Swaniti Global

EXTREME WEATHER EVENTS AND ENERGY TRANSITION

(Tipping or Turning Point)

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About Us

Swaniti Global, is an international policy and governance organization that operates at the intersection of policy, governance, and community needs to drive meaningful, long-term change. Swaniti works across regions to identify opportunities, unlock critical resources, and accelerate the energy transition through context-specific, collaborative strategies. Its approach is rooted in building partnerships with governments, communities, industry clusters, and civil society organizations to co-create solutions that are both innovative and impactful. By engaging with government systems to understand existing capacities and aligning them with community aspirations, Swaniti facilitates the design and implementation of integrated programs that address structural and developmental challenges.

Swaniti also invests in high-quality research on climate and development issues and collaborates actively with policymakers, elected officials, and communities worldwide to address pressing climate concerns and harness opportunities for impactful climate action. With deep technical expertise in public service delivery systems and a strong understanding of last-mile development challenges, Swaniti specializes in orchestrating multi-stakeholder engagements that drive systemic change. This includes unlocking public funding and leveraging institutional mechanisms to support large-scale transitions. Through its work, Swaniti Global aligns local development priorities with national policies and global climate objectives, contributing to the creation of resilient communities and inclusive, low-carbon economies.

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Introduction

Climate change is intensifying global hazards such as rising temperatures, erratic rainfall, sea level rise, and more frequent extreme weather events that pose profound risks to both the energy transition and electricity security. Power systems worldwide are already straining under climate anomalies, with events such as searing heatwaves in Europe, devastating floods in Pakistan, raging wildfires in North America and powerful cyclones in Asia, these disasters have become the new norm, underscoring that the climate crisis is not a distant threat but a present-day reality. While the global push toward cleaner energy rightly aims to tackle climate change, it must also contend with a sobering truth: the transition itself is vulnerable to the very disruptions it seeks to avert. Extreme weather is both a symptom of climate change and a formidable disruptor of energy systems, exposing the fragility of infrastructure and the gaps in resilience.

India exemplifies this challenge. In recent years, the country has endured record-breaking heatwaves, erratic monsoons, catastrophic floods, powerful coastal cyclones, and prolonged droughts in once water-secure regions. These climate shocks are reshaping landscapes, damaging infrastructure, and straining energy supply. The convergence of these impacts with India's clean energy ambitions raises a pivotal question: Are we approaching a tipping point where climate risks undermine the transition, or a turning point where decisive action strengthens it?

India now stands at a crossroads. One path risks leaving the energy sector exposed with renewable assets damaged by extreme weather, fossil fuel dependence extended, and adaptation sidelined. The other embraces a forward-looking approach that hardens infrastructure, decentralizes generation, and harnesses nature-based solutions to buffer climate shocks. The next decade will determine whether India's energy transition merely survives or actively thrives amid climate extremes, a test with consequences for its decarbonization goals and for the millions whose futures depend on a stable climate and secure, equitable energy access.

Climate Disruption and Energy Systems

Climate refers to the long-term average weather of a location, shaped over decades to millennia, while weather changes can occur within minutes or hours. It is defined by the type, frequency, duration, and intensity of phenomena such as heatwaves, cold spells, storms, floods, and droughts, alongside average temperature and precipitation patterns. As climate change accelerates, rethinking how we produce and consume energy has become critical to securing a sustainable future. Fossil fuels remain a primary driver of climate change, carrying severe environmental costs. Global greenhouse gas emissions have reached unprecedented levels in the last decade, and without urgent action, emissions could rise significantly by 2030, deepening the climate crisis.

The International Energy Agency (IEA) estimated that global energy-related CO_2 emissions increased by 0.8%[01] in 2024, setting yet another record high. Natural gas emissions alone are projected to grow by 2.5% which is around 180 million tonnes of CO_2[02], driven by demand in countries including China, the United States, the Middle East, and India. At the same time, the Intergovernmental Panel on Climate Change (IPCC) warns that global warming will intensify the frequency and severity of extreme weather events, endangering both human lives and critical infrastructure.

