





BUILDING CLIMATE RESILIENCE FOR INDIAN INDUSTRY

November 2025



Building
Climate Resilience
for Indian Industry

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Foreword



Mr Sanjiv Puri
President, Confederation of Indian Industry
Chairman & Managing Director, ITC Limited

Building Climate Resilience for Indian Industry" has developed a framework to assess and quantify climate risks for Indian businesses and their value chains. The framework is designed to help enterprises identify risks from floods, droughts, heatwaves, cyclones, and other phenomena caused by climate change and guide them in prioritizing appropriate adaptation actions across sectors and in different regions.

Around the world, including in India, an increased occurrence of extreme climate events has been noted over the years, resulting in significant human and economic losses. In India, while the central and state governments are taking action and allocating more resources to disaster recovery efforts, the private sector urgently needs to assess and effectively tackle the severe impacts of extreme climate events.

From an adaptation and resilience perspective, businesses are increasingly realising that they face significant challenges ranging from capital damage due to physical risks such as floods and cyclones, impact on social aspects including decline in productivity from extreme heat or heavy rainfall, and supply chain disruptions affecting transportation of raw materials and finished products.

Building adaptive capacity has its own share of challenges, including the absence of a unified framework for assessing climate risks across sectors, limited access to reliable climate data, inadequate use of technology in resilience strategies, lack of established funding sources and the complexity associated with modelling and forecasting extreme weather events.

Addressing these challenges demands coordinated efforts between industry, different tiers of government, urban planners, municipalities, and experts in the field, along with industry actors playing a key role in sharing best practices, offering technological solutions, and leading resilient infrastructure development.

Driven by these requirements and to actively engage with its members to enhance climate

resilience, the Confederation of Indian Industry (CII) is working to stimulate collective action to address climate change risks faced by the Indian industry.

The study on "Building Climate Resilience for Indian Industry" has developed a framework to assess and quantify climate risks for Indian businesses and their value chains. The framework is designed to help enterprises identify risks from floods, droughts, heatwaves, cyclones, and other phenomena caused by climate change and guide them in prioritizing appropriate adaptation actions across sectors and in different regions. Although primarily focused on industry, the framework can also form the foundation for a national strategy to assess and manage climate risks.

As outlined in the report, under the ongoing development of India's National Adaptation Plan (NAP), the relevant state departments could work with stakeholders towards the creation of a climate change adaptation taxonomy. This taxonomy could establish clear definitions on building adaptive capacity and climate resilience in the Indian context, along with setting specific project guidelines. It would facilitate private sector adoption of adaptation practices, prioritize.

Investments for building resilience and allow for greater public-private participation, eventually leading to building resilience at scale. The study highlights the role of industry in bringing in private capital, conducting in-depth site-specific studies that allow for clarity in investments, and building resilient infrastructure. Initiatives such as the climate risk assessment framework provide the necessary tools for Indian industry to play its part and should be further encouraged for uptake through appropriate incentives.

In the coming years, addressing existing data gaps by investing in required satellite technology, weather monitoring stations, and developing advanced predictive models complemented by evidence-based policy research will be crucial.

Addressing the impact of climate change is a very complex endeavour and calls for intensive collaboration among policymakers, businesses, and civil society. As we chart this course, CII remains committed to leading from the front, driving innovation, advocating for conducive policies, and facilitating the sharing of best practices.

Through concerted efforts, knowledge sharing and united and collaborative actions, businesses can play an indispensable role in driving transformative change towards a future with sustainable action that enhances social and economic well-being of individuals and communities. The present study is a step in this direction, and I am confident that it will set a benchmark for future industry action in this critical area.

This article was originally published as part of the Summary Report: Building Climate Resilience for Indian Industry during the 19th Sustainability Summit in November 2024.

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Mr Chandrajit Banerjee

Director General
Confederation of Indian Industry

Indian industry is at a critical moment, facing dual challenges of mitigating climate change and adapting to its inevitable impacts. While India's commitment to achieving net-zero emissions by 2070 is a significant milestone, the urgency of prioritizing adaptation measures to build industry-wide resilience is equally critical. As a nation that is significantly vulnerable to the impacts of climate variability, including extreme events such as heatwaves, floods, droughts & cyclones, prioritizing integration of climate concerns (both mitigation and adaptation measures), into the country's policy initiatives as well as development planning and priorities, will be essential to achieve the nation's goal of Viksit Bharat by 2047.

In recognition of this imperative, CII has been working on several fronts and is dedicated to spearheading climate action initiatives, driving policy advocacy, and assisting the industry in its transition towards a more sustainable and green economy.

Through our Centres of Excellence (CoEs) on Green Business, Water, Food and Agriculture, Sustainable Development and Competitiveness for SMEs, among others, we have been working closely and proactively with industry to drive forward business-led climate action.

CII has facilitated the green buildings movement in India over the last two decades resulting in more than 14,000+ green buildings projects coming up with a registered footprint of 11.92 billion sq. ft.

One key initiative has been the CII Climate Action Charter (CCAC) through which MSMEs located across various industrial clusters in India have begun measuring GHG emissions by using a free to access toolkit. In addition to measuring emissions, we have also been conducting awareness building and knowledge sharing sessions for these MSMEs at the cluster level on assessing climate risk.

On the climate policy front, through the CII Mission Net Zero, we have been working towards developing a strategy and action plan which will ensure an efficient, expedited, and inclusive Net Zero transition for Indian Industry.

While reducing emissions is an important area, we are also keenly aware of the rising impacts of extreme-weather events such as floods and heat waves on India and industry. In recognition of this imperative, this study on "Building Climate Resilience for Indian Industry" highlights our commitment to helping industry assess the vulnerabilities to physical climate risks, prioritize adaptive strategies, strengthen resilience and help in contributing towards India's adaptation targets.

The survey conducted as part of this study has provided valuable insights into how climate risks are assessed and prioritized by specific sectors and their current realities.

These insights have helped identify low-cost yet highly effective strategies that can significantly enhance adaptive capacity while showcasing not only the immense potential of risk assessments and resilience planning, but also the appetite for it within the Indian industry.

Another key insight has been that there needs to be more dialogues and collaborations between Government at both the national and subnational level and industry on building climate resilient infrastructure. Given the highly location specific nature of extreme-weather events, it is essential

that stakeholders work together to develop state and district-specific resilience plans with clearly defined guidelines and roles.

Through our regional and state offices, CII will help facilitate the dialogues and collaborations required to drive action on this key issue. In addition to taking forward this initiative through our offices, we also intend to leverage our CoEs and their expertise to help industry implement the framework developed as well as to identify key adaptive strategies as per their specific requirements.

Building climate resilience calls for a strategic and collaborative approach, uniting policymakers, industry stakeholders, and the financial institutions to address the multifaceted challenges of this incredibly complex challenge. By fostering innovation, enhancing awareness, co-developing solutions, and by leveraging public-private partnerships for joint initiatives, we can ensure that India is on the path towards economic prosperity while safeguarding ourselves from the vagaries of climate change.

This article was originally published as part of the Summary Report: Building Climate Resilience for Indian Industry during the 19th Sustainability Summit in November, 2024.

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Building Climate Resilience for

Indian Industry" highlights our



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Acronyms

AAL	Annual Average Loss
ASI	Annual Survey of Industries
ВСР	Business Continuity Plans
BRP	Business Resilience Plans
BRSR	Business Responsibility and Sustainability Reporting
CII	Confederation of Indian Industry
СОР	Conference of Parties
DEM	Digital Elevation Model
DMP	Disaster Management Plan
EM DAT	Emergency Events Database
ESRI	Environmental Systems Research Institute
EWS	Early Warning Systems
GDP	Gross Domestic Product
GVA	Gross Value Added
HVAC	Heating, Ventilation, and Air Conditioning
IMD	India Meteorological Department

IPCC's AR5	Intergovernmental Panel on Climate Change's Fifth Assessment Report	
LULC	Land Use Land Cover	
MoSPI	Ministry of Statistics and Programme Implementation	
MSMEs	Ministry of Micro, Small and Medium Enterprises	
SMEs	Small and Medium Enterprises	
NIDM	National Institute of Disaster Management	
OEM	Original Equipment Manufacturer	
SOP	Standard Operating Procedure	
SRTM	Shuttle Radar Topography Mission	
TANSIDCO	Tamil Nadu Small Industries Development Corporation Limited	
TCFD	Task Force on Climate-related Financial Disclosures	
UNDRR	United Nations Office for Disaster Risk Reduction	
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific	
UNFCCC	United Nations Framework Convention on Climate Change	
WEF	World Economic Forum	

Executive Summary

The impacts of climate change are being felt globally, with industries facing significant challenges due to the increasing intensity and frequency of extreme weather events. These impacts include supply chain disruptions, loss of infrastructure, loss in working hours and shifting market demands. Data shows that between19 and 24 percent of industrial assets in Asia are highly exposed to flooding (Moody's 2021). Such exposure can damage materials, costly machinery, and products, ultimately causing temporary operational shutdowns. These challenges are particularly pronounced in India due to the country's diverse climate profile and the highly climate-sensitive economic sectors. Despite growing awareness, many industries are under-prepared to address these challenges effectively, primarily due to different degrees of awareness on addressing these risks, insufficient data, limited access to resources, and differences in policies in different jurisdictions. The vulnerability of Indian industry to cascading climate impacts, especially in sectors like manufacturing and agriculture, necessitates the development of a comprehensive approach to assessing these physical risks and following this up with thorough planning. This report aims to address the urgent need to equip Indian industry with strategies necessary to plan for and adapt to these climate risks systematically.

In 2023, the first global stocktake of the world's efforts to address climate change under the Paris Agreement, held at COP28, concluded that while reducing greenhouse gas emissions remains crucial for curbing the rate of warming, equal focus and priority must be given to adapting to the increasing physical risks posed by climate change impacts (UNFCCC 2024). While the focus has been mainly on climate change mitigation, driven by India's Net Zero commitment by 2070, there is an increasing interest in prioritising climate change adaptation. Moreover, it bolsters industry's capacity to cope with slow-onset events like droughts, ensuring long-term sustainability. Further, COP29, held in Baku, formally adopted the New Collective Quantified Goal on Climate Finance (NCQG). This goal aims to mobilise USD 300 billion annually by 2030 to support developing countries in mitigation, adaptation, and addressing loss and damage. This ambitious target reflects growing recognition of the financial needs in vulnerable nations, building on the overdue USD 100 billion per year pledge made over a decade ago (WEF 2024).

CII-ITC's Centre of Excellence for Sustainable Development (CESD) has been a pioneer in environment management systems, biodiversity mapping, sustainability reporting and social & natural capital valuation in India. The industry forum has been pushing for active participation of the industry in climate action, and thereby significantly contribute to the national targets in this regard while upgrading their own global competitiveness. The adaptation initiative leverages CII's role in partnering industry, government, and civil society members to advocate for focused action on adaptation and resilience building and allocation of necessary resources for effective and efficient implementation.



Objectives

- 1. Develop a framework for climate risk assessment and adaptation planning, focusing on extreme events like floods, droughts, and cyclones for prioritised sectors: a) Manufacturing (Automobile and Iron and steel).

 - b) Agriculture (Food processing).
- 2. Create a set of possible overall and sector-specific adaptation strategies involving technology, policy, finance, early warning systems, and disaster management.
- 3. Build capacity among stakeholders in the prioritised sectors by helping them understand climate risks and adopt suitable adaptation strategies effectively.

Methodology

The study uses the IPCC AR5 climate risk assessment framework that includes variables like climate hazard, exposure and vulnerability, where vulnerability is defined as directly related to sensitivity and indirectly related to adaptive capacity (IPCC, 2014). The indicators that determine these variables have been shortlisted for the Indian context based on literature and inputs from stakeholder consultations.

First, three sectors were shortlisted- (1) Food processing, (2) Automobile and (3) Iron & Steel -based on gross-value added, working capital and employment share of the sector. Then, three states were selected based on their economic share of each of the selected sectors - (1) Maharashtra, (2) Tamil Nadu and (3) Odisha, respectively. The following schematic summarises the methodology.

Figure 1: IPCC AR5 Climate Risk Assessment: Risk = Hazard * Exposure * Vulnerability

Prioritisation of sites based on climate hazard assessment

(Using the past hazard and extreme event data recorded, industry can identify key hazards it's getting impacted by)

Exposure identification

(From the comprehensive list of indicators from the framework industry can select indicators relevant for their sector and hazards they are exposed to)

/ulnerability assessment

(For the selected indicators from the list below, data would be collected at the industrial site and state level data would be collected from public domain)

Risk = Hazard Exposure Vulnerability (Sensitivity/Adaptive Capacity)

Exposure Sensitivity

Hazard

Flood Cyclone

Drought

Extreme heat

Extreme Precipitation No. of manufacturing plants

No. of warehouses & distribution centres Length of national &

state highways Length of railway tracks

> & ports Proximity to water bodies (Sea, river)

No. of railways stations

Site topography (elevation, drainage)

Vulnerability

Change in built-up area

Change in groundwater

Change in soil permeability

Industrial Preparedness

Adaptive capacity

Industrial Management

Structural Safeguarding

Financial **Preparedness**

Technology & Innovation

Compute the climate risk score of site/ industrial cluster

(To compute the physical climate risk of industry, input the collected data in the IPCC AR5 risk assessment formula stated above)

Identification and prioritisation of adaptation strategies

After calculating the risk, industry can prioritze adaptation strategies specific to their needs from the indicator categories given under Adaptive capacity

Key Findings

From Stakeholder Consultation

- i. Nascent action against climate risk: The Indian industry is beginning to grasp the long-term climate impacts of physical risks on their operations. Given this, while some businesses are developing adaptation practices, the focus is mainly on ensuring water and power security, with limited attention on broader climate resilience.
- ii. Need for collective action and expertise:
 While companies with global value chains seem to fare better with necessary compliances, there is a general lack of expertise and research needed to address physical climate risks in the Indian context, underscoring the need for better awareness and collective action on enhancing capacities.
- iii. Regulatory support and policy guidelines:
 Industry stakeholders emphasise the
 importance of regulatory support and clear
 policy guidelines to enhance climate
 resilience. This support is crucial for
 encouraging investment in adaptation
 measures and ensuring that efforts are
 aligned across the industry and its value
 chains.
- iv. Importance of building a business case: A strong business case that highlights the return on investment is essential to foster investment in climate adaptation. A compendium of best practices and resources would facilitate swift and effective decision-making.

From the Climate Risk Assessment

The analysis shows that the western and central zones are prone to droughts, the northern and northeastern zones to floods, and the eastern and southern zones to a combination of cyclones, floods, and droughts (Mohanty and Wadhawan 2021).

