
research vessel
Sagar Nidhi

One of the technologies developed under this Mission is Matsya 6000, a manned submersible capable of travelling to a depth of 6000 m in the ocean. It has positive buoyancy and features a watertight pressure hull and lights for subsea visibility. The submersible's underwater thrusters enable subsea research, surveying, sampling, and intervention (Murthy, 2023). The research vessel Sagar Nidhi also plays a significant role in the mission for geo-scientific, meteorological, and oceanographic research.

high-pressure conditions
low soil strength
power requirements

The development of Matsya 6000 challenges include spear design, system welding, high-pressure conditions, system configuration, and a life support system. Similarly, the underwater mining system faces challenges in the oceanic ecosystem, such as high-pressure conditions, low soil strength, power requirements, and drag forces (Murthy, 2023). Overcoming these obstacles is essential to harness the oceans' opportunities sustainably.

deep ocean survey
exploration

Developing such technologies will enable India to provide ocean and climate change advisory services, sustainable utilization of resources such as minerals, energy, and freshwater, exploration and conservation of deep-sea biodiversity, deep ocean survey and exploration, and establishment of advanced marine stations for ocean biology. These innovative means can also raise awareness among the public, students, academia, and other communities about the earth system.

6.5 Ocean-Based Observations

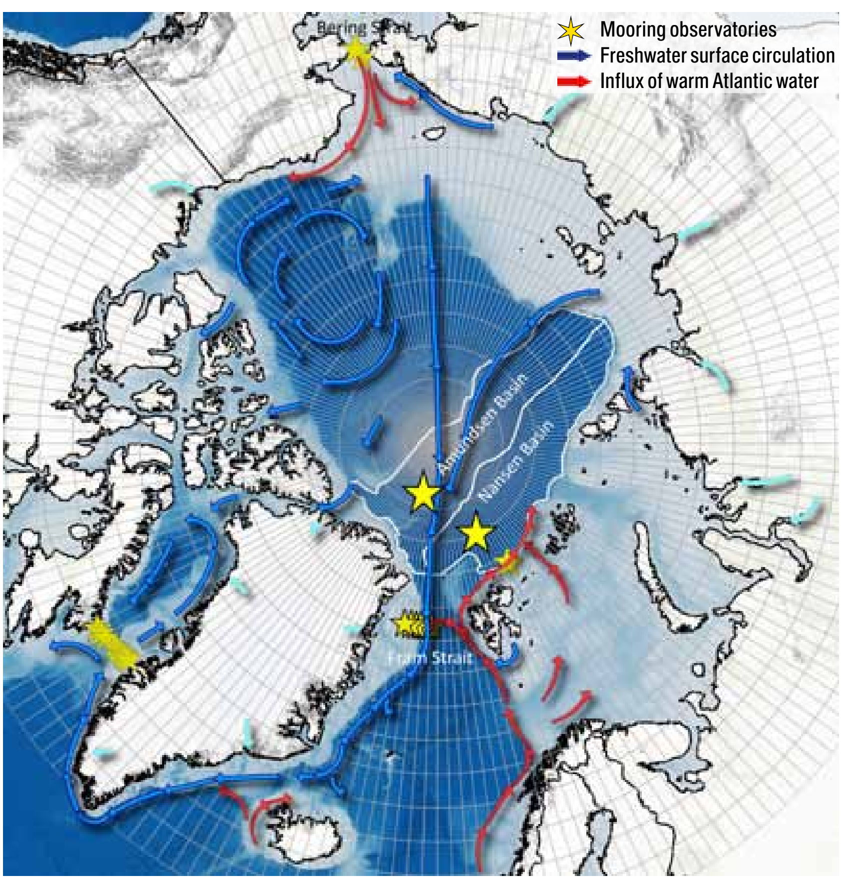
Understanding the interaction between ice-sheets, climate, and the ocean is now more important than ever. The latest IPCC Report highlights sea level rise as a significant source of uncertainty for the future. Measuring sea level rise involves determining the difference between ice flow discharges and snowfall. Regional climate models estimate snowfall, while ice flow discharge results from ice flow speed and thickness. Measuring ice thickness requires intensive topographical research, comparing ice surface and bed elevation.

topographical research

Topographical research and ocean observation are data-intensive processes. Modelling and developing prediction systems rely on diverse datasets, making data collection crucial. In addition to data availability, the accuracy of input data is vital. Therefore, fieldwork plays a significant role in accumulating accurate data and informed modelling efforts. Consequently, investing more resources in fieldwork becomes necessary.