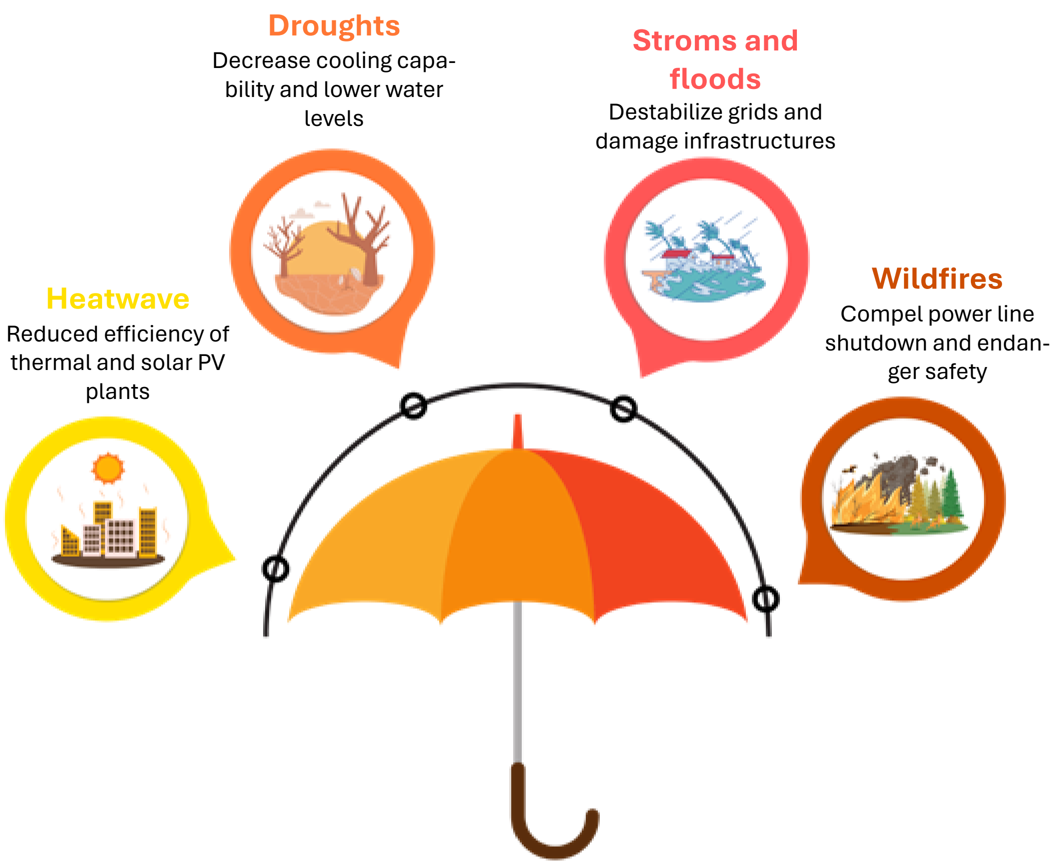
01 https://www.iea.org/reports/global-energy-review-2025/co2-emissions
02 Ibid

Renewable energy sources (RES) are essential for achieving carbon neutrality and reducing the environmental and social impacts of climate change. Yet, their availability, whether wind, solar radiation, or hydropower, is influenced by existing weather patterns and the uncertainties of future climate conditions. Accurate climate projections are vital to anticipate how renewable resources may shift over time, reducing uncertainty in building a truly low-carbon, resilient energy system. The path to decarbonization will be among the greatest societal challenges of this century, especially as rising sea levels, stronger winds, reduced subtropical rainfall, and higher temperatures threaten both energy demand and supply.