- i. Impact of exposure: Industries in Tamil Nadu and Odisha face higher physical climate risks than those in Maharashtra, primarily due to exposure to multiple hazards within the same districts. In Tamil Nadu, risks to industries are high (0.6-0.8) and very high (0.8-1), whereas for Maharashtra, they lie in the low range (0-0.2).
- i. Location matters: Industries located in coastal districts are particularly vulnerable to physical climate risks compared to those located farther inland. Industry A and B in Chennai, Tamil Nadu, located in coastal districts, have risks ranging from 0.7 to 0.95 (high to very high), compared to Industry B in Nagpur, Maharashtra and Industry A in Jagatsinghpur, Odisha. While heavy export industries must be near the coast to reduce transportation costs, these industries also need to invest in safeguarding their assets, machinery, and raw materials from the impacts of extreme events.

Policy Recommendations

The study yields a set of policy recommendations for regulators and recommended actions for the industry, both sector-specific and sector-agnostic, for the short-term and long-term. The graphic below shows broad recommendations for both major stakeholders towards the overarching targets.





Figure 2: Overarching recommendations for major stakeholders



Recommendation 01: Building Capacity for Assessing and Reporting Physical Risks

Policymakers

Recognise the need for adaptation and collect necessary data and for assessing climate risk use tools like the PCRAF to quantify the physical risks across the supply chains

Invest in conducting site-specific studies to identify worst-case extreme weather scenarios to facilitates effective investment

Identify challenges within your sector/operations and invest in building and incorporate financial impacts

Develop an open-access utility providing data on extreme weather and climate projections for industry and other stakeholders to assess physical climate risks.

Mainstream the Physical Climate Risk Assessment Framework (PCRAF) and promote its implementation under SAPCCs and state DRM plans for industrial parks.

2

Regulatory requirements need to involve climate risk assessment and preparedness through initiatives like the RBI 2024 Climate Risk Disclosure Framework, currently applicable to Regulated Entities (REs).

3

Recommendation 02: Create an Enabling Enviro Environment for Climate-Resilient Industry

Policymakers

Invest in climateresilient infrastructure to minimise risks from extreme weather events-including decentralised power and water efficient options to minimise operational disruptions

Implement worker rotation mechanisms, staggered working hours, increased ventilation, smart cooling systems etc. for workers wellbeing.

2

Ensure workers

protection through

including elements

of thermal comfort

in guidelines issued

by the state

Promote resource sharing and collaboration through cluster development approach for reduced individual costs and increasing the feasibility of adopting climate-smart technology

Avail market assistance such as insurance products products to safeguard against climate extremes

governments need to collaborate with industry and urban planners to

Sub-national

develop cohesive guidelines for establishing green, climate-resilient industrial parks and zones, to promote adaptation solutions for climate-induced disasters

Offer greater financial and non-financial support by integrating climate adaptation and resilience elements into existing schemes, particularly for **MSMEs**

Introducing innovative climate insurance products

4

and making them accessible to all industries through bodies like the Insurance Regulatory and Development Authority of India (IRDAI), including setting up legal entities to resolve disputes







1

INTRODUCTION

Climate change and its impacts on human lives, businesses, infrastructure, natural ecosystems, and economies globally have become more evident and recognised in recent years (WEF 2021; United Nations n.d.). The rise in intensity and frequency of extreme weather events, causing nearly USD 202 billion in damages and losses and affecting 93.1 million people in 2023, highlights the urgent need for climate adaptation (CRED 2024).

As the impacts of the changing climate rise rapidly, South Asia stands as one of the most vulnerable regions (Global Climate Risk Index 2021) that has warmed at a rate faster than the global average in the last two decades (Eckstein, et al. 2021, WMO, 2024). With the breach of the 1.5°C global warming limit in 2024 from January- September (1.54 (±0.13))°C above pre-industrial level, 2024 is set to become the warmest year on record (WMO 2024).

India, being a tropical country, is highly vulnerable to the intensifying impacts of extreme climate events (World Bank Group 2021). This vulnerability has become increasingly apparent over recent decades and is projected to worsen in the coming years (Kumar et al. 2021; The Climate Reality Project 2022). The UNESCAP estimates India's annualised average loss (AAL) from extreme events, slow-onset hazards, and biological hazards at USD 93 billion, almost 3.35 percent India's GDP (UNESCAP 2019).

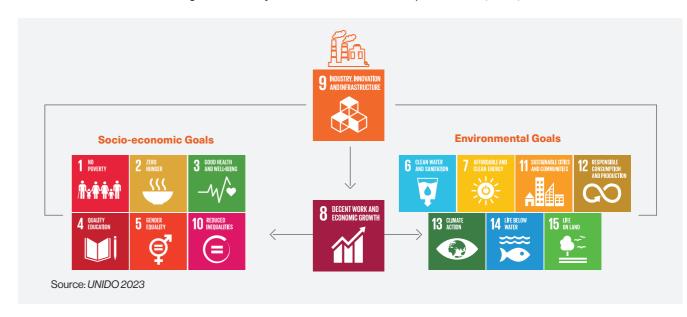
Climate change presents significant economic, business, and social risks, making it crucial for developing countries like India to safeguard the economy and ensure sustained growth.

1.1 Established hubs

Globally, industries represent about 21.4 percent or one-fifth of the global GDP (UNIDO 2023), driving productivity, generating employment, and fuelling a nation's overall development (United Nations n.d.). It supports the development and adoption of greener production technologies, promoting environmental sustainability alongside economic and social progress (UNIDO 2023).

Climate change presents significant economic, business, and social risks, making it crucial for developing countries like India to safeguard the economy and ensure sustained growth. The World Economic Forum (WEF) identifies failure to adapt to climate change as the greatest risk for businesses over a long term (10 years) and the second greatest risk over a short term (2 years) period (Global Risks Report 2024).

Figure 3: Industry and the Sustainable Development Goals (SDGs)



A study with 5,000 large public companies and their exposure to six climate hazards reveals that physical climate risk threatens business operations across all sectors globally, with the manufacturing sector being the most 'exposed' to climate hazards (Moody's 2021). Both heat stress and water stress pose significant threats to companies by impacting labour productivity, water consumption, and energy demand (S&P Global 2021). Climate change adaptation is emerging as a priority area to address these challenges and a pathway to achieving long-term resilience in the global policy landscape.

Climate-related risks affect industries both directly and indirectly. Direct impacts include damage to physical assets such as manufacturing plants, factories, warehouses, equipment, and machinery caused by natural phenomena. Indirect impacts involve supply chain disruptions, affecting raw material availability and hindering logistics and transportation networks (UNEPFI 2023).

The extent of physical risk to Indian industries is influenced by their geographical location and the resilience of their supply chains (UNEPFI 2023). To maintain smooth operations, industries depend on critical infrastructure such as power, water supply, transportation networks, and stable climatic conditions. Any disruptions would expose them to climate hazards (UNEPFI 2023). A notable example is the Chennai floods of 2015, which caused an estimated property loss of INR 14,602 Crores,

making it one of the costliest disasters in India that year, highlighting the financial toll extreme weather events can have on industrial operations (Bandyopadhyay, C. et al. 2021).

As per a recent UNEPFI study, the physical climate risk is particularly acute for resource-intensive activities such as manufacturing, agriculture, transportation, utilities, and mining (UNEP FI, 2024). In India, these climate consequences come at a high price. Rising temperatures and shifting monsoon patterns could reduce India's GDP by 2.8 percent and lower the living standards of nearly half of its population by 2050 (World Bank 2018). In 2021, extreme heat resulted in a USD 159 billion loss in labour capacity across manufacturing, agriculture, construction, and services, equivalent to about 5.4 percent of India's GDP (Climate Transparency 2022).

With the frequency and severity of extreme climate events on the rise, industrial operations are becoming increasingly vulnerable to disruptions, underscoring the urgent need for industries to prioritise climate adaptation measures. Proactive adaptation mitigates potential losses and ensures long-term sustainability by enhancing resilience to climate hazards. Integrating climate risk assessments, diversifying supply chains, and investing in resilient infrastructure are critical steps for safeguarding industrial operations against the growing risk of operational losses.



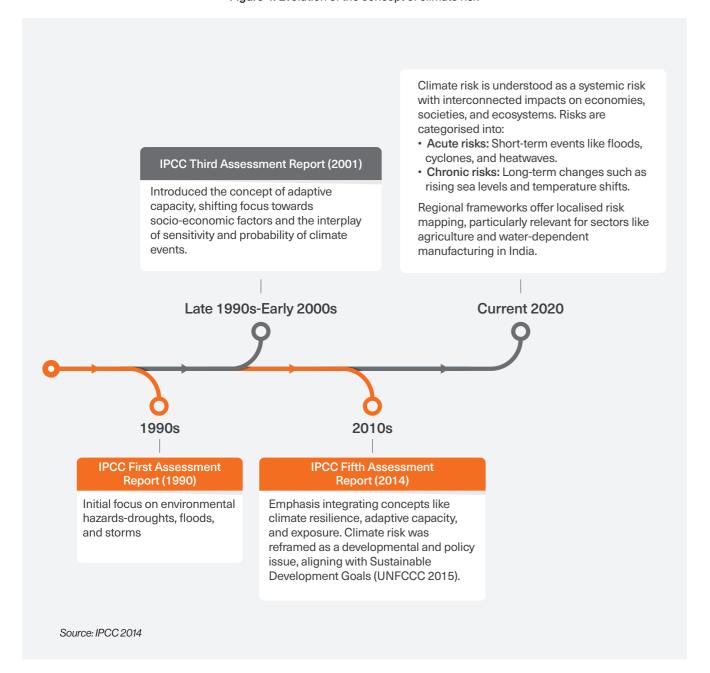


1.2 Understanding climate risk

Climate risk refers to the potential adverse impacts of climate change on physical, environmental, social, and economic systems (IPCC 2014). The concept of climate risk has significantly evolved, reflecting the growing awareness of climate change and its impacts. Early definitions of climate risk focused on the physical impacts of climate change, such as the likelihood of droughts, floods, and storms (IPCC 1990). Primarily defined in terms of environmental hazards, with limited focus on socio-economic and policy dimensions.

By the late 1990s and early 2000s, the concept expanded to include the vulnerability of communities and ecosystems to these changes. The IPCC's Third Assessment Report (2001) introduced the idea that climate risk is a combination of the probability of climate events and the sensitivity of systems to those events, highlighting the importance of adaptive capacity (IPCC 2001). This marked a shift towards integrating socio-economic factors into the climate risk discourse.

Figure 4: Evolution of the concept of climate risk

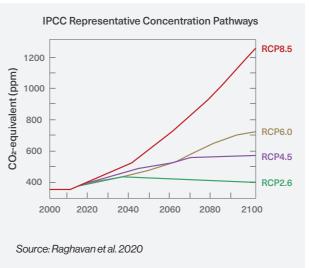


The 2010s saw further refinement with the introduction of frameworks that emphasised resilience and adaptation to climate change. Concepts such as climate resilience, adaptive capacity, and exposure were integrated into climate risk assessments, making it clear that managing climate risk involves reducing vulnerability, improving governance, and fostering innovation (IPCC 2014). The notion of climate risk expanded from being solely an environmental concern to encompassing developmental and policy issues, particularly within the framework of sustainable development goals (UNFCCC n.d.).

Representative Concentration Pathways (RCPs) provide a framework to study the potential impacts of climate change by simulating different future greenhouse gas emission scenarios and are a set of scenarios used in climate projections that outline different possible future trajectories of GHG concentrations (Coast Adapt, 2014). RCPs complement this framework by offering scenarios that model future greenhouse gas emissions (GHGs) and their potential impacts on global temperatures and climate systems. With their use, this study explores how varying emission pathways influence the risks posed by climate change in India, enabling more targeted strategies for mitigation and adaptation.

The pathways are labelled after their projected radiative forcing values in the year 2100 (2.6, 4.5, 6, and 8.5 W/m², respectively). More information on the RCP scenarios is placed in the Annex.

Figure 5: IPCC Representative Concentration Pathways



Scenarios for RCP 4.5 and RCP 8.5 using the PCRAF

As climate patterns become more unpredictable, industries must adopt adaptive measures and resilience strategies to mitigate future risks and ensure long-term sustainability.

To understand these variabilities better, the IMD (India Meteorological Department) uses two different Representative Concentration Pathway (RCP) scenarios to calculate climate projections. RCP 4.5 is a stabilisation scenario where emissions peak by mid-century and then decline due to significant mitigation efforts, resulting in a warming of approximately 2.4°C above pre-industrial levels by 2100 (IPCC 2014). RCP 8.5 represents a high-emissions scenario with minimal mitigation, leading to unrestrained growth in emissions and a more extreme warming of about 4.3°C by 2100 (IPCC 2014).

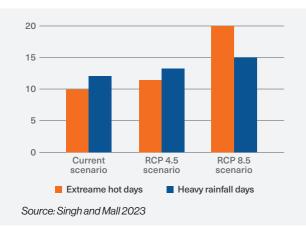
Under RCP 4.5, IMD projections indicate a gradual increase in extreme heat events over the decades, particularly in the northern and central regions. By mid-century, the number of hot days (days with temperatures exceeding 35°C) could increase by 15-20% compared to the historical baseline (refer to Figure 6). However, stabilisation efforts under this scenario could prevent a catastrophic increase in heatwave duration and intensity, providing a somewhat more manageable adaptation window. Similarly, extreme rainfall events are projected to intensify under RCP 4.5, with a 5-10% increase in the annual maximum one-day rainfall events, particularly during the monsoon.

RCP 8.5 paints a much grimmer picture with no significant emission curtailment. Extreme heat events are projected to escalate dramatically after 2050 with a doubling of heatwave days in key regions, with some areas enduring prolonged periods of temperatures above 40°C by 2100. The annual maximum one-day precipitation could also increase by 20-25% under RCP 8.5. Figure 6 provides a visualisation of projected extreme hot days and heavy rainfall days under both scenarios. Monsoon patterns are likely to become highly erratic, characterised by intense downpours interspersed with extended dry periods. This variability is expected to further strain water resources, agriculture, and infrastructure, leading to increased flooding and drought risks (Singh and Mall 2023).





Figure 6: Projected changes in hot days and extreme rainfall under different emission scenarios



Climate risk is increasingly being recognised as a systemic issue, interconnected with economies, societies, and ecosystems. Climate risk assessments now incorporate long-term projections and account for socio-political, economic, and cultural dimensions (Stern 2007). Additionally, many regional frameworks, such as the climate risk assessment study done in Himachal Pradesh, using the Climate Risk Management (CRM) framework for India developed by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and National Institute of

Disaster Management (NIDM) (CRM, GIZ, 2020), the study on climate variability trend and extreme indices for the Thanjavur Delta region of Tamil Nadu by Centre for Climate Change and Disaster Management (CCCDM), Anna University (Srinivasan, Pavithrapriya et al. 2024), among others, have emerged to map risks at more localised levels, providing granular insights into vulnerability and adaptive capacity at regional and national scales. Over time, climate risk has evolved to include complex interdependencies between climate systems and human activities, and for businesses- it highlights differential vulnerabilities across sectors in supply chains, infrastructure and resource availability. Across supply chains, infrastructure, and resource availability.

