Climate-Ready Rural Infrastructure

Climate change is reshaping rural India, making resilient infrastructure essential for protecting lives, livelihoods and development gains. From roads, housing and energy systems to water resources and community assets, rural infrastructure must withstand floods, droughts, heat waves and other climate-related stresses. At the same time, it must remain affordable, sustainable and responsive to local conditions. Building climate-resilient rural infrastructure can strengthen agricultural productivity, improve access to essential services and create more secure communities, supporting India's journey towards a resilient and prosperous *Viksit Bharat@2047*.

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The consequences of climate change are evident worldwide, with increasing intensity and severity of extreme weather events. This is evident this year as well, with the continuing impacts of El Niño. According to the Climate Risk Index 2026 by Germanwatch, more than 5.6 billion people were affected between 1995 and 2024 by over 9,700 extreme weather events globally, resulting in 832,000 deaths and direct economic losses of over USD 4.5 trillion. According to the report, India ranks ninth globally among the nations most affected by extreme weather events. Nearly, 430 such events occurred in India during this three-decade period, causing economic losses of nearly USD 170 billion, affecting more than one billion people and resulting in more than 80,000 fatalities.

Rural populations in India face increasing risks from climate change due to their dependence on agriculture, high exposure to extreme weather events such as floods

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and droughts, and limited access to robust healthcare, social protection and resilient infrastructure. Tribal communities, which are an integral part of our natural ecosystem, face multiple forms of ecological and socio-economic vulnerability. Many reside in ecologically fragile regions such as forested lands, hills and rain-fed areas, with livelihoods closely tied to the surrounding ecosystem.

According to a study by the Council on Energy, Environment and Water, over 75 per cent of Indian districts, home to more than 638 million people, are hotspots of extreme climate events such as cyclones, floods, droughts, heat waves and cold waves. The study notes that India recorded 310 extreme weather events in the 15 years after 2005, compared to 250 events in the 35 years prior to that (1970–2005). The frequency of extreme floods increased nearly eightfold over 50 years, affecting over 97 million people annually. The annual average number of drought-affected districts also increased significantly after 2005, exposing millions of rural residents to agricultural distress.

The impacts of climate change, including rising temperatures, shifting rainfall patterns, more frequent and intense extreme weather events and rising sea levels, will affect infrastructure ranging from energy and transport to water, waste management and telecommunications. Climate resilience is the capacity of a system or community to resist, absorb, adapt to and recover from climate hazards while preserving its core functions through effective risk management. Climate resilience in rural infrastructure involves planning, designing and maintaining assets such as local roads, water systems and energy grids so that they can withstand extreme weather events such as floods, droughts and landslides. Such efforts can protect vulnerable agrarian communities by ensuring year-round access to markets, medical assistance and essential services.

Focus on Clean Energy

Energy is vital for development, and renewable energy can support sustainable development in harmony with nature and the environment. Renewable energy can provide a major thrust to economic development, enhance energy security, facilitate access to energy and mitigate the impacts of climate change. As some parts of the country receive more than 300 days of sunshine every year, India has a strategic advantage in solar energy production. The country also has a similar advantage in wind energy, given its 8,000-kilometre coastline.

The National Institute of Solar Energy has assessed India's solar potential at about 748 GW, assuming that 3 per cent of wasteland is used for installing such facilities. Among renewable sources, solar energy has maintained its dominance, contributing 164.59 GW. Other renewable sources include wind energy (58.14 GW), hydropower (57.24 GW) and bio-power (11.75 GW), while nuclear power accounted for 8.78 GW. During 2025–26, a record 55.29 GW of non-fossil fuel-based electricity capacity was installed in the country, with 44.6 GW from solar power and 6 GW from wind power.