A paradox lies at the heart of the energy transition: the same climate instability that drives the need for clean energy also threatens to undermine it. Extreme weather disrupts infrastructure across fossil fuel and renewable systems alike, exposing the vulnerabilities of today's energy networks.

Common Extreme Weather Impacts on Energy Systems:

- **Heatwaves:** Reduce the efficiency of thermal and solar PV plants. In India, the 2022 and 2024 summer heatwaves forced several coal plants to operate at reduced capacity and increased cooling demand, straining grids in Delhi, Rajasthan, and Uttar Pradesh.
- **Droughts:** Lower water availability for cooling thermal and nuclear plants and reduce reservoir levels in hydropower dams, as seen in Karnataka and Himachal Pradesh during recent monsoon deficits.
- **Storms and Floods:** Damage transmission and distribution infrastructure, disrupting both centralized and decentralized grids. Cyclone Fani (2019) and the 2023 Him-



achal floods caused extensive power outages and costly repairs.

- **Wildfires:** While less common in India, increasingly dry conditions in states like Uttarakhand have led to forest fires that threaten transmission lines and force preventive shutdowns.

In India's context, building climate resilience into the energy transition is no longer optional rather it is a necessity. Without adaptation measures, climate shocks could delay renewable deployment, prolong fossil fuel reliance, and compromise electricity security at a time when demand is set to grow rapidly.

Role of Fossil Fuels in Driving Climate Chaos

The scientific consensus is unequivocal: fossil fuel combustion is the primary driver of climate change[03]. The concept of petroculture which refers to our deep-seated societal, economic, and political dependence on fossil fuels, illustrates that this is not merely an energy source, but a way of life embedded in modern systems, particularly in the Global North. Fossil fuels have powered industrialisation, colonial expansion, and capitalist economies, permeating every layer of society. This close integration between fossil fuel companies and societal structures has often shielded the sector from the level of public scrutiny that the climate emergency demands[04].

The IPCC's 2021 report leaves no doubt that human influence has warmed the atmosphere, oceans, and land[05]. Since pre-industrial times, atmospheric CO_2 concentrations have risen over 40%, from 280 ppm to 419[06] ppm in 2023, driven mainly by fossil fuel burning. Methane levels have surged to more than 2.5 times than the pre-industrial levels (722 ppb to 1,922 ppb in 2023)[07], and nitrous oxide has climbed by about 20% (270 ppb to 337 ppb in 2023)[08]. In 2023, CO_2 emissions from fossil fuels hit a record 36.8 billion metric tons[09], up 1.1% from 2022; factoring in land-use changes and wildfires, total global emissions reached about 40.9 billion metric tons.

These unprecedented concentrations have made 2023 the hottest year on record, with global surface temperatures averaging 1.2°C above the 1951-1980 baseline. While large carbon sinks like oceans and terrestrial ecosystems absorb around 56%[10] of annual emissions, their capacity is weakening due to ocean saturation, warming, and altered circulation patterns. At current emission rates, the world has only about seven years before exceeding the 1.5°C warming threshold with a 50%[11] probability, which is a critical line beyond which climate impacts will escalate dramatically.

For India, the implications are stark. Rising global temperatures are amplifying extreme weather events such as heatwaves, floods, droughts, cyclones, that are already being felt nationwide. The 2022 and 2024 heatwaves in northern India strained power grids and cut crop yields; Cyclone Amphan (2020) caused billions in damages, including to energy infrastructure; and erratic monsoons have repeatedly disrupted agriculture and hydropower generation. These impacts risk compounding the vulnerability of India's en-