Physical climate risks are categorised into two broad categories: acute risks, such as floods, cyclones, and heatwaves, and chronic risks, like rising sea levels and long-term temperature changes (UNEPFI 2023). These risks are particularly pertinent for Indian industries due to the country's geographical diversity, reliance on critical infrastructure, and exposure to climate-sensitive sectors like agriculture and water-dependent manufacturing. Figure below provides an overview of these impacts on the Indian industry.

Figure 7.a: Mapping the impacts of physical climate risks across the industrial supply chain









Acute Risk

Acute physical risks rise from rapid onset hazards such as cyclones, floods, extreme precipitation, usually driven by an individual event.

Operations

- · Damage to production facilities, machinery and power sources.
- · Damage to/ reduced crop yield causing risk to raw material supply and price volatility.
- · Increased risks to employee health and safety.

Supply Chain

- · Disruption in transportation.
- · Price volatility of raw materials due to disruptions in the supply chain.

Market

- · Temporary operational shutdown.
- · Increase in cost of services.
- · Immediate expenses for cleaning premises and restarting operations.
- · Altered product demand in consumer markets.







Chronic Risk

Chronic physical risks are a result of long-term shifts in climate patterns, also known as slow-onset disasters. It includes hazards such as heatwayes, droughts, rising daytime & night-time temperatures, and sea level rise.

- · Risk to water-intensive operations and manufacturing.
- · Reduced worker productivity.
- · Risk to employee health and productivity.
- · Damage to sensitive machinery and equipments.
- · Reduced harvest and crop yield.
- Increased costs due to disrupted energy access, water availability, and changing soil patterns.

Supply Chain

- · Decline in raw material availability.
- · Transportation/shipping disruption.

Market

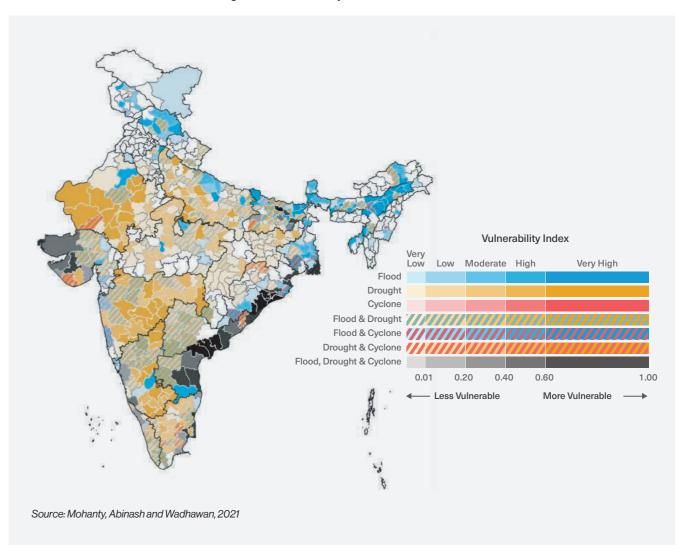
- · Increased overall energy demand and cost of generation.
- · Increased cooling energy demand or demand for other forms of climate control.

Source: Compiled from Moody's 2021; UNEPFI 2023; Network for Greening the Financial System 2020

In India, the number of extreme climate events have increased significantly from 1970 to 2019, with a prominent acceleration between 2000 and 2019 (Mohanty 2020). Climate vulnerability assessment

undertaken for 27 of 35 states and UTs are highly vulnerable to extreme hydro-meteorological disasters and their compounded impacts (Figure 7.b).

Figure 7.b: Vulnerability Index for Indian States



1.3 Assessing climate risk

There are global frameworks recognised for understanding and managing climate risk that provide a structured, standardised approach to identifying, assessing, and mitigating climate impacts. The Task Force on Climate-Related Financial Disclosures (TCFD) (now International Sustainability Standards Board, ISSB) is one of the most widely accepted global frameworks that offers recommendations for integrating climate risks into corporate strategy and decision-making.

In India, there is the National Disaster Management Plan (NDMP), released in 2016 and revised in 2019, which integrates climate risks into disaster preparedness and response, focusing on disaster risk reduction through pre-emptive planning and community resilience measures (NDMP, 2019). However, the Government of India has not yet adopted a national-level framework for assessing the impacts of physical climate risks.



2(0) YEARS OF CELEBRATING SUSTAINABILIT

The Climate Resilience Information System and Planning (CRISP-M), launched by the International Institute of Environment and Development (IIED) and the Madhya Pradesh Council of Science and Technology (MPSCT), provides granular risk assessments for local governments, enabling climate-resilient planning (IIED 2022). Similarly, the India Climate Risk Atlas by the Centre for Study of Science, Technology and Policy (CSTEP) offers projections based on spatial and sectoral analyses of risks from extreme events such as floods, droughts, and cyclones (CSTEP 2022), and the Climate Vulnerability Index developed by the Council on Energy, Environment and Water (CEEW), which evaluates district-level risks by integrating environmental, social, and economic indicators (Mohanty and Wadhawan 2021). National organisations like the National Institute of Disaster Management (NIDM) and the Department of Science and Technology (DST) have also released physical climate risk management and assessment frameworks (NIDM and GIZ 2019; DST 2024). These frameworks highlight the importance of tailored risk assessments to address India's varied climate challenges.

1.4 Adaptation: A businesses case

Growing adaptation focus

According to the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5), adaptation is the "process of adjusting to actual or expected climate impacts that span across ecological, social, and economic systems" (IPCC 2014, Biagini et al. 2014). The UNFCCC further elaborates that these adjustments can include "processes, practices, and structures of ecological, social or economic systems" (UNFCCC n.d). An adaptation strategy with the overarching objective of reducing vulnerability to climate change impacts (IPCC 2014). In a business context, these strategies work best when- (1) there is an understanding about the impacts of extreme climate events on value chains, key operations and human resources; (2) the recommendations are tailored to the unique context of specific hazards, geographies, sectors, and climate scenario predictions (WEF 2023).

Identifying the most critical risk to a business requires comprehensive identification, assessment and quantification of the climate risks faced by it across its entire supply chain. This thorough assessment helps develop adaptation strategies tailored to various industrial sectors and operations. For example, in the food-processing industry, cold storage facilities and temperature-controlled transport are crucial for maintaining the supply chain, whereas maintaining the supply of critical raw materials is a priority for the iron and steel industry (Nastasijević et al., 2022). Adaptation strategies also vary depending on the geographies. An industrial unit near the coast may need to protect itself from water inundation during cyclones or coastal floods. In contrast, an inland industrial unit might need measures to safeguard against extreme heat or water scarcity to continue uninterrupted operations.

There are several inherent challenges to the nature of adaptation, particularly for private sector entities. Lack of mandates or clear policy guidelines pertaining to each sector, incomplete awareness of the nature of risk faced by them, that further leads to incomplete skill development and training and lack of funds allocated for building resilience. Developing this risk to define remediating strategies for specific sectors is a first step towards. Providing this pathway to relevant stakeholders can help prioritise actions for businesses, thus encouraging them to allocate required funds in a phased manner.

Adaptation and industry

The required recognition and quantification of physical climate risks to the industries is an area that is slowly gaining momentum (PwC 2021). However, in the Indian context, the lack of a structured framework for assessing and addressing these risks hinders proactive response and planning, leading to various economic and financial losses by industries during the onset of extreme climate events (Bressan et al. 2024). Despite the increasing threat of physical climate risks, adaptation efforts remain significantly slow, with less than 8 percent of global climate finance directed toward resilience projects (S&P Global 2023). Businesses often overlook adaptation because of its preventive nature and the delayed visibility of its benefits (Gold Standard 2024) According to the World Bank, investments in climate

adaptation typically offer a benefit-to-cost ratio of 4:1 (World Bank 2019). Despite this, many businesses perceive adaptation more as a regulatory obligation than a strategic opportunity, with 43 percent of companies perceiving it as an expense rather than a tool for resilience and competitive advantage (Micale et al. 2018, Gold Standard 2024). Investing in adaptation strengthens operations and supply chains, and secures potential returns on investments. One survey with 6,871 companies across sectors and countries shows that only 21 percent of private entities have have climate adaptation strategies and plans; even among these, many lack a dedicated timeline and implementation plan (S&P Global 2024). This gap highlights the need for deeper engagement with the industry stakeholders to generate awareness and enhance capacities on physical climate impacts as a material risks and potential adaptation solutions.

Increased exposure to climate hazards, such as floods, droughts, and heatwaves, negatively impacts business operations, supply chains, and long-term sustainability. For instance, industries relying on water-intensive processes may face operational disruptions due to water scarcity or pollution exacerbated by climate change. The World Bank notes that India is among the world's most water-stressed countries, with a significant portion of its population facing high to extreme water stress (World Bank 2023). Additionally, investments in infrastructure that are not climate-resilient may incur substantial financial losses. The 'District-Level Climate Risk Assessment for India' report by DST highlights that almost two-thirds of India's districts are threatened by falling groundwater levels, with water scarcity potentially affecting at least 25 percent of India's agriculture if current trends persist (DST 2024).

This can lead to adaptation measures that fail or worsen the underlying vulnerabilities to climate risk, also known as 'maladaptation'. To mitigate these risks, industries must integrate climate risk assessments into business strategies, invest in climate-resilient infrastructure, and ensure that adaptation measures are flexible and responsive to evolving climate scenarios. Government policies and industry guidelines that promote climate adaptation

planning can also reduce maladaptive practices, providing a more sustainable path forward (Niti Aayog 2022).

Proactively investing in resilient infrastructure along with nature-based solutions (NbS) reduces downtime and mitigates risks. The Global Commission on Adaptation report estimated that every USD 1 invested in adaptation could result in USD 2–10 in net economic benefits (WEF 2023; GCA 2019). And the World Economic Forum report estimates the cost of inaction to be as high as a decrease of 11-18 percent in the global economic output, by 2050 (WEF 2023).

Additionally, companies across 16 sectors, in a CDP analysis (2021), that are integrating adaptation measures might be better positioned to attract climate-conscious investors and customers, improving their market value (WEF 2023).







1.5 Study design and approach

The literature highlights how industries get impacted by extreme climate events through ripple effects, disrupting supply chains, delaying production, and increasing costs. The United Nations Environment Programme Finance Initiative (UNEPFI 2023) and the World Bank, emphasise the importance of assessing and reporting both transitional and physical risks by the industries. Conducting comprehensive climate risk assessments and investing in adaptation strategies is essential for industries to safeguard their operations and financial stability, to seize opportunities for innovation and market leadership in a rapidly changing global landscape. A review of literature was undertaken that included reports from the Asian Development Bank (Patankar 2019), German development cooperation (GIZ and SIDBI n.d.), Marsh McLennan, Boston Consulting Group (Castoldi et al. 2024) and McKinsey (Woetzel et al. 2020), among others.

Using a structured approach to assess physical climate risks for industries, to provide actionable strategies for climate-proofing industries by integrating sector-specific insights would contribute to this gap in the literature. This study seeks to address this gap by developing a unified framework and identifying the key challenges within the industry for scaling of climate adaptation. Further, the framework for assessing the physical climate risks provides a list of indicators for quantifying physical risks at the industrial cluster level and outlines the most relevant adaptation strategies in the Indian context for the identified sectors.

Research questions

 What physical climate risks do Indian industries face due to extreme climate events, and how can we quantify them?

- 2. What are the key gaps and challenges that hinder industries from assessing physical climate risks and reporting climate-related disclosures?
- 3. How can we build the resilience of Indian industries to climate change, and what implementable and scalable adaptation strategies can be suggested?

Objectives

- Develop a framework for climate risk assessment and adaptation planning, focusing on extreme events like floods, droughts, and cyclones for prioritised sectors.
- Create a set of possible overall and sector-specific adaptation strategies involving technology, policy, finance, early warning systems, and disaster management.
- Build capacity among stakeholders in the prioritised sectors by helping them understand climate risks and recommend suitable adaptation strategies effectively.

Limitations

- The focus of the study is limited to three major industrial sectors: automobile, food processing, and iron and steel. The risk assessment will be specific to these industries and their prioritised industrial clusters/ estates in the identified states.
- The industrial statistical data sourced from the Annual Survey of Industries (ASI) on metrics like gross value added (GVA), working capital, and the number and wages of all workers includes data primarily for registered entities only and does not reflect the statistics for unorganised, unregistered, or informal sector enterprises.

2

METHODOLOGY

2.1 Setting the scope: Selecting sectors and states

The study focuses on the most important contributors to the Indian economy that are also susceptible to climate impacts. The literature review examined the classification and categorisation of Indian sectors based on the National Industrial Classification (MoSPI 2008), their contribution to GDP, and other economic parameters from the Annual Survey of Industries (MoSPI 2024). The selection of the states also considers the GVA contribution from the sub-sectors. The final selections were Tamil Nadu for the automobile sector, Odisha for the iron and steel sector, and Maharashtra for the food processing sector.

Agriculture and its associated value chains form the backbone of the Indian economy and are central to ensuring food security. However, both the production and downstream stages of agri-food systems are very susceptible to changes in temperature, rainfall, and soil conditions (FAO 2021), with over half of all shocks to crop production being caused by extreme weather events, highlighting the vulnerability of arable systems to climatic and meteorological volatility (FAO 2021). Manufacturing plays a pivotal role in economic

The literature review examined the classification and categorisation of Indian sectors based on the National Industrial Classification (MoSPI 2008), their contribution to GDP, and other economic parameters from the Annual Survey of Industries (MoSPI 2024).

growth and is particularly prone to climate uncertainties due to its resource-intensive nature (Tingey-Holyoak et al, 2024). The Department of Economic and Policy Research (DEPR) of the Reserve Bank of India (RBI) notes that up to 4.5 percent of India's GDP could be at risk by 2030 due to lost labour hours from climate-induced extreme heat and humidity (RBI 2023).

To select the sub-sectors and the respective states within the manufacturing and agriculture, the study uses the Annual Survey of Industries (ASI) database for data on four metrics- Gross Value Added (GVA), working capital, number of employees, and total wages for 2021-22 (MoSPI 2024) with equal weightage assigned to each.