data-intensive

Fig. 6.2: New Central Arctic Observing System



Source: Dodd, 2023

ice-sheet dynamics
sea level rise
ice flow
Drones

Furthermore, the challenge arises in determining the most effective means of collecting data to study ice-sheet dynamics and understand their role in rising sea levels. Jets flying at high altitudes make obtaining detailed information about the bed topography beneath the ice sheets nearly impossible. One alternative is to fly at lower altitudes using smaller aeroplanes, which, however, require refuelling every 1000-2000 km (Matsuoka, 2023). Moreover, technologies like satellite remote sensing are used for the regular monitoring of ice sheet surface, but measuring the bed elevation accurately from satellites is difficult. The lack of relevant and precise bed topography data hampers significant investment in satellite technology to answer sea level rise questions. Consequently, the availability of advanced computational technologies is crucial for further advancements in climatic research (Matsuoka, 2023). Additionally, apart from the need for innovation in computational technologies, technologies such as ice-penetrating radars are critical for understanding and calculating ice flow. Drones can also be deployed to study ice-sheet dynamics (Matsuoka, 2023).

vulnerable
2100

As widely known, nations and communities are vulnerable to climate change and its implications. For instance, by 2100, nearly 12 per cent of India's population will be significantly affected by sea level rise along with many economic centers located along the coast that are exposed to this threat. It is necessary to understand the contributing factors to be better prepared (Matsuoka, 2023).

Antarctic RINGS
Action Group

The vulnerability of coastal regions necessitates the development and enhancement of research capabilities. International, multi-stakeholder initiatives have been undertaken in the Antarctic and the Arctic to improve observations, modelling, and predictions. For instance, the Antarctic RINGS Action Group, under the Scientific Committee on Antarctic Research, is an international effort aimed at providing more accurate and comprehensive reference bed topography data to enable robust assessments of ice discharge from all regions of Antarctica, thereby enhancing the accuracy of ice-sheet modelling and mapping of grounding zones. The initiative also seeks to quantify ice-ocean interactions and pursue other related goals. The consortium plans to conduct geophysical surveys across the Antarctic ice sheet using aeroplanes equipped with multiple sensors, including ice-penetrating radars, magnetometers, and gravimeters, to assess surface mass balance and other factors (Matsuoka, 2023). This opportunity facilitates multidisciplinary research and the generation of robust datasets for assessments.

NPI
Amundsen
Nansen
Ice Profiling

Similarly, the Central Arctic Monitoring System has deployed moorings to observe the Arctic Ocean. The NPI has installed two moorings at the Amundsen and Nansen basins of the Central Arctic Ocean (Fig. 6.2). These moorings are equipped with various technologies, including Sonar, acoustic current profiler, Ice Profiling, SUNA, automatic water samplers, acoustic recorders, and sediment traps (Dodd, 2023). These technologies enable ocean observation beyond collecting long-term measurements at peripheral straits.

6.6 Recommendations

i. The knowledge about geothermal utilisation must be disseminated, along with capacity building through trainings, and short courses (Dolma, 2023).

ii. Geothermal tourism should be popularized as an energy source and a pilgrimage site, and site-specific demonstration projects should be planned (Dolma, 2023).

iii. The absence of a geothermal policy can act as a deterrent for foreign investors who are interested in investing money in geothermal development. Therefore, it is essential to implement a geothermal policy to attract such investors. (Dolma, 2023).

iv. As the grounding line of Antarctica measures approximately 62,000 km, which is larger than the earth's circumference of 40,000 km, there is a need for significant international collaboration to monitor it. It entails creating and merging regional initiatives to generate uninterrupted data (Matsuoka, 2023).

v. Frequent usage of drones can improve understanding of sea-ice dynamics (Matsuoka, 2023).

vi. A self-propelled track-based seabed mining system is required to address the challenges of manned submersibles due to ocean dynamics (Murthy, 2023).

vii. Innovative technologies for mapping groundwater and aquifers can enable the mapping of subsurface aquifers and their depths with spatial resolutions (Tiwari, 2023).

viii. Development of newer instruments capable of measuring subtle variations in ocean observations for effective forecasting, data assessment, and ocean and atmospheric modelling are significant requirements (Atmanand, 2023).