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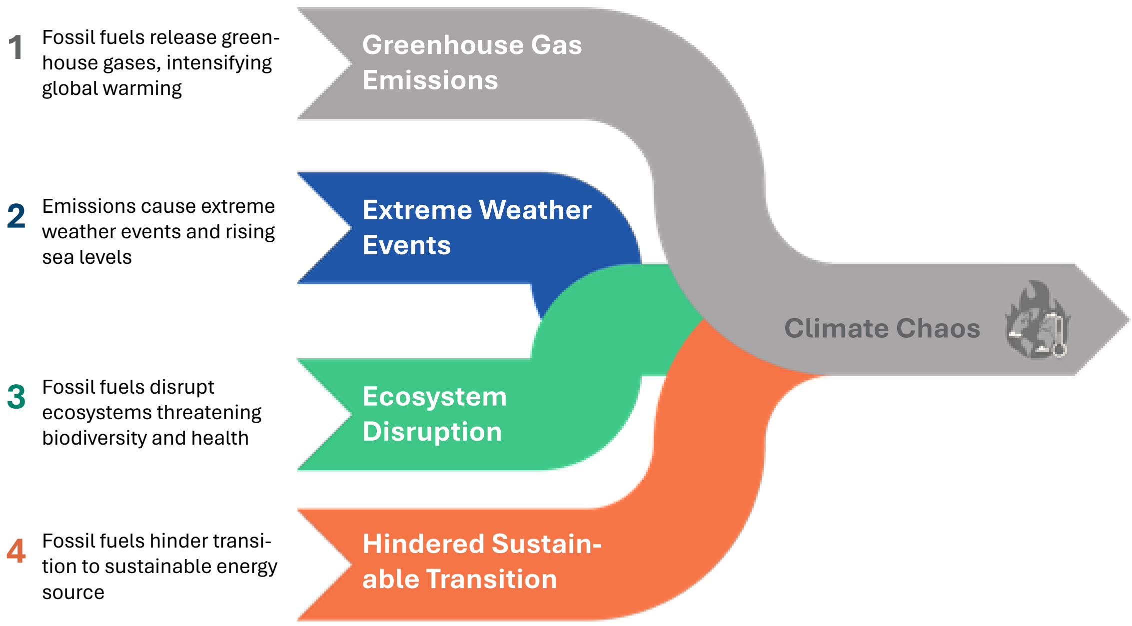
03 https://www.sciencedirect.com/science/article/pii/S1364032125000322
04 ibid
05 IPCC. (2021). Climate change 2021: The physical science basis (pdf) (242 MB). Working Group I contribution to the sixth assessment report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu & B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom, p. SPM-5.
06 https://www.epa.gov/climatechange-science/causes-climate-change#ref10
07 Ibid
08 Ibid
09 https://earthobservatory.nasa.gov/images/152519/emissions-from-fossil-fuels-continue-to-rise
10 Ibid
11 Ibid

ergy system, which still derives around 75%[12] of its electricity from coal, oil, and gas.

Fossil fuel-driven warming is not just a global statistic but is a direct trigger for climate chaos that threatens India's food security, water availability, biodiversity, and infrastructure resilience. Unless the dependency on fossil fuels is broken through accelerated renewable deployment, storage solutions, and systemic policy shifts, the country could face escalating economic losses and humanitarian crises.