Table 1: Definition and rational of the four metrics used for selection of the sub-sectors

Criterion	Definition	Rationale
Gross value added (GVA)	GVA is defined as the additional value created by the process of production. It is the difference between output and intermediate consumption.	GVA measures the industry's overall economic contribution. Including it as one of the selection criteria ensures that the study addresses industrial sectors that contribute significantly to the country's overall economy.
Working capital closing	The sum of the physical working capital and the cash deposits in hand and at the bank, land, and the net balance of amounts receivable over amounts payable at the end of the accounting year.	Working capital reflects an industry's financial health. Capital-intensive industries employ a larger workforce and require more significant infrastructure investments, thus accounting for the high exposure of these sectors due to their high economic importance.
Number of employees	All persons engaged directly or indirectly with the manufacturing process, including all administrative, technical, and clerical staff, in the production of capital assets.	Using the number of employees as a criterion for selection ensures an inclusive and holistic approach while evaluating the effects of climate change. These are linked with the potential job impacts due to disruptions and help quantify the impacts of climate risk on the workforce. For example, the loss of productivity due to heat stress.
Wages of all employees	All monetary compensation regularly paid during each pay period to workers for their work throughout the accounting year.	Industry salaries are a crucial gauge of economic significance, reflecting contributions to GDP, innovation and workforce well-being. Competitive wages attract skilled professionals, fostering productivity and reducing unemployment, while stimulating demand, creating a positive multiplier effect on economic activity.

Source: Annual Survey of Industries (ASI) Introduction, MoSPI

Table 2: Identifying the most significant sub-sector under the manufacturing and agriculture sectors

Industry type	Selection criteria			
Industry type	GVA (in crore INR)	Working Capital (in crore INR)	Number of employees (in lakhs INR)	Wages of all employees (in crore INR)
Automobiles*	135,459	81,967	10,38,763 (~10 Lakhs)	62,349
Iron and steel**	341,541	111,227	11,75,314 (~11 Lakhs)	57,483
Cereal and Dairy***	142,260	156,378	14,69,229 (~14 Lakhs)	52,240

Note: Industries are not listed rank-wise. *Automobiles include the Manufacture of motor vehicles, trailers and semi-trailers; **Manufacture of Iron & Steel Industry is the prioritised industry type under the division 'Manufacture of basic metals'; ***Manufacture of food products or Food processing includes 'growing of non-perishable crops', 'cereal industry' and 'dairy industry' as per NIC Code, MoSPI.

Source: (Annual Survey of Industries, MoSPI)

Table 3: States with highest economic contributions from the sub-sectors

Manufacturing of motor vehicles, trailers and semi-trailers: Automobile				
Industry type	GVA (crore INR)	Working Capital (crore INR)	Number of employees (thousands)	Wages of all employees (crore INR)
Tamil Nadu	30,951	34,943	25	10,373
Maharashtra	27,216	9,036	23	10,520
Haryana	26,687	7,994	21	9,913
Karnataka	8.451	7.266	8	3,431

Manufacturing of basic metals: Iron and steel					
Industry type	GVA (crore INR)	Working Capital (crore INR)	Number of employees (thousands)	Wages of all employees (crore INR)	
Odisha	81,292	-2,732	19	8,619	
Karnataka	41,318	16,566	6	2,697	
Maharashtra	39,085	9,586	13	5,711	
Jharkhand	39,067	-8,922	10	5,917	

Manufacturing and processing of food products: Cereals and Dairy					
Industry type	GVA (crore INR)	Working Capital (crore INR)	Number of employees (thousands)	Wages of all employees (crore INR)	
Maharashtra	17,909	18,412	22	6,630	
Uttar Pradesh	14,639	11,573	17	4,781	
Gujarat	13,464	17,332	12	3,636	
Tamil Nadu	11,226	15,438	18	4,075	

Source: Annual Survey of Industries, MoSPI

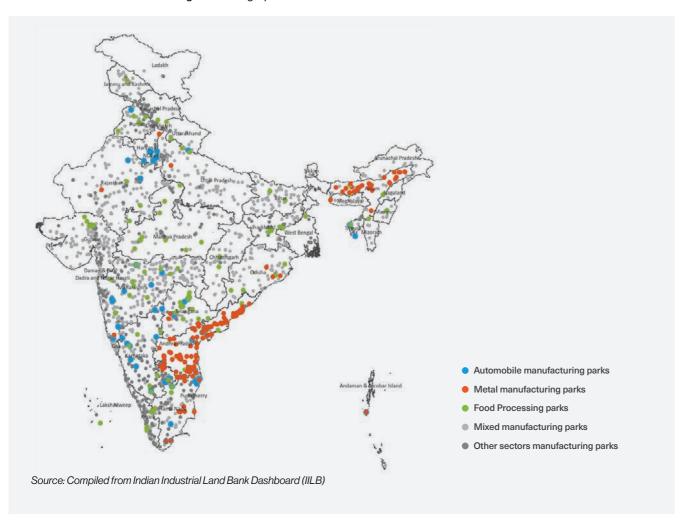
The distribution of the selected sub-sectors' clusters across Indian states highlights the geographic spread and regional concentration of industries, offering insights into the varying levels of exposure and further justifies the selection of the states.







Figure 8: Geographical distribution of industrial clusters in India



2.2 Contextualising the assessment framework

The IPCC AR 5 framework defines 'risk' as the "probability or likelihood of occurrence of hazardous events or trends multiplied by the

impacts if these events or trends occur" and estimates this risk as an interaction between hazard, exposure, and vulnerability (IPCC 2014).

Risk = Hazard * Exposure * Vulnerability (Sensitivity/Adaptive Capacity)

Hazard: "The potential occurrence of climate-related physical events or trends or their physical impacts". (India-level assessment of floods, droughts, and cyclones for a fifty-three-year timeframe between 1970 to 2023; And extreme precipitation and heat stress for the 10 years from 2012-2022 compared to the baseline of the previous 30 years)

Exposure: "The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected". (Including a) Operations exposure, which captures exposure to industries' facilities and assets; and b) Market access exposure, which examines downstream climate risks concerning transportation services and market access)

Vulnerability: "The propensity or predisposition to be adversely affected". Vulnerability's two components- a Sensitivity- involves spatial mapping of the landscape indicators (change in land-use-land-cover, soil moisture, groundwater, and elevation) to climate extremes and b) Adaptive Capacity- evaluating the existing ability of the industries to adapt to the impacts of extreme climate events.

Various studies by Indian government bodies use the IPCC AR5 climate risk assessment framework (Rama Rao, C.A. et al. 2019) (Dasgupta, S. et al. 2024). These studies focus on state or district-level climate risk mapping for various hydro-meteorological hazards for agriculture and population, respectively, leading to a national-level assessment of India's Drinking Water, Sanitation, and Hygiene Systems from Extreme Climate Events (UNICEF and CEEW 2024) (TMC and CEEW 2024) (GIZ 2020).

In this study, a penta-decadal analysis computes the hazards component, which uses extreme climate events data for the period of 50 years, between 1970 and 2023, for floods, droughts, cyclones, heat stress, and excessive precipitation. Following that, a geographic information system (GIS) software is applied to quantify this stress. It is then overlain with the locations of prioritised industries, for the exposure component, and the landscape-based attributes account for sensitivity.

2.3 Assessing adaptive capacity: Selection of indicators

Survey questions were developed with semi-structured interview questions, used to refine and validate the long list of indicators under hazard, exposure and vulnerability through the stakeholder consultations that represented various industries, with 44 participants that included state industrial development organisations such as the Maharashtra Industrial Development Corporation (MIDC) and Tamil Nadu Small Industries Development Corporation Limited (TANSIDCO). The consultations used the Delphi method to collect information through an online questionnaire followed by in-person discussions with the participants to achieve a consensus on ranking indicators and adaptation strategies. Figure 9 visually represents the approach and methodology adopted to develop the unified framework.

In these consultations and surveys, each indicator was evaluated based on i.) relevance to current industry needs, ii.) feasibility of implementation, iii.) clarity of terminology, and iv.) the availability of open-access data. This iterative assessment

process allowed for constructive feedback, balancing between comprehensiveness and applicability and brought out insights crucial for refining the list and narrowing down the total of 102 indicators to 59 practical and actionable key indicators.

In this study, a penta-decadal analysis computes the hazards component, which uses extreme climate events data for the period of 50 years, between 1970 and 2023, for floods, droughts, cyclones, heat stress, and excessive precipitation.







Figure 9: Schematic for the study's methodology

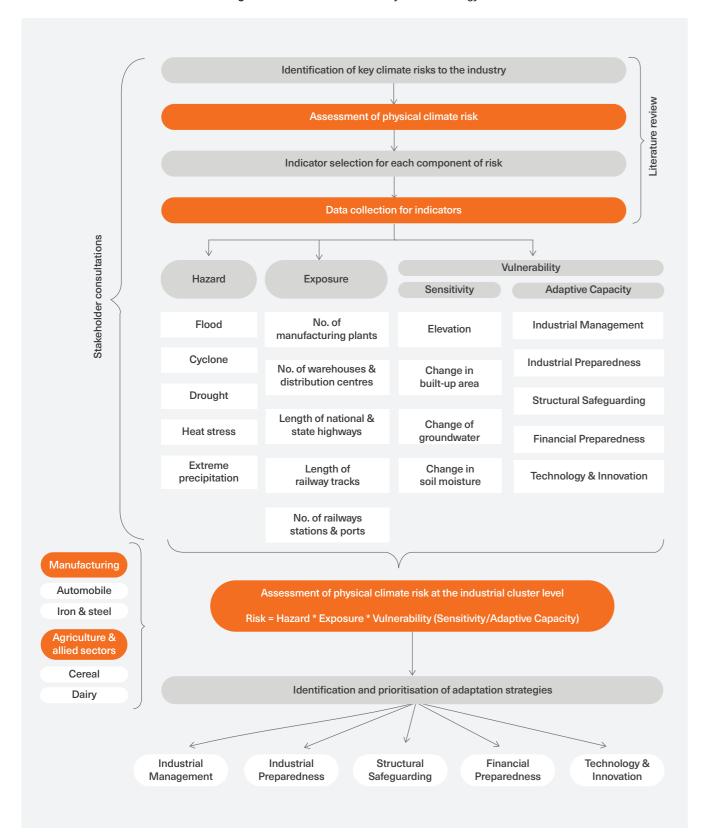


Table 4: Final indicators under each variable for climate risk assessment

Component	Selected indicators	Source	Correlation
	Occurrence of floods in the past 50 years	EM-DAT database	Direct
	Occurrence of droughts in the past 50 years	EM-DAT database	Direct
Past Hazards	Occurrence of cyclones in the past 50 years	EM-DAT database	Direct
	Frequency of hot days in the past 30 years		Direct
	Frequency of heavy rainfall days in the past 30 years	IMP I .	Direct
Projected	Projection of hot days for 20 years	IMD data	Direct
Hazards	Projection of heavy rainfall days for 20 years	IMD data	Direct
	No. of manufacturing plants	Primary data from industry	Direct
	No. of warehouses	Primary data from industry	Direct
	No. of distribution centres	Primary data from industry	Direct
	Distance between industry's plants, warehouses, distribution centres and the coast (in km)	Euclidean distance from coastline	Inverse
Exposure	Distance between industry's plants, warehouses, distribution centres and the water body (in km)	Euclidean distance from water bodies	Inverse
	Length of national highways (in km)	OpenStreetMap Database 2024	Direct
	Length of state highways (in km)	Open Street Map Database 2024	Direct
	Length of railway tracks (in km)	Open Street Map Database 2024	Direct
	No. of railway stations	Indian Railways website	Direct
	No. of ports exposed to cyclones	Indian Ports Association	Direct

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Component	Selected indicators	Source	Correlation
Sensitivity	Change in built-up area (%)	ESRI Sentinel-2 LULC	Direct
	Elevation	United States Geological Survey - SRTM DEM data	Inverse
	Change in groundwater (%)	India - Water Resources Information System	Inverse
	Change in soil moisture (%)	India - Water Resources Information System	Inverse
	Presence of a Business Continuity Plan	Primary data from consultation	Inverse
Adaptive Capacity (Industrial management)	Presence of a Disaster/ Crisis Management Plan	Primary data from consultation	Inverse
	Identifying extreme climate events as a material risk (as per BRSR reporting standards)	Primary data from consultation	Inverse
	Identifying heat-related illness as an occupational hazard (as per the OSH guidelines)	Primary data from consultation	Inverse
	Presence of adaptation strategies to address physical climate risks (as per BRSR reporting standards)	Primary data from consultation	Inverse
	Presence of a nodal/focal point officer for disaster management	Primary data from consultation	Inverse
	Access to flood and cyclone early warning systems	Primary data from consultation	Inverse
	Presence of SOPs for disseminating early warnings for climate action	Primary data from consultation	Inverse
	Sourcing of raw materials from multiple locations	Primary data from consultation	Inverse
	Sourcing of raw materials from nearby locations	Primary data from consultation	Inverse
Adaptive Capacity (Industrial preparedness)	In-house power generation (e.g., captive power, renewable energy)	Primary data from consultation	Inverse
	Presence of power storage solutions (e.g., redox batteries)	Primary data from consultation	Inverse

Component	Selected indicators	Source	Correlation
	Presence of water storage facility for industrial purposes	Primary data from consultation	Inverse
	Presence of a structure for rainwater harvesting	Primary data from consultation	Inverse
	Presence of water treatment facility within industrial premises	Primary data from consultation	Inverse
	Access to emergency water supply tankers	Primary data from consultation	Inverse
	Maintaining safety stock of finished products	Primary data from consultation	Inverse
	Storing raw materials and finished products in multiple locations	Primary data from consultation	Inverse
	Presence of cooling systems (HVAC)/cooling shelters for employees	Primary data from consultation	Inverse
	Elevated platforms for critical machinery/ assets above the base flood level	Primary data from consultation	Inverse
	Rapidly deployable measures to prevent water inundation	Primary data from consultation	Inverse
Adaptive Capacity (Structural safeguarding)	Connection to a functional stormwater drain	Primary data collection	Inverse
	Flood water pumping system connected to a back-up power source	Primary data collection	Inverse
	Elevated platforms for storage of raw materials and finished products above the base flood level	Primary data collection	Inverse
	Backup allocation for training employees for disaster safety	Primary data collection	Inverse
	Periodic repair and maintenance of machinery	Primary data from consultation	Inverse
Adaptive Capacity (Financial preparedness)	Regular maintenance of industrial buildings and assets according to ISO standards	Primary data collection	Inverse
	Insurance coverage for industrial buildings, raw materials, finished products, and transportation facilities	Primary data collection	Inverse

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Component	Selected indicators	Source	Correlation
Adaptive Capacity (Innovation and	Presence of a mechanism to reduce water consumption for industrial operations	Primary data collection	Inverse
Technology)	Research in developing more climate-resilient raw material	Primary data collection	Inverse
	Research and development in building a more climate-resilient supply chain and transportation facility	Primary data collection	Inverse
	Presence of a cold chain transportation facility	Primary data collection	Inverse
	Presence of warehouses and distribution centres with climate-controlling measures (E.g.: HVAC, heat-proof rooftop)	Primary data collection	Inverse



3

INSIGHTS FROM STAKEHOLDER CONSULTATIONS

Adaptation strategies can be 'soft' - denoting operational changes, 'grey' - denoting structural changes or 'green' -adopting sustainable practices or technology. The indicators used for determining adaptive capacity can be classified under these categories.