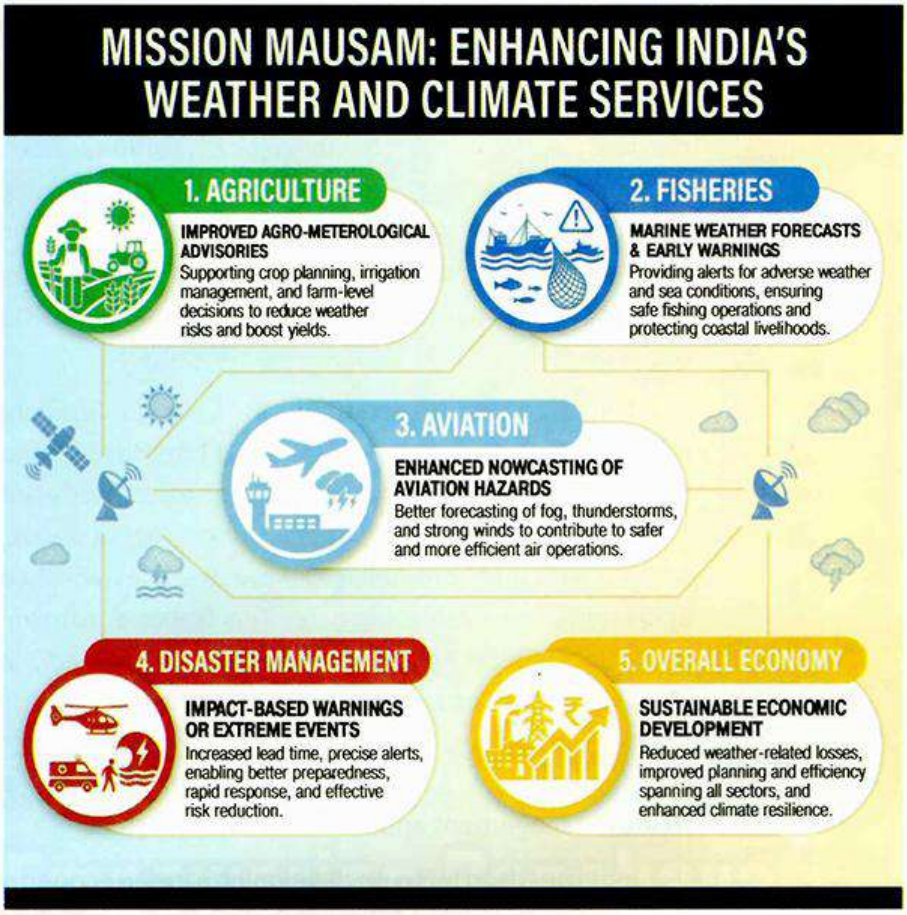
Modhera village in Gujarat is the first village in the country to be powered entirely by solar energy, with 1,300 rooftop panels installed on residential and government buildings. The solar power plant has reduced electricity bills to zero and is also becoming a source of income, as surplus power is sold back to the grid. Similar initiatives are being undertaken in other States. In Telangana, villages are preparing to adopt decentralised solar systems, from rooftops to farm feeders, reducing outages, lowering costs and improving access to reliable electricity.

Himachal Pradesh is progressing towards becoming a green energy State. A total of 728.4 MW of solar projects implemented by the Himachal Pradesh Power Corporation Limited are at various stages of progress, including 120 ground-mounted projects with a capacity of 150.13 MW that have already been initiated.

The National Unified Scheme for Compressed Biogas, known as GOBARdhan, launched in 2026–27 with an outlay of ₹23,731 crore, aims to convert India's organic wealth into clean energy, rural prosperity and economic growth. It seeks to transform agricultural residue, cattle dung, press mud, municipal organic waste and other biomass resources into clean fuel, organic manure, rural income and national economic value.

Need for Green Rural Infrastructure

The building sector plays a crucial role in boosting the economy through employment, infrastructure development and overall economic growth. At the same time, it is responsible for about one-third



of India's greenhouse gas (GHG) emissions. These include emissions from electricity use and cooking, as well as those embodied in materials such as cement, steel, bricks, aluminium and glass. Embodied carbon emissions account for about half of total emissions from the buildings sector.

There is a need to draw upon India's civilisational legacy of climate-responsive design. Traditional rural buildings use sustainable designs and local materials such as mud, bamboo, thatch and stone. Earthen and agricultural-composite walls can regulate indoor temperatures naturally. Repurposing construction and demolition debris can also divert rubble from landfills and convert it into structural aggregates. Such structures adapt to local weather, keeping interiors cool in summer and warm in winter without mechanical cooling or heating.

Ancient architectural texts such as Vastu Shastra, Manasara, Mayamatam and Samarangana Sutradhara treated buildings as living entities. Guided by the principle of *desa-kala-paristhiti* (space, time and circumstance), these treatises integrated structures with natural forces such as the sun, wind and water. Vernacular architecture traditionally employed passive strategies such as courtyards, thermal mass, cross-ventilation, shading and locally sourced materials.

Climate-resilient and energy-efficient rural housing is critical to protecting vulnerable populations from extreme weather, reducing carbon emissions and alleviating energy poverty. Integrating passive cooling, solar energy and local, eco-friendly materials can help future-proof rural habitats in line with national net-zero goals.

The Climate Resilient Villages programme, launched in 2022–23, is a flagship Tamil Nadu Government initiative managed under the Tamil Nadu Climate Change Mission. It targets 11 vulnerable districts and has impacted 2.7 million people through solar power, water systems and ecosystem restoration. Killai has transformed from a climate-vulnerable coastal settlement into a climate-resilient model village, where ecosystem restoration, renewable energy and community-led action have helped address cyclones, sea-level rise, saline intrusion, coastal erosion and biodiversity loss.