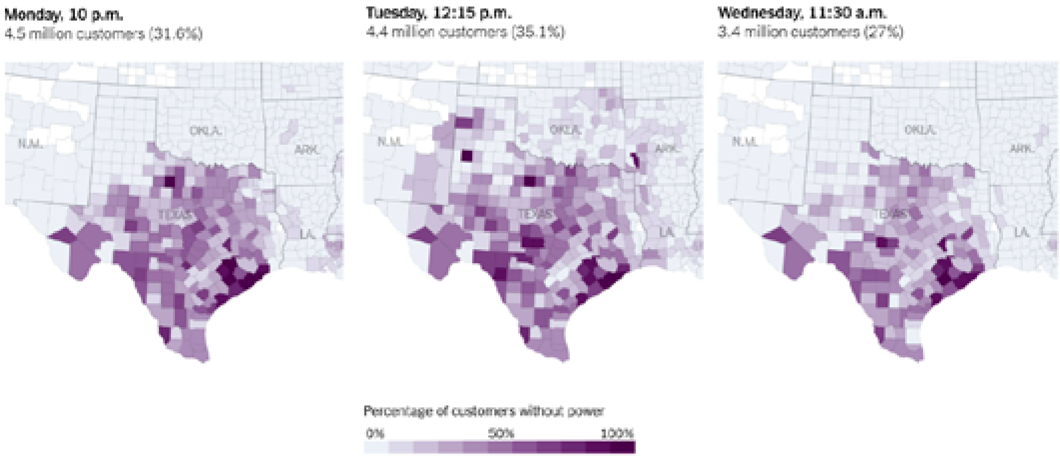
Extreme Weather Events And their impact

For instance, during the winter storm that slammed Texas in 2021, frozen gas pipelines and halted wind turbines contributed significantly to widespread power outages. In 2023, India suffered over 300 heatwave days across numerous states, driving electricity consumption to all-time highs and revealing the limits of coal storage and distribution under intense heat. In 2023 alone, the United States had 28 major weather and climate disasters, costing an estimated $92.9 billion[13] in damages. Beyond the financial cost, natural disasters such as the devastating wildfire on Maui Island in Hawaii put enor-

12 https://beeindia.gov.in/sites/default/files/BEE_India_Energy_Scenario_Report-2024_web_version-rev2.pdf

13 https://www.indiatoday.in/environment/story/us-suffered-28-extreme-weather-events-in-2023-lost-93-billion-in-damages

mous strain on key systems that rely on modern energy infrastructure. The pattern only becomes more pronounced in 2024. That year, the world experienced some of the most severe weather occurrences on record.



Source: PowerOutage.us/outages in Texas, 2021/ frozen gas pipelines and halted wind turbines

Hurricane Milton tore across sections of Florida, causing billions of dollars in damage

and displacing thousands of citizens. The Atlantic hurricane season also produced hurricanes of unprecedented power and ferocity.

Heatwaves across Europe surpassed records, pushing temperatures above 40°C in countries unaccustomed to such extremes, putting a strain on electrical networks and healthcare systems. As fires raged across Australia and the western United States, terrible flooding in South Asia submerged entire communities. Scientists warn that unless strong action is taken, the global pattern of these calamities will only worsen.

Source: Hawai'i Department of Education, 2023, www.jw.org/ destructive wildfires on Maui, USA, 2023

On 9 April 2024, a deadly summer storm destroyed the world's largest floating solar plant, a 600 MW[14] facility on the backwaters of the Omkareshwar Dam in Madhya Pradesh, India. Strong winds generated large waves that ripped hundreds of solar panels from their mounts, shattering them and damaging the undersea cables linking the

14 https://www.junipergreenenergy.com/overcoming-the-challenges-of-solar-energy-in-extreme-weather-conditions




array to the power grid. Similarly, in 2023, Cyclone Biparjoy that lasted for 13 days, struck India's eastern coast, causing severe damage across multiple states. Gujarat was among the hardest-hit, with nearly 1,000[15] villages suffering prolonged blackouts.

In September 2025, floods in Punjab caused over Rs 102 crore[16] in damage to electricity assets across the state as per the Punjab State Power Corporation Limited (PSPCL). Critical infrastructure was severely affected including the Upper Beas Diversion Channel hydel project, which alone suffered losses of around Rs 62.5 crore[17]. Additionally, more than 2,300 distribution transformers were damaged, over 7,000 electricity poles were washed away, and nearly 864 kilometres of conductors collapsed under floodwaters[18].

15 https://www.deccanherald.com/india/cyclone-biparjoy-aftermath-1000-villages-in-gujarat-without-power-trees-uprooted-houses-damaged-1228316.html
16 https://www.hindustantimes.com/cities/chandigarh-news/punjab-floods-cause-102-crore-damage-to-pspcl-infra
17 Ibid
18 Ibid

These incidents highlight the vulnerability of conventional and renewable energy infrastructure to the increasing severity of climate-related extreme weather events and underscore the urgent need for resilient designs, robust engineering standards, and improved protective measures to safeguard clean energy investments. In addition to decarbonization, the net-zero pathway must involve risk-informed planning and climate adaptation.