Table 4: List of adaptation strategies identified from literature review

Category	Key Strategy	Туре	Intervention/s
Industrial Management	Mainstreaming climate resilience considerations into decision-making for businesses	Soft	 Integrating climate risk assessment and adaptation planning into risk management and business continuity planning.
Industrial Preparedness	Facilitating prompt restoration of critical infrastructure and services	Soft	 Establishing response protocols, pre-arranged/post-disaster agreements, emergency contracts Developing response strategies and plans to handle climate-related disruption effectively.
Structural Safeguarding	Increasing the reliability of infrastructure services	Grey	 Incorporating built-in redundancy in the infrastructure redundancy in the infrastructure, (resource recovery systems) with backup power, alternative water supply systems, regular inspections, maintenance, and monitoring mechanisms.
Financial Preparedness	Robust financial planning, tools, and incentives	Soft	 Introducing insurance mechanisms for extreme weather events. Financial incentives for contingency planning, business continuity planning, post-disaster recovery. Offering technical and financial aid to community organisations or NGOs engaged in adaptation efforts. Technical assistance to producers/farmers to increase their resilience to extreme climate events.
Technology and Innovation	Expanding research and development, and investment in new adaptation solutions	Green	 Ensuring long-term water security with wastewater treatment, rainwater harvesting, water storage/reservoir facilities, etc. Building resilience to heat stress with increased usage of heat-tolerant and drought-resistant crops and heat-tolerant livestock variants, etc.





3.1 Consultations in three cities

Adaptive capacity indicators are given priority in this study since industry actors can exercise the most control over this parameter. In the consultations, a list of indicators were presented to the stakeholders, to be ranked in the order of importance, within each indicator category, to determine adaptive capacity. These consultations were undertaken and they were asked to rank indicators in order of importance for

each category of adaptive capacity. Stakeholder consultations were undertaken in phases in New Delhi, Chennai, Mumbai, and Bhubaneswar. The discussions focussed on validating the framework and prioritising the indicators for assessing physical risks to improve its effectiveness and identified components of business operations in India, most impacted by climate events.

Figure 10: Glimpses from various stakeholder consultations



1. Industry stakeholders at the end of a successful consultation in Tamil Nadu



3. Industry stakeholders at the end of a successful consultation in Maharashtra CII Office



5. Industry stakeholders at the end of a successful consultation in Odisha

Source: Images from the stakeholder consultation



2. Meeting with Tamil Nadu Small Industries
Development Corporation Limited (TANSIDCO)



4. Meeting with the Director of State Climate Action Cell, Maharashtra and Consultant Maharashtra Industrial Development Corporation (MIDC)



6. Stakeholders mark the location of their industry on the map of Odisha

During the in-person sessions, the identified strategies were categorised and ranked using 'menti-meter', an online tool that collates real-time inputs to ensure anonymity. The ranking was based on a scale of 1 to 5 corresponding to its potential effectiveness in adapting to climate-related risks, i.e.,

Impact (efficiency, profitability, productivity) and the practicality of implementation, considering the current resources and the capacities of the stakeholders involved, i.e., Feasibility (time, resources, potential loss avoided).

Figure 11: The following figures show the menti-meter process, the feasibility and impact quadrants and the ranking of the sub-indicators under each indicator category



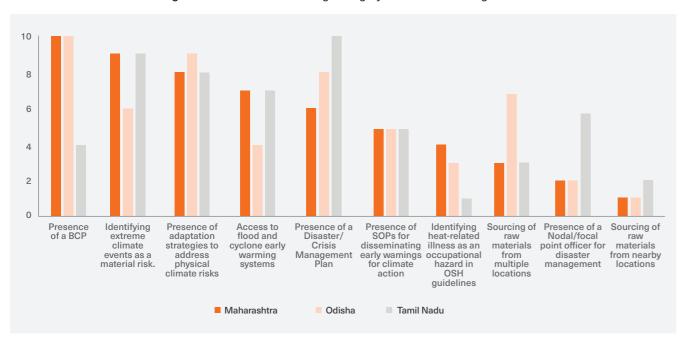
3.2 Ranking adaptive capacity sub-indicators

Adaptive capacity is determined using the 5 indicator categories and ranking of the sub-indicators under each, during the stakeholder consultations

conducted in the 3 states. Ranking in this manner demonstrates the unique needs and priorities of the diverse stakeholders.



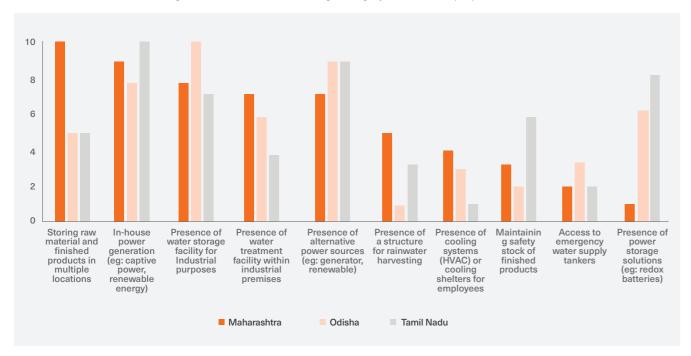
Figure 12: Sub-indicator ranking- Category 1- 'Industrial management'



Key Takeaways: Heat-related illness for workers is anticipated as a severe issue in food processing and steel industries relative to the automobile sector, where processes are comparatively automated and in closed environments. Early warning systems in Odisha are more robust because of state initiatives

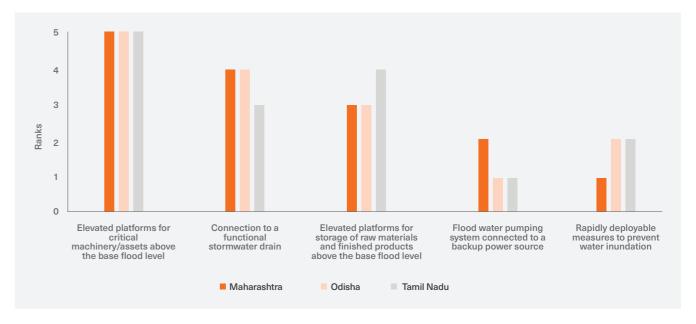
and open access public data, particularly EWS. In contrast, the automobile industry representatives indicated that the presence of nodal officers for disaster management was significant, while for the iron and steel industry, it was a diversified sourcing of raw materials.

Figure 13: Sub-indicator ranking- Category 2- 'Industrial preparedness'



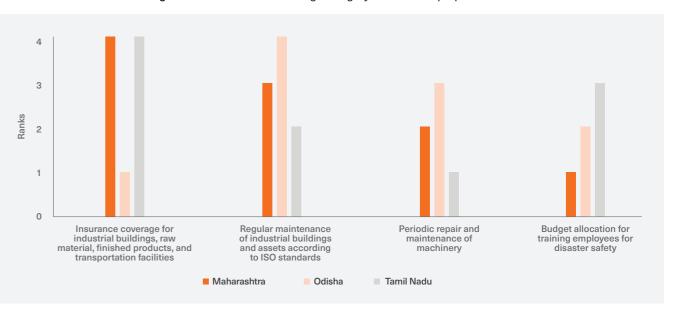
Key Takeaways: As highlighted by stakeholders from the iron and steel industry during the consultation, any disruption in power supply leads to cascading impacts on reheating furnaces. Thus, the presence of alternative power sources is ranked higher by the iron-steel and automobile industry as their assembling are almost entirely automated. For food processing industries, raw materials and finished products are perishable and sensitive to climatic extremes; thus, storing raw materials and finished products in multiple locations is ranked high by food processing industries.

Figure 14: Sub-indicator ranking- Category 3- 'Structural safeguarding'



Key Takeaways: Repair costs and longer recovery time objectives of capital-intensive assets and machinery are an extensive burden on industries; thus, elevated platforms to prevent damage from water inundation are ranked highest by all industrial sectors.

Figure 15: Sub-indicator ranking- Category 4- 'Financial preparedness'



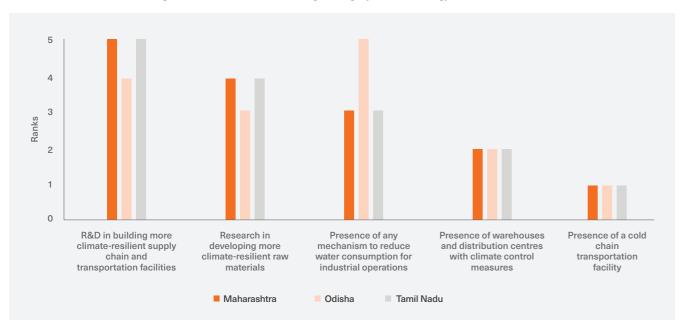




Key Takeaways: Industry actors have highlighted insurance coverage as the most crucial indicator from a financial perspective since it offers protection and helps industries recover from losses caused by

extreme events. Industries already engage in regular maintenance and repair of machinery, highlighting its importance for operational reliability.

Figure 16: Sub-indicator ranking- Category 5- 'Technology and Innovation'



Key Takeaways: Some industry experts also highlighted that since R&D budgets for companies are focused on their product development, they

prefer to invest in deploying best practices to safeguard from climate hazards.

3.3 Assigning weights

The study assigns weights to the sub-indicators based on ranks collected from three consultations with varying participant numbers, a weighted average is calculated for each indicator category, that reflects the influence of each consultation proportionately. For example, suppose Consultation 1 had 50

participants, Consultation 2 had 30, and Consultation 3 had 20. If Strategy A is ranked 1st in Consultation 1, 2nd in Consultation 2, and 3rd in Consultation 3, weights are assigned to these ranks by factoring in the number of participants. The weighted rank of Strategy A is calculated as follows:

Weighted Rank =
$$\frac{(50 \times 1) + (30 \times 2) + (20 \times 3)}{50 + 30 + 20} = \frac{50 + 60 + 60}{100} = 1.7$$

This weighted rank gives a consolidated measure that accounts for both the popularity of the strategy in each consultation and the size of the group providing the feedback, ensuring fair representation of all voices.

Table 6: Final weights of sub-indicators within each adaptive capacity indicator category

Category	Indicator	Final rank within the category	Weighted score
	Presence of a Business Continuity Plan	4	0.13
	Presence of a Disaster/ Crisis Management Plan	1	0.18
	Identifying extreme climate events as a material risk (as per BRSR reporting standards)	2	0.16
	Identifying heat-related illness as an occupational hazard in OSH guideline	9	0.04
	Presence of adaptation strategies to address physical climate risks (as per BRSR reporting standards)	3	0.15
Industrial management	Presence of a nodal/focal point officer for disaster management	7	0.07
	Access to flood and cyclone early warning systems	5	0.11
	Presence of SOPs for disseminating early warnings for climate action	6	0.09
	Sourcing of raw materials from multiple locations	8	0.05
	Sourcing of raw materials from nearby locations	10	0.02
	In-house power generation (e.g., captive power, renewable energy)	1	0.18
	Presence of alternative power sources (e.g., generator, renewable)	2	0.16
	Presence of power storage solutions (e.g., redox batteries)	5	0.11
	Presence of water storage facility for industrial purposes	3	0.15
Industrial	Presence of a structure for rainwater harvesting	8	0.05
preparedness	Presence of water treatment facility within industrial premises	6	0.09
	Access to emergency water supply tankers	9	0.04
	Maintaining safety stock of finished products	7	0.07
	Storing raw materials and finished products in multiple locations	4	0.13
	Presence of cooling systems (HVAC)/cooling shelters for employees	10	0.02





Category	Indicator	Final rank within the category	Weighted score
	Elevated platforms for critical machinery/ assets above the base flood level	1	0.33
Structural	Rapidly deployable measures to prevent water inundation	4	0.13
Safeguarding	Connection to a functional stormwater drain	3	0.20
	Flood water pumping system connected to a backup power source	5	0.07
	Elevated platforms for storage of raw materials and finished products above the base flood level	2	0.27
	Budget allocation for training employees for disaster safety	3	0.20
	Periodic repair and maintenance of machinery	4	0.10
Financial Preparedness	Regular maintenance of industrial buildings and assets according to ISO standards	2	0.30
	Insurance coverage for industrial buildings, raw materials, finished products, and transportation facilities	1	0.40
	Presence of a mechanism to reduce water consumption for industrial operations	3	0.20
	Research in developing more climate-resilient raw material	2	0.27
Technology and Innovation	Research and development in building a more climate-resilient supply chain and transportation facility	1	0.33
	Presence of cold chain transportation facility (temperature-controlled transportation facility)	5	0.07
	Presence of warehouses and distribution centres with climate-controlling measures (E.g., HVAC, heat-proof rooftop)	4	0.13

3.4 Linear scale normalisation

Also known as min-max normalisation, this helps rescale data values to a specific range, often between 0 and 1 (Moreira, Luana Lavagnoli et al. 2021), reducing the impact of varying scales among

categories, improving model convergence and performance. The normalisation formula for the indicators with direct and indirect correlation to the core-indicator in each category is:

	Direct	Indirect
	x - min(x)	min(x) - x
x'=	max(x) - min(x)	$x' = \frac{1}{\max(x) - \min(x)}$

The following schematic, Figure 17, shows the whole ranking process for each indictor category and sub-indicators.

Figure 17: Schematic on ranking indicators in different stages









RESULTS AND FINDINGS

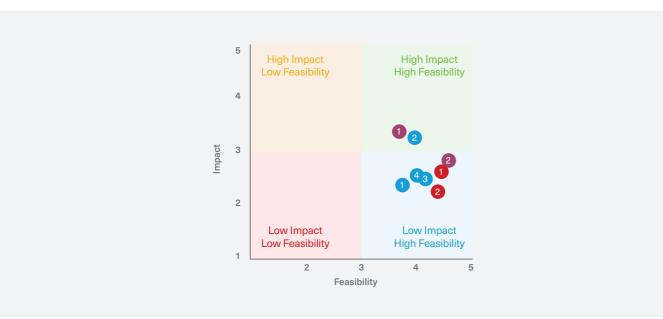
4.1 Prioritising adaptation strategies

4.1.1 Ranking exercise for adaptive capacity: Impact vs. feasibility

The rankings obtained for different adaptation strategies reveal the differences in operationality

and functionality of different industrial sectors among various states. This variation is largely due to the unique risks and challenges faced by specific stakeholders and their circumstances.





When plotted on a graph, most of the adaptation strategies ranked are in the high-impact sites are in the high-impact and high-feasibility quadrant, with a few in the low-impact and high-feasibility quadrant.