Roads are another important component of rural infrastructure. There is a need for climate-resilient technologies that can withstand heavy rain and floods. These include recycled materials such as shredded plastic waste, industrial steel slag and crumb rubber blended into asphalt, alongside local agricultural biomass and natural fibres. Such measures can reduce virgin bitumen consumption, lower carbon emissions and prevent monsoon potholes. Plastic geocells can also use local soil to stabilise hilly terrain. Milled and crushed old asphalt can be remixed into new road layers, while fly ash and steel slag can replace traditional aggregates. Shredded end-of-life vehicle tyres can increase pavement flexibility and reduce traffic noise.

According to the Ministry of Rural Development, 43,700 km of roads had been constructed using waste plastic technology under the Pradhan Mantri Gram Sadak Yojana (PMGSY) till July 2025, and it is mandatory to use waste plastic technology in at least 70 per cent of such projects. Studies conducted by IIT Madras have found that roads constructed using plastic waste

materials have better performance attributes than conventional roads.

The Gujarat Government allocated ₹1,147 crore in the State Budget to develop 20 climate-resilient roads spanning 271 km using green technology. The initiative focuses on sustainable infrastructure, recycling old pavement materials and using advanced anti-cracking layers. Karnataka is also adopting eco-friendly construction materials and climate-resilient engineering under national programmes such as PMGSY-III. These initiatives integrate waste plastic, cold-mix technology, fly ash and geocells to reduce carbon footprints and prevent monsoon damage.

Conservation of Water Resources

Water is at the core of sustainable development and is critical for socio-economic development, energy and food production, healthy ecosystems and human survival. It is also at the heart of adaptation to climate change, serving as a crucial link between society and the environment. Climate variations are causing sea-level rise, disruptions in rainfall patterns, droughts and extreme weather conditions.

Climate-induced changes in water-resource systems affect economies, food systems, rural landscapes, energy, health, ecosystems and community security, including that of smallholder farmers. Rising global temperatures are projected to exacerbate these risks. Nine out of ten disasters triggered by natural hazards during the last decade were water-related. Water-related disaster deaths have more than doubled in the last 10 years. Nearly 95 per cent of infrastructure losses and damages were reported between 2010 and 2019 due to water-related disasters. At least 1.4 billion people were affected by droughts and 1.6 billion by floods between 2000 and 2019.

There is a need to restore wetlands, floodplains and natural ponds to absorb excess storm runoff. Protecting upstream forests and promoting agroforestry can prevent soil erosion, slow heavy rainfall runoff and reduce landslides in fragile mountain areas. Managed Aquifer Recharge (MAR) captures excess surface runoff and floodwaters, directing them underground to replenish depleted aquifers while mitigating downstream flood risks.

Local water committees should be strengthened to design community safety plans, enforce equitable distribution policies and establish transparent pricing structures. Integrating indigenous and local knowledge into formal watershed management can create climate-resilient systems by combining community-based ecological monitoring with modern science. Traditional methods such as contour trenches, check dams and farm ponds capture rainwater, prevent soil erosion and recharge local groundwater, improving water availability and crop yields.

The National Innovations in Climate Resilient Agriculture (NICRA), launched in 2011 by the Central Government, is a landmark network project designed to enhance farming resilience. Under the initiative, 448 Climate Resilient Villages have been established across 151 vulnerable districts. The National Mission for Sustainable Agriculture (NMSA), launched in 2014–15 as part of the National Action Plan on Climate Change, promotes climate-resilient farming through components such as Rainfed Area Development, Soil Health Management and Per Drop More Crop.

India needs to focus on developing a green economy at the village level that is low-carbon, resource-efficient and socially inclusive. Clean and green initiatives are important for improving overall human development and ensuring sustainable development. This can be achieved through nature-based solutions, based on the principle that healthy, well-functioning ecosystems can provide multiple benefits for societal and environmental well-being.

Ensuring climate resilience in infrastructure will help protect lives and livelihoods and reduce direct losses resulting from extreme weather events.

The way Forward

The way forward lies in integrating climate resilience into every stage of rural infrastructure planning, from design and construction to maintenance and renewal. Greater use of renewable energy, water conservation, nature-based solutions, local materials and climate-smart technologies can reduce environmental risks and costs. Stronger community participation, local knowledge, skilled human resources and better climate-risk data are equally important. Convergence among government programmes, research institutions, local bodies and communities can help build infrastructure that is inclusive, durable and responsive to a changing climate. ❑