Preferred Steps to Minimize or Avoid the Risk of Extreme Climate Impacts

Extreme weather events, aggravated by climate change, are already testing the resilience of energy systems globally, from cyclones damaging coastal infrastructure to heatwaves straining thermal plants and solar arrays. Building climate resilience into the energy sector is no longer optional; it is a necessity. Mitigation and adaptation must be pursued in parallel, supported by robust technical, human, and institutional capacity.

1. Comprehensive Climate Risk Assessments

The first step is to conduct detailed vulnerability assessments for all critical energy assets. This involves mapping climate hazards such as heatwaves, floods, storms, droughts, against infrastructure location and design parameters. In India, for example, coastal wind farms in Tamil Nadu and Gujarat must be assessed for cyclone risk, while solar plants in Rajasthan and other states should be evaluated for heat and dust storm resilience. These assessments must inform both national development plans and state-level renewable energy policies.

2. Engineering Resilience into Infrastructure

Energy infrastructure should be designed or retrofitted to withstand extreme weather. Measures include:

- **Wind Power:** Turbines in cyclone-prone states (Tamil Nadu, Odisha, Gujarat) should be designed with typhoon-resistant blades, reinforced towers, and yaw control systems to withstand high wind speeds. Offshore wind platforms must be anchored with cyclone-rated moorings.
- **Solar Power:** Panels in high-heat zones (Rajasthan, Gujarat) should use heat-tolerant photovoltaic cells to limit efficiency loss and be mounted with structures rated for high wind speeds (over 180-200 km/h). In hail-prone regions (parts of Himachal, Uttarakhand), panels should have impact-resistant glass. Floating solar plants should use wave-resistant pontoons, flexible mooring lines, and waterproof cabling to prevent storm damage.
- **Hydropower:** Dams must adopt adaptive reservoir management to deal with erratic rainfall, while spillway capacity should be enhanced to handle extreme precipitation events.

3. Site Selection & Risk Assessment

- Conduct climate hazard mapping (heatwaves, floods, cyclones, droughts, hailstorms) using IMD and disaster management data.

Building Climate-Resilient Energy Systems

- Evaluate flood zone maps before selecting sites for solar parks or substations.
- Assess wind speeds & cyclone patterns for coastal wind farms (e.g., Tamil Nadu, Gujarat, Odisha).
- Identify water scarcity risk for hydro and thermal plants using long-term hydrological data.

4. Use future climate projections to guide renewable energy siting

Incorporate high-resolution climate model data and long-term meteorological forecasts to identify locations that will maintain stable solar irradiation and wind speeds under future climate scenarios. This means going beyond present-day resource maps and factoring in projected shifts in temperature, precipitation patterns, wind regimes, and extreme weather frequency due to climate change. By integrating this forward-looking data into Geographic Information System (GIS) analyses and resource mapping, developers and planners can pinpoint areas less vulnerable to climatic variability ensuring that new solar and wind projects remain productive, reliable, and financially viable over their entire operating life. This approach is particularly relevant in India, where monsoon variability, heatwaves, and changing wind patterns can significantly alter generation potential in different regions.

5. Integrating Smart Monitoring and Early Warning Systems

Advanced grid visualization tools such as IoT sensors, AI-driven fault detection, and satellite-based weather monitoring can improve real-time decision-making. For instance, predictive maintenance can be triggered ahead of storms, while automatic shut-down protocols can protect wind turbines and solar farms from damage. India's National Load Dispatch Centre and state load dispatch centres should integrate high-resolution weather forecasting into daily operations.