Table 7: Final impact and feasibility score of different adaptation strategies

Indicator	Impact score	Feasibility score
Industrial Management		
Conducting climate risk assessment and ensuring transparent disclosures	3.40	3.47
Climate resilient considerations in the Business Continuity Plans	3.77	3.40
Robust business continuity planning and management	3.63	3.80
Developing emergency/contingency plans	3.53	3.87
Implementing ecosystem management practices across businesses' operations and supply chains	3.50	3.27
Leveraging adaptation opportunities contributing to net-zero transition	3.70	3.13
Industrial Preparedness		
Using climate monitoring/early warning systems	4.33	4.17
Providing emergency preparedness training to workers and employees	3.80	4.33
Providing technical assistance and capacity building for suppliers/producers across the supply chain	3.43	2.83
Regionally diversifying the buyer base	3.73	3.53
Risk-informed agreements with partners across global value chains	4.33	4.17
Structural Safeguarding		
Using climate defences for existing infrastructures	4.33	4.17
Increasing the reliability of infrastructure services	3.73	3.57
Increasing investments in climate-ready assets	3.93	2.97
Facilitating prompt restoration of critical infrastructures and services	3.80	3.03
Financial Preparedness		
Robust financial planning and tools for building climate resilience	4.17	3.13
Providing financial incentives	4.07	2.80
Technology & Innovation		
Using digital technologies to embed redundancy into infrastructure system design and operations	3.60	3.67
Expanding research, development, and investment in new adaptation solutions	4.23	3.20

Source: Compiled from stakeholder consultations





The higher the impact and feasibility score of the adaptation solutions, the more viable the strategies are for implementation. However, since most of the strategies lie in the high impact, high feasibility category (score 3-5), it's important for the industry to prioritise them according to their risk scores.

4.1.2 Gaps and challenges

- The Indian industry is beginning to recognise physical climate risks, with some industries beginning to explore management beyond mitigation, through climate adaptation strategies like diversifying raw materials, ensuring water security, and alternative power sources. However, challenges such as supply chain disruptions, operational downtime, and diminished worker productivity due to extreme weather events, thus maintaining and contributing to overall resilience, remain significant.
- Stakeholders stressed the need for government intervention to mandate climate risk reduction measures and regulatory support to improve industry readiness through clear policy guidelines. Limited awareness and technical expertise among suppliers and operators highlight the need for regular training and workshops on climate impacts and the role of adaptation.
- State industrial development authorities noted that Small and Medium Enterprises (SMEs) are particularly vulnerable to extreme weather events, while larger industries are better equipped.
 Collaboration, sharing best practices, and collective action across the industry, in an ecosystem-based approach, are essential for building resilience.

Table 8: Defining the range of adaptive capacity scenarios

Scenarios	Scores
Low Adaptive Capacity: Industries are assumed to have inadequate infrastructure, minimal coverage of early warning systems, and weak governance with limited community engagement. In these industries, the ability to respond to and recover from climate events was significantly compromised.	0.1-0.49
Moderate Adaptive Capacity: Industries are assumed to have some adaptation measures in place, like adequate infrastructure and proactive governance. However, some elements, such as coverage of EWS and limited community engagement, reduce their capacity to respond to and recover from climate events.	0.5-0.89
High Adaptive Capacity: Industries are assumed to have robust infrastructure, well-established EWS, and proactive governance with strong community involvement. These industries were well-prepared for climate impacts, with resources allocated efficiently to mitigate risks.	0.9-1.00

The assumptive scenario analysis reveals that increasing adaptive capacity scores alone can lead to a significant reduction in overall risk. By enhancing factors such as infrastructure resilience, access to resources, and emergency response

mechanisms, among others, industries can meaningfully lower their vulnerability. Figures 19 to 21 below represent the adaptive capacity scenarios and the overall risk score for the identified clusters.

Figure 19: Physical climate risk assessment for the automobile industry in Tamil Nadu across three adaptive capacity scenarios

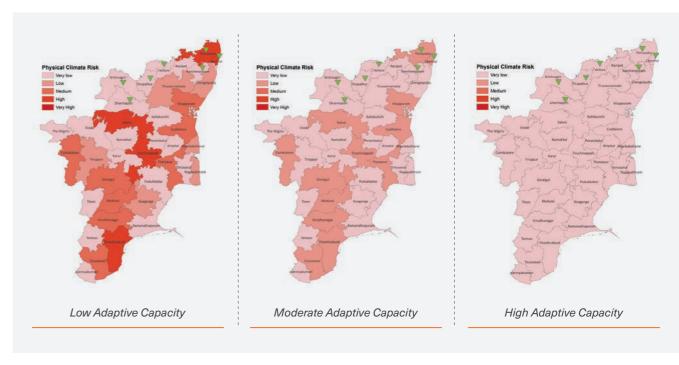


Figure 20: Physical climate risk assessment for the dairy industry in Maharashtra across three adaptive capacity scenarios

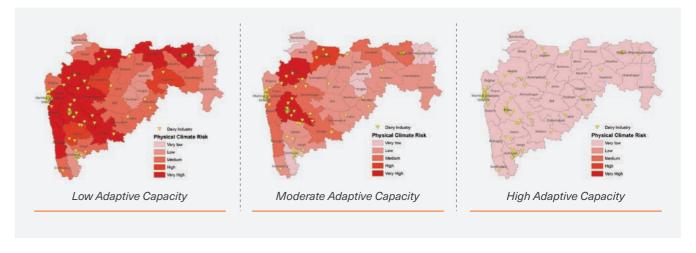
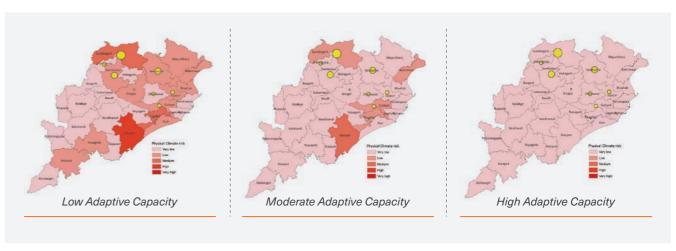


Figure 21: Physical climate risk for the iron and steel industry in Odisha across three adaptive capacity scenarios







4.2 PCRAF and the risk scores

The IPCC AR5 risk assessment framework enables the integration of sector-specific vulnerabilities with localised climate hazards; by combining the validated indicators of hazard, exposure, sensitivity, and adaptive capacity, the assessment provided a better understanding of the potential climate risks and their implications for the industrial sectors, enabling more targeted and effective adaptation strategies.

Figure 22-(a): Overall risk key for all variables

Categories of risk → Components of risk ↓	Very low	Low	Moderate	High	Very high
Hazard	0- 0.20	0.21- 0.40	0.41- 0.60	0.61- 0.80	0.80- 1
Exposure	0- 0.20	0.21- 0.40	0.41-0.60	0.61- 0.80	0.80- 1
Senitivity	0- 0.20	0.21- 0.40	0.41- 0.60	0.61- 0.80	0.80- 1
Adaptive Capacity*	0- 0.20	0.21- 0.40	0.41- 0.60	0.61- 0.80	0.80- 1
Risk	0- 0.20	0.21- 0.40	0.41-0.60	0.61- 0.80	0.80- 1

^{*}Note: Hazard, Exposure and Sensitivity are directly proportional to risk, while Adaptive capacity is inversely proportional to risk. An increase in adaptive capacity will decrease the risk.

To assess how climate risk varies with adaptive capacity, the degrees of adaptive capacity, is categorised as-low, moderate, and high adaptive capacity, based on several sub-indicators.

Figure 22-(b): Overall risk categories

Very low (0-0.2) and Low Risk (0.21-0.4):

Clusters with low scores are less likely to experience some disruption due to climate hazards, with low impact and/or low frequency. Although they typically have strong adaptive capacity or minimal exposure.

High Risk (0.6- 0.8):

Clusters with high-risk scores are vulnerable to frequent or intense climate events. Their exposure is significant, and their adaptive capacity is limited, which could result in severe disruption of industrial activities.

Moderate Risk (0.41-0.6):

Clusters with moderate risk scores are subject to occasional or moderate climate impacts. These areas may have some adaptive capacity, but gaps in infrastructure, preparedness, or responses leading to operational challenges.

Very High Risk (0.81-1):

These clusters are extremely vulnerable to climate hazards, with high exposure and low adaptive capacity. Immediate attention is required to develop or enhance resilience measures, as these areas are at the greatest risk of sustained operational impacts from delayed recovery.

4.3 Results from the site assessment

4.3.1 Automobile in Tamil Nadu

Tamil Nadu features a diverse topography that includes coastal plains, fertile river basins, hills, and plateaus, a region known for its biodiversity.

Chennai has one of India's oldest and largest ports, making it a strategic location for industries to set up. Chennai has been prone to extreme weather events. The 2015 Chennai floods, caused by unprecedented rainfall, highlighted the city's vulnerability to climate-related disasters.

Conversely, the region has also experienced severe droughts, such as during the 2019 water crisis, when reservoirs dried up due to deficient rainfall. These extremes underscore Chennai's sensitivity to climate variability, emphasising the need for robust urban planning and climate resilience measures (Mohanty and Wadhawan 2021). The pilot assessment was conducted in two clusters of the automobile industry in the state, using the identified indicators across all components of risk.

Table 9: PCRAF for the automobile industry in Tamil Nadu

	Hazard x Exposure x (Sensitivity/Adaptive Capacity) = Risk					
Site	District	Hazard	Exposure	Sensitivity	Adaptive Capacity	Risk
Α	Chennai	1.00	0.42	0.21	0.13	0.70
В	Chennai	1.00	0.41	0.21	0.09	0.95

Source: Analysis using PCRAF

Both industry A and B are in Chennai, making their hazard and sensitivity profile similar but industry A which is closer to the coast makes it more exposed to cyclone, but having better adaptive capacity score puts it at a lesser risk level as compared to industry B. Both fall into high and very high-risk categories.

4.3.2 Food processing in Maharashtra

Maharashtra, also features a diverse landscape, including the Western Ghats, the Deccan Plateau, rivers like the Godavari, Krishna, and Tapi supporting agriculture and livelihoods, and a long coastline along the Konkan region.

The north-south alignment of the Sahyadri mountain range forms a natural divide, shaping the climate of Maharashtra's coastal districts, differently from the rest of the state. This separation leads to distinct climatic patterns, with the western slopes and coastal areas receiving heavy monsoon rainfall. In contrast, the Deccan Plateau lies in a rain shadow region, resulting in significantly less rainfall.

The risk assessment for food processing and dairy industry was done for 2 industries, one food processing industry cluster in Thane, and one dairy industry cluster in Nagpur.

Table 10: PCRAF for the dairy and food processing industry in Maharashtra

Hazard x Exposure x (Sensitivity/Adaptive Capacity) = Risk						
Site	District	Hazard	Exposure	Sensitivity	Adaptive Capacity	Risk
Α	Thane	0.78	0.50	0.15	0.59	0.097
В	Nagpur	0.10	1.00	0.56	0.88	0.066

Source: Analysis using PCRAF





The analysis shows that Industry A is at higher risk than Industry B and more vulnerable (sensitive to certain hazards) due to its location in the low-lying areas near the coast compared to B, which is in a relatively higher elevation region. In addition to this, industry B identifies physical climate risks and acts to address these risks in its business continuity plans. It also invests in research and development to make its value chains more resilient. Therefore, the overall risk is higher for industry A than for B, but both industries are in the very low-risk category.

4.3.3 Iron and steel in Odisha

Odisha, located on the eastern coast of India, covers an area of approximately 1.5 lakh sq. km with a coastline of 480 kilometres along Bay of Bengal to the east. The state is characterised by diverse topography, including fertile coastal plains, the Eastern Ghats Mountain range, central plateaus,

and river basins formed by major rivers like the Mahanadi, Brahmani, and Baitarani.

Odisha experiences extreme climatic conditions due to its geographical location. The coastal region is highly prone to cyclones and storm surges, with notable events like the 1999 Super Cyclone and Cyclone Fani in 2019, which caused widespread devastation. Summers are hot and humid, while monsoons bring heavy rainfall, leading to frequent flooding in riverine and low-lying areas. Additionally, parts of Odisha experience droughts, highlighting the state's vulnerability to both water excess and scarcity, requiring comprehensive adaptation strategies.

The risk assessment was conducted for four industrial clusters of iron and steel in the state-Bhadrak, Jagatsinghpur, Jajpur and Keonjhar districts of Odisha.

Table 11: Physical climate risk assessment for the iron and steel industry in Odisha

	Hazard x Exposure x (Sensitivity/Adaptive Capacity) = Risk					
Site	District	Hazard	Exposure	Sensitivity	Adaptive Capacity	Risk
Α	Jagatsinghpur	0.49	0.22	1.00	0.79	0.136
В	Bhadrak	0.69	0.21	0.83	0.41	0.293
С	Keonjhar	0.22	0.42	0.51	0.65	0.072
D	Jajpur	0.25	0.76	0.78	0.57	0.260

Source: Analysis using PCRAF

Analysis reveals that both industries A and B have high historical occurrences of all three chronic extreme events- floods, cyclones and droughts, which increases the hazard score for these industries compared to industries C and D in inland districts like Keonjhar and Jajpur. Both Bhadrak and Jagatsinghpur districts have rapidly urbanised in the past decade, increasing their sensitivity to heat and

urban floods. Since industry A has a higher adaptive capacity, it increases its capability to cope in times of disasters compared to B, C and D. The lower adaptive capacity score of industry B is on account of insufficient structural safeguarding of its assets, machinery and raw materials, making B the most exposed site.

4.4 Best practices

Climate resilience is defined as the capacity or ability to anticipate and cope with climate-induced disasters and to recover from their impacts in a timely and efficient manner.

- UNFCCC



a) Automobile industry

Hazard	Best practice	Key intervention
All extreme climate events	Diversification of raw material sourcing	The companies prioritise diversification of raw material sourcing for a consistent supply of quality raw materials and uninterrupted operations. They focus on real-time monitoring of raw material prices and transportation. One company in Tamil Nadu mentioned engaging with 52 MSMEs to procure quality components consistently.
Drought/Water scarcity, heat stress	Taking measures for water security	The companies use the collected water through rainwater harvesting and treating industrial wastewater for industrial applications. One companies mentioned that they achieved a 5 percent year-on-year increase in water reuse, with 2,284,154 tons of water being reused, up from 2,179,600 tons in 2021, resulting in a reuse ratio of 21 percent.
Cyclone, flood, extreme precipitation	In-house power generation	Companies rely on in-house power generation for critical operations. One company mentioned that renewable power contributes to 88 percent of its total power requirements, the majority of which comes from wind energy and the rest from hydroelectric and solar power generation.
Drought, heat stress, flood	Adapting strategies for mitigating climate risk	Companies are taking specific measures to mitigate physical climate risks. One company in flood-prone areas focuses on landscaping and building design to mitigate climate risk. Cooling systems are installed in the manufacturing facility to prevent productivity loss due to heat stress.
All extreme climate events	Capacity building of workforce	Health and safety training sessions are conducted regularly.

Source: TVS Motor Limited 2023; Hyundai Motors 2023; Eicher Motors Limited 2023





b) Food Processing industry

Hazard	Best practice	Key intervention
All extreme climate events	Diversification of raw material sourcing	Companies rely on the supply of raw materials from local MSMEs.
Drought/Water scarcity, heat stress	Taking measures for water security	To reduce water consumption, the companies recycle and reuse water, place water metres on every line, and track water use.
Cyclone, flood, extreme Precipitation	In-house power generation	Companies rely on power generation through renewable sources such as hybrid solar thermal systems and rooftop solar.
Drought, heat stress, flood	Adapting strategies for mitigating climate risk	Food products are stored in cold storage facilities to ensure quality and safety for more extended periods during heat stress.
All extreme climate events	Capacity building of workforce	Training programs are conducted for capacity building of the farmers, making them aware of good farming practices, and helping them to grow high genetic seeds that could sustain extreme climate events.

Source: Bikaji 2023; Amul 2023; Dodla Dairy Limited 2023

b) Iron and steel industry

Hazard	Best practice	Key intervention
All extreme climate events	Diversification of raw material sourcing	These companies focus on diversifying their raw materials sourcing, such as iron ore and fuel, for consistent supply. Subsequently, the raw materials are carefully blended to ensure consistent quality of raw materials for smooth operations.
Drought/Water scarcity, heat stress	Taking measures for water security	The companies address water security through the '4R framework' of reduce, reuse, recycle, and recover by utilising the available technologies. One company developed and adopted a water management plan, which helped it reduce its water intake by 6 million m3/year despite a 17 percent increase in production.
Cyclone, flood, extreme precipitation	In-house power generation	For uninterrupted critical operations, companies in the steel sector have traditionally relied on the by-product gases and conventional fuel for power generation. However, there has been a notable shift towards the adoption of renewable and non-conventional power sources. Companies are increasingly investing in alternative energy options.
Drought, heat stress, flood	Adapting strategies for mitigating climate risk	Companies are at the identification of physical climate risks. Some of them have identified the risks and are in the process of developing mitigation strategies.
All extreme climate events	Capacity building of workforce	Health and safety training sessions are conducted regularly.

Source: Tata Steel 2023; Lloyd Steels Industries Limited 2023; JSW Steel 2021; Jindal Steel and Power 2020

5

SUGGESTED ACTIONS AND POLICY RECOMMENDATIONS

The proposed adaptation strategies are designed to minimise economic losses and create opportunities for innovation and growth within the sectors.

Key Areas of Change

- It was highlighted through stakeholder consultations, that potential opportunities for the uptake of adaptation strategies by the industries lie in collaborative efforts and structured implementation. Industry associations can play a crucial role in translating these measures into implementable actions on the ground.
- To maximise effectiveness, the adaptation solutions should be mapped for shorter durations for effective implementation and monitoring.
- There should be evidence-based implementation of adaptation solutions, as it can play a crucial role in site selection and establishment of upcoming industries.
- The importance of water treatment facilities was emphasised for their role in disaster resilience and reducing water consumption, with a suggestion to focus on maximising water reuse. It was also highlighted that it is easier to incorporate structurally resilient practices than retrofitting infrastructures.

- It was highlighted that renewable energy options alone may not suffice during cyclones, as generators only support small machinery and intermediate processes. Thereby, the presence of power storage solutions could ensure a reliable in-house power supply for the industry.
- Further, the importance of periodic repair and maintenance of machinery was emphasised, suggesting it should be ranked higher due to its role as a significant long-term capital investment.
- Well-trained employees can better manage disaster situations, thereby protecting themselves and the industry's assets. It was highlighted that budget allocation for training employees in disaster safety is crucial.

Based on the study, industry consultations and dialogues with other experts, a set of policy recommendations for government and recommended actions by industry (both sector-specific and sector-agnostic) across short-term (2-3 years) and long-term (5-7 years) are summarised in the table below.





5.1 General recommendations

Figure 23: Sector-agnostic recommendations for Industry actors and Policy makers



Policymakers

Recommendation 01: Building Capacity for Assessing and Reporting Physical Risks

Recognise the need for adaptation and collect necessary data and for assessing climate risk use tools like the PCRAF to quantify the physical risks

Invest in conducting site-specific studies to identify worst-case extreme weather scenarios to facilitates effective investment

Identify challenges within your sector/operations and invest in building and incorporate financial impacts

across the supply chains

Develop an open-access utility providing data on extreme weather and climate projections for industry and other stakeholders to assess physical climate risks.

Mainstream the Physical Climate Risk Assessment Framework (PCRAF) and promote its implementation under SAPCCs and state DRM plans for industrial parks.

2

Regulatory requirements need to involve climate risk assessment and preparedness through initiatives like the RBI 2024 Climate Risk Disclosure Framework, currently applicable to Regulated Entities (REs).

3



Recommendation 02: Create an Enabling Environment for Climate-Resilient Industry

resilient infrastructure to minimise risks from extreme weather events-including decentralised power and water efficient options to minimise

operational

disruptions

Invest in climate-Implement worker rotation mechanisms, staggered working hours, increased ventilation, smart cooling systems etc. for workers wellbeing.

Promote resource sharing and collaboration through cluster development approach for reduced individual costs and increasing the feasibility of adopting climate-smart technology

Avail market assistance such as insurance products for climatic extremes

Sub-national

governments need to collaborate with industry and urban planners to develop guidelines

for establishing green, climate-resilient industrial parks and zones, to include adaptive solutions for climate-induced disasters

Policymakers

Ensure workers protection through including elements of thermal comfort

2

Offer greater financial and non-financial support by integrating climate adaptation and resilience elements into existing schemes, particularly for **MSMEs**

Introducing innovative climate insurance products

4

and making them accessible to all industries through bodies like the Insurance Regulatory and Development Authority of India (IRDAI), including setting up legal entities to resolve disputes







5.2 Sector-specific recommendations

Table 13: Sector-specific recommendations for Industry actors and Policy makers

Sector 01: Iron and steel

Short-term

Develop and practise robust disaster management plans and invest in strengthening and safeguarding critical infrastructures such as cost-intensive machinery and equipment. E.g., a leading steel industry in Sambalpur district Odisha has built an internal drainage system within plant premises to deal with flooding and flash floods. Resource sharing and collaboration through cluster development approach.

Encouraging collaboration among secondary steel industries will help reduce individual costs and increase the feasibility of adopting climate-ready assets.

Develop holistic water management practices for water security in water stressed districts, e.g., a leading iron and steel industry has developed a water management plan which includes-improving water consumption efficiency, recycling, rainwater harvesting and storage to ensure water security for industry as well as the neighbouring communities.

Long-term

Adopt Long Duration Energy Storage (LDES) solutions and Vanadium Redox Flow Batteries (VRFBs) strategically. In urban and industrial park locations with reliable power, short to medium-duration batteries are cost-effective, but LDES can be beneficial where diesel genset regulations are strict. For areas with high outage frequencies, particularly rural regions, LDES technologies may offer long-term savings and environmental benefits compared to gas/biogas generators. Assessments should align with operational needs, financial capacity, and regulatory requirements.

Sector 02: Automobile

Short-term

Conduct asset-level climate risk assessments to identify vulnerable assets within the company/ manufacturing facility to devise targeted adaptation solutions Evaluate climate-related supply chain vulnerabilities twice a year including those related to raw materials and component suppliers; while companies generally monitor geopolitical risks, suppliers' financial health and quality, it would be important to also incorporate climate risks into such assessments

Strengthen technical expertise in the suppliers and operators regarding physical climate risks, underscoring the need for building their capacities through regular training and workshops (for instance, a leading automobile manufacturer in Tamil Nadu, supported by knowledge partners, facilitated climate resilience capacity building workshops for 10 MSMEs from its supply chain).

Long-term

Diversify supply chains (particularly relevant for EV-specific supply chains); increase the use of local suppliers to reduce dependency on long-distance transportation, which can be disrupted by extreme weather

Enhance inventory capacities, build strategic reserves of critical components and raw materials to reduce losses and enhance adaptive capacity; it would also be important to sensitise and collaborate with the government to develop a mineral policy and national strategic mineral reserves (as we do with strategic petroleum reserves).

Sector 03: Food processing

Cereals

Short-term

Explore and apply sustainable agricultural practices and systems that have proven effective to reduce losses due to climate change impacts For e.g., pre-monsoon dry sowing (PMDS) allows farmers even in semi-arid regions like Marathwada in Maharashtra, to grow three crops a year; alternate furrow irrigation (AFI) is a water-efficient irrigation method that conserves water, lowers irrigation costs while ensuring high grain yields.

Adopt sustainable irrigation practices using accessible technologies such as drip and micro-irrigation and small farm ponds, tailored to regional agro-ecological conditions. With the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) successfully expanding micro-irrigation in states like Gujarat and Andhra Pradesh, industries can further facilitate this by investing in local manufacturing and distribution. This will optimise water use, increase efficiency, and align with the National Water Mission goals.

Engage Farmer Producer Organizations (FPOs) in a phased approach to diversify cropping systems and encourage resource-efficient farming practices.

Long-term

Mainstream sustainable food systems practice by investing in accessible, affordable technologies that benefit farmers of all scales and incorporating a gender-sensitive approach to improve livelihood security and household productivity. This strategy will not only enhance climate resilience but also drive economic growth by increasing agricultural output and contributing to industrial productivity.

Industries can enhance their resilience by supporting the transition to sustainable agricultural practices. This can be achieved by promoting and adopting agroecological methods, such as natural farming, agroforestry, and nature-based solutions. For instance, the Andhra Pradesh Community Natural Farming Programme exemplifies a nature-based solution that enhances soil health, diversifies incomes, and reduces the cost of cultivation by minimizing dependency on market-based inputs like fertilizers and pesticides.

Agro-industries can further this transition by sourcing produce from sustainable farms that practise agroecology, thereby ensuring the sustainability of their supply chains. Additionally, they can invest in community-led land restoration projects, which not only benefit the environment but also secure the long-term viability of their raw material sources. These actions, while contributing to the broader goal of sustainability, directly enhance the industry's resilience to environmental and market fluctuations.

Dairy

Short-term

Enhance the cold chain infrastructure by integrating decentralised renewable technologies (DRE), such as solar-powered refrigeration and battery storage systems, which provide reliable, cost-effective energy solutions, which will be crucial for adapting to the impacts of heatwaves. Develop hybrid energy systems combining renewable sources with conventional power for backup and establish localised microgrids to support cold storage and transport in remote areas. Invest in training for effective implementation and maintenance of these technologies.

Subscribe to parametric insurance models for ensuring coverage for productivity losses during weather extremes e.g., Kerala has introduced parametric insurance for livestock.

Long-term

Incorporate heat-resilient cattle breeds such as 'Red Sindhi', 'Bhadawari' into breeding programs in arid regions like Rajasthan and Gujarat, using custom shelters and trace mineral supplements, and change in feed type, time and frequency. Integrate resilient indigenous breeds such as 'Tharparkar' and 'Gir', identified by the ICAR*, that are naturally heat-tolerant and suited for arid regions. The industry can put efforts on enhancing the productivity of indigenous breeds on the lines of Rashtriya Gokul Mission.



6

CONCLUSION AND WAY FORWARD

Indian industry is at a crucial juncture, facing dual challenges of mitigating climate change and adapting to its inevitable impacts. While India's commitment to achieving net-zero emissions by 2070 is a significant milestone, the urgency of prioritising adaptation measures to build industry-wide resilience is equally critical. As industries across the country confront climate change realities- such as devastating floods, prolonged droughts, and rising heat stress- the need for robust adaptation becomes more evident.

The Physical Climate Risk Assessment Framework (PCRAF) presented in this study, provides a comprehensive roadmap for enhancing climate resilience. Although primarily presented as a step forward for Indian industries, the framework also offers insights applicable to India and other nations in the global South facing similar challenges. The report emphasises both short-term strategies for addressing immediate risks and long-term approaches for fostering sustainable practices and policies. By adopting these strategies, Indian industry can secure their operations and contribute to national adaptation goals.

The adaptation strategies ranked the most impactful and feasible to the stakeholders and includes considerations towards building future-proof climate resilience, improving climate

The Physical Climate Risk Assessment Framework (PCRAF) presented in this study, provides a comprehensive roadmap for enhancing climate resilience. Although primarily presented as a step forward for Indian industries, the framework also offers insights applicable to India and other nations in the global South facing similar challenges.

risk reporting and developing green and climate-resilient industrial parks.

The B20 Summit 2023 in India under the Action Council 'ESG in Business Action Council' recommended establishing a Centre of Excellence (CoE) under the B20 institute by 2025 to develop a disclosure framework for adaptation and awareness generation on business resilience, adaptation, and disaster management. A similar public utility, that follows a multistakeholder approach, could also be established in India to facilitate better dialogue between industry and policymakers to strengthen the overall ecosystem's resilience.

Addressing the physical risks of climate change is complex and multifaceted. The framework, though primarily focused on industry, could form the foundation for a national strategy to assess and manage climate risks.

7

END NOTES

7.1 Annexure

7.1.1 Overview of literature review conducted for the study

Type of literature	Reviewed	Purpose of review
Research articles and academic papers	17	To derive data-driven conclusions and avoid reliance on unverified information as well as to understand the existing trends and gaps regarding climate risk for industries.
Reports, working papers and blogs	62	For shortlisting of indicators for developing the physical climate risk assessment framework for Industries we conducted literature review.
Reporting Frameworks	5	To assess the current state and specifics of physical risk reporting across different industry reporting frameworks worldwide.
Annual reports; Sustainability reports; BRSR reports of companies	32	To understand how Indian industries are reporting risks and the best practices implemented by different industries on ground.

7.1.2 Representative Concentration Pathways (RCP) climate change scenarios to project future greenhouse gas concentrations

RCP Scenario	Range	Range of Global Mean Temperature Increase (Celsius) – 2100 from pre-Industrial baseline	Description
RCP 2.6	Very Low	≈1.5 to ≈2	
RCP 4.5	Low	≈2.5 to ≈3	RCP 4.5 is a stabilisation scenario where emissions peak by mid-century and then decline due to significant mitigation efforts, resulting in a warming of approximately 2.4°C above pre-industrial levels.
RCP 6.0	High	≈3 to ≈3.5	
RCP 8.5	Very High	≈5	RCP 8.5 is a high-emissions scenario with minimal mitigation, leading to unrestrained growth in emissions and a more extreme warming of about 4.3°C by 2100.