6. Decentralization and Distributed Energy Systems (DES)

Distributed generation, microgrids, and energy storage systems can reduce dependency on vulnerable transmission corridors. In disaster-prone regions like the North-east, hilly regions and coastal islands, microgrids powered by solar-plus-storage can keep critical facilities running during large-scale outages.

7. Climate-Resilient Storage Solutions

Energy storage is vital to bridge the gap between erratic supply and steady demand. Scaling up Li-ion, flow batteries, pumped hydro, and thermal storage can ensure power availability during extended outages. In India, integrating storage into large solar parks (like those in Pavagada, Karnataka) can improve both reliability and economic returns.

8. Regulatory and Institutional Measures

Non-engineering solutions are equally important:

- Updating regulatory frameworks to mandate resilience standards in all new renewable projects.
- Streamlining emergency response protocols so utilities can mobilize repair teams and spare parts rapidly after an event.
- Incentivizing insurance mechanisms for renewable energy assets in high-risk zones.

9. Energy Efficiency and Demand-Side Management

Reducing peak demand through energy efficiency measures in appliances, buildings, and industries can lower stress on infrastructure during extreme conditions. Smart grids and demand response programs can shift consumption away from vulnerable hours, especially during heatwaves and cold spells.

10. Aligning National and State Policies

Finally, resilience must be embedded in India's renewable energy mission. State renewable energy agencies, in partnership with the Ministry of New and Renewable Energy (MNRE), should require climate-proofing in tenders, particularly for wind and solar projects in hazard-prone areas.

Conclusion

The world stands at a defining crossroads. The extreme weather events we witness today, in the form of scorching heatwaves, devastating floods, powerful cyclones, and prolonged droughts are not isolated anomalies but urgent warnings of the accelerating climate crisis. They reveal the vulnerabilities of our current energy systems and the dire consequences of inaction. If we fail to act with urgency, the risks to human life, ecosystems, and economic stability will escalate beyond control.

The global energy transition cannot be reduced to a mere shift from fossil fuels to renewables; it must aim to build a flexible, reliable, and inclusive energy system capable of withstanding the disruptions of a changing climate. This means embedding resilience as a central pillar of energy planning in order to ensure that infrastructure, markets, and institutions are equipped to function under increasingly hostile conditions.

A comprehensive paradigm of resilience demands integration across multiple dimensions:

- *Social inclusion*, so that vulnerable communities are not left behind in the transition and have equitable access to clean energy.
- *Disaster preparedness*, ensuring energy systems can maintain critical services during and after extreme events.
- *Climate adaptation*, where infrastructure is designed for future climate realities rather than past norms.
- *Technological innovation*, from advanced storage systems and smart grids to climate-resilient wind and solar designs.

India ranks among the world's most climate-vulnerable nations, placed 10th in the Climate Risk Index (CRI)[19] 2025 by Germanwatch. The country is already facing escalating climate-induced disasters - floods, heatwaves, and droughts, that threaten lives, livelihoods, and infrastructure. The CRI findings underscore not only India's exposure to extreme weather but also the urgency for robust adaptation and mitigation strategies.

For India, this challenge is both a pressing imperative and a strategic opportunity. With ambitious renewable energy targets, the nation has the potential to lead globally by developing projects that not only reduce emissions but also withstand the intensifying impacts of climate extremes. Key priorities include integrating distributed energy systems, expanding large-scale storage capacity, modernizing the national grid, and enforcing climate-resilient design standards for all new infrastructure.

The decisions made in the next decade will be pivotal in determining whether we cross dangerous climate tipping points or secure a future of stability, sustainability, and shared prosperity. By coupling climate action with resilience-building, India can ensure its energy transition is not just green, but also strong, equitable, and future-ready.

19 Schulheiß, L., Künzel, V., and Schwarz, R., 2025, Escalating Threats: How Climate Change Increasingly Affects Human Security, www.germanwatch.org/en/93087.

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