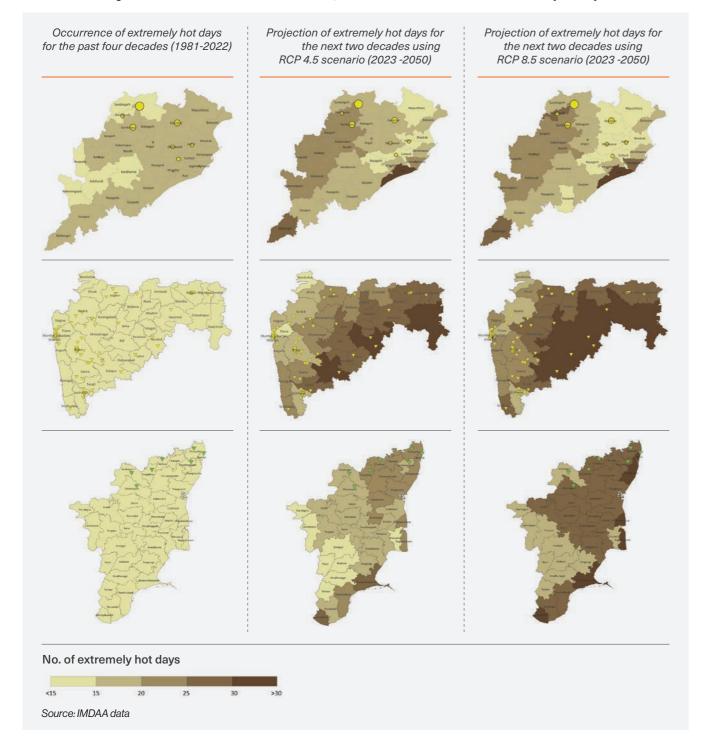


7.1.3 State-level scenarios: Heat and rainfall in RCP 4.5 and 8.5 scenarios

Scenario 1: A severe case of heat

Over the coming decades, an increase in the number of hot days is expected to significantly impact industries across various sectors due to heightened risks to productivity, safety, and economic output. Industries that involve more outdoor work, like agriculture, construction, and mining, higher temperatures will directly reduce labour productivity and reduce working hours, with a projected rise in lost output (World Bank 2023). A 1°C increase in temperature correlating to a 2% drop in annual economic activity in affected regions (Casey et al. 2022).

Figure 3.1: The two RCP scenarios in Orissa, Maharashtra and Tamil Nadu for extremely hot days



All three states show a three-fold increase in the occurrence of extremely hot days in the next two decades under RCP 4.5 and 8.5 scenarios, indicating significant increase in heat risk in the coming decades. In Maharashtra, Marathwada and Vidarbha regions will see an increase of 64% and 62% for the number of extremely hot days under the RCP 8.5 scenario.

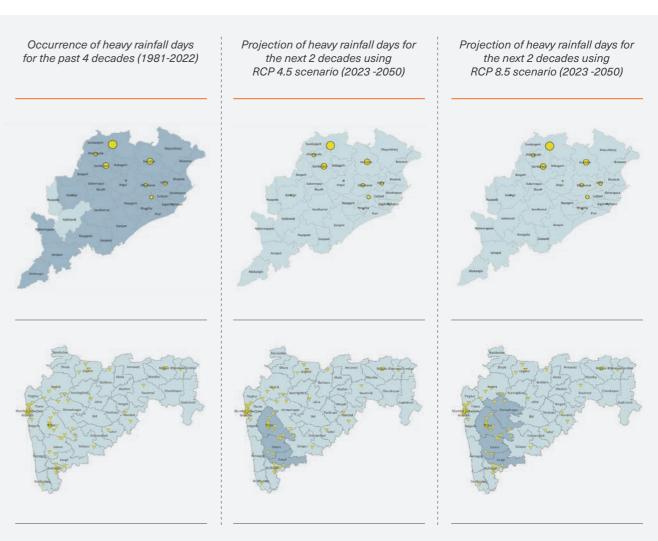
In Odisha, Jagatsingpur, Puri, Jarsuguda and Sambalpur, with lower risk profiles in the past, will face a severe number of extremely hot days according to both RCP 4.5 and 8.5 scenarios, while the coastal districts in Tamil Nadu will face a 46% and 53% increase in the number of extremely hot days by 2050 under the RCP 4.5 and 8.5 scenario respectively. Figure 3.1 shows how industry representatives from all three sectors have ranked

cooling shelters for employees as a lower priority; however, the evidence shown in the maps above demonstrates a need for prioritising action to combat heat.

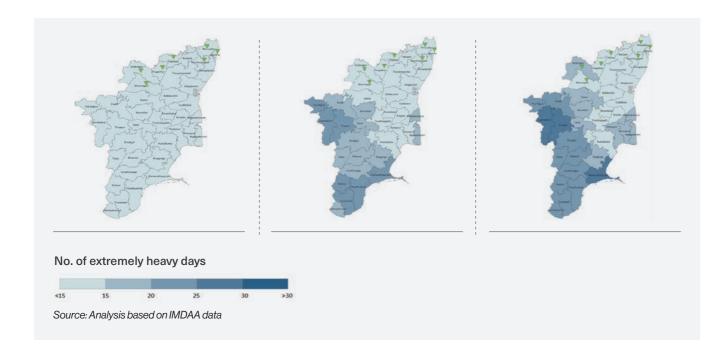
Scenario 2: Unpredictable monsoon patterns

Urban infrastructure can suffer severe strain from inadequate drainage systems during extreme rainfall events, leading to factory shutdowns and transportation bottlenecks. Industries are likely to face complex risks from flooding, as heavy rainfall intensifies soil erosion, overloads drainage systems, and causes waterlogging. Moreover, it impacts energy systems, especially hydropower and thermal plants, that may experience operational disruptions due to floods or siltation caused by excessive rainfall.

Figure 3.2: The two RCP scenarios for the prioritised states for heavy rainfall days







The projected rainfall analysis for Odisha shows a declining trend, where the number of very heavy rainfall days shows a decline of 35.5% and 41% under the RCP 4.5 and RCP 8.5 scenarios, respectively. This pattern is validated by the future projections of extreme rainfall events and precipitation for Odisha, highlighting significant challenges in enhancing the state's resilience against more frequent drought extreme events (OSDMA n.d.). Consequently, water-intensive industries should prioritise investing in sustainable water harvesting and storage solutions.

The state of Maharashtra, due to its wide geographic spread, is witnessing a complex change in the projected rainfall scenarios. The Konkan region is witnessing an 11.6% decline in the projected rainfall days, whereas the Western and Khandesh regions are experiencing a 17% and 9% increase in rainfall days, respectively, under RCP 4.5 scenario. Industries with value chains in these locations need to adapt to the changing climate scenarios and invest in long-term and sustainable solutions to prevent incurring financial losses and safeguard their supply chain and processes.

Tamil Nadu faces a 20% and 25% increase in the number of heavy rainfall days under the RCP 4.5 and 8.5 scenarios respectively, indicating a need for robust adaptation measures to deal with the water inundation in industrial units and warehouses as well as broken linkages with supply chains both

upstream and downstream. Over decades, if no substantial adaptive measures are taken, industries could face mounting operational costs, reduced productivity, and increased insurance premiums, emphasising the need for robust climate resilience planning. These trends necessitate the adaptation of industries through investments in resilient infrastructure and robust early warning systems, along with periodically updating managerial strategies to capitalise on gains in resilience.



7.1.4 Working of the PCRAF: Odisha risk calculation demonstration

Step 1: The normalisation formula when the indicator is

$$x' = \frac{x - min(x)}{max(x) - min(x)}$$

$$x' = \frac{min(x) - x}{max(x) - min(x)}$$
Directly correlated

Indirectly correlated

where x is the original value, min(x) and max(x) are the minimum and maximum values of the dataset, and x' is the normalised value.

Step 2: The above normalisation is carried out for all relevant variables

Category & Indicators	Industry A	Industry B	Industry C	Industry D
Hazard	0.48906567	0.68681585	0.21846887	0.24965524
1. Occurrence of floods in past 50 years.				
2. Occurrence of droughts in past 50 years.				

4. Frequency of hot days in past 30 years.

5. Frequency of heavy rainfall days in past 30 years

3. Occurrence of cyclones in past 50 years.

Exposure	0.22 0.21	0.42	0.76
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1. Length of National highways (in km)

2. Length of state highways (in km)

3. Length of railway tracks (in km)

4. No. of Railway Stations.

5. Number of ports exposed to cyclones.

6. No. of manufacturing plants

7. No. of warehouses

8. No. of distribution centres

9. Average distance from the coastline

10. Average distance from water body

Sensitivity	1	0.83	0.51	0.78

1. Change in built-up area (%)

2. Elevation

3. Change of groundwater (%).

4. Change in soil moisture (%)

Adaptive Capacity	0.792	0.413	0.649	0.57

1. Industrial Preparedness.

2. Industrial Management.

3. Structural Safeguarding

4. Financial Preparedness

5. Technology & Innovation





Risk Calculation

Step 3: For final risk calculation- Risk= Hazard*Exposure* (Sensitivity/ Adaptive capacity) Risk= 0.489 * 0.22 * (1.00 * 0.79) = Risk= 0.136

Site	Hazard	Exposure	Sensitivity	Adaptive Capacity	Risk
А	0.49	0.22	1.00	0.79	0.136
В	0.69	0.21	0.83	0.41	0.293
С	0.22	0.42	0.51	0.65	0.072
D	0.25	0.76	0.78	0.57	0.260

Step 4: The different risk scores from this calculation is put in context with the adaptive capacity ranking provided for each proposed strategy by the stakeholders on site- to be categorised as short-term (2-3 years) and long-term (5-7 years), and to be assigned to industry actors versus policymakers.



7.2 References

Barbara, L., 2024. 'Climate finance, carbon markets and more: 4 key takeaways from COP29', November, https://www.weforum.org/stories/2024/11/cop29-4-key-takeaways/

Bandyopadhyay, C., Bindal, M.K., & Manna, M. (2021). Chennai Floods 2015. New Delhi-110042: National Institute of Disaster Management (NIDM), Ministry of Home Affairs. https://nidm.gov.in/PDF/pubs/Chennail-Flood_NIDM2021.pdf

Biagini, Bonizella, Rosina Bierbaum, Missy Stults, Saliha Dobardzic, and Shannon M. McNeeley. "A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility." Global environmental change 25 (2014): 97-108. https://www.sciencedirect.com/science/article/pii/S0959378014000065

Bikaji. 2022. "FROM STREET TO STOCKS." https://www.bikaji.com/pub/media/Bikaji-Annual-Rport-2022-23.pdf.

Bressan, G., Đuranović, A., Monasterolo, I. et al. 2024. "Asset-level assessment of climate physical risk matters for adaptation finance". Nat Commun 15. https://doi.org/10.1038/s41467-024-48820-1

Casey, Gregory, Stephie Fried, and Matthew Gibson. 2022. "Understanding Climate Damages: Consumption versus Investment." FRB San Francisco Working Paper 2022-21 https://www.frbsf.org/research-and-insights/-publitions/econoic-letter/2024/05/impact-of-us-labor-productivity-losses-from-extreme-heat/#toc_References

Castoldi, Andrea, Giovanni Lucini, Bruno Micale, Amine Benaya, and Matteo Coppola. 2024. 'How Banks Can Transform Physical Climate Risk into an Opportunity', July. https://media-publications.bcg.com/How-Banks-Can-Transform-Physical-Climate-Risk-into-an-Opportunity.pdf.

Climate Transparency, 2022. "CLIMATE TRANSPARENCY REPORT: COMPARING G20 CLIMATE ACTION." https://www.climate-transparency.org/wp-content/uploads/2022/10/CT2022-India-Web.pdf.

CoastAdapt 2014. 'Coastal climate change infographic series- What are the RCPs?', https://coastadapt.com.au/sites/default/files/infographics/15-117-NCCARFINFOGRAPHICS-01-UPLOADED-WEB%2827Feb%29.pdf

CRED, 2023: Disasters in Numbers. Brussels: CRED, 2024. https://files.emdat.be/reports/2023_EMDAT_report.pdf

CSTEP, 2022. 'Climate Atlas of India: District-Level Analysis of Historical and Projected Climate Change Scenarios'. 2022. https://cstep.in/publications-details.php?id=2282&utm_source=chatgpt.com.

Dasgupta, S., Barua, A., Murthy, I. K., Borgohain, P. L., Baghel, T., Sankhyayan, P., Vidya S., Narwal, H., Jan, A., Vyas, S., Luniwal, Y., Ghosh, S., Cheranda, T. M., Alam, M. K., Matthew, S., & Pradeep M. S. (2024). District-Level Climate Risk Assessment for India: Mapping Flood and Drought Risks Using IPCC Framework. Department of Science and Technology, Government of India and the Swiss Agency for Development and Cooperation (SDC), Embassy of Switzerland.

David Eckstein, Vera Künzel, Laura Schäfer. 2021. "Global Climate Risk Index 2021." https://www.german-watch.org/en/19777.

DST. 2024. "District-Level Climate Risk Assessment for India: Mapping Flood and Drought Risks Released | Department Of Science & Technology". 2024. https://dst.gov.in/district-level-climate-risk-assessment-in-





dia-mapping-flood-and-drought-risks-released.

Eccles et al. 2014. Eccles, Robert G., and George Serafeim. "Sustainability in Financial Reporting: The Case of SASB." Journal of Applied Corporate Finance 26, no. 2 (2014): 56–64.

Eicher. 2023. "Eicher Motors Integrated Annual Report 2022-23." https://eicher.in/content/dam/eicher-motors/pdf/Eicher-Motors-Annual-Report-2022-23.pdf.coredownload.inline.pdf.

EU. n.d. "EU Climate Adaptation Strategy." https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en#:~:text=2021%20%E2%80%93%20EU%20Adaptation%20Strategy&text=Triggers,climate%20change%20on%20European%20forests%20link-edit

FAO. 2021. The State of Food and Agriculture 2021. Making agrifood systems more resilient to shocks and stresses. Rome, FAO. https://openknowledge.fao.org/items/437c1215-556b-4161-9af6-68163f5a1f84

GCA 2019. "ADAPT NOW: A GLOBAL CALL FOR LEADERSHIP ON CLIMATE RESILIENCE" THE GLOBAL COM-MISSION ON ADAPTATION, 13 September 2019 https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/?_gl=1*cdt8rz*_ga*MTIxMDM5Mjl5LjE3MzYzMTE3OTI.*_up*MQ..

GIZ 2020. "CLIMATE RISK ASSESSMENT Ministry of Environment, Forests and Climate Change A Pilot study in Kullu, Himachal Pradesh" Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH Environment, Climate Change and Natural Resource Management. March 2020 https://weadapt.org/wp-content/up-loads/2023/05/himachal_padesh_report2.pdf

GIZ, and SIDBI. n.d. 'Facing the Impacts of Climate Change: Indian MSME and Adaptation'. GIZ. https://www.-giz.de/de/downloads/giz2013-en-climate-risk-study.pdf

Gold Standard. 2024. 'The Business Case for Climate Adaptation: Why It's a Profitable Investment.' https://www.-goldstandard.org/news/the-business-case-for-climate-adaptation-why-its-a-profitable-investment.

Global Reporting Initiative. GRI Standards Overview. Amsterdam: GRI, 2021.

GRI n.d. "The Evolution of GRI Standards," Global Reporting Initiative, accessed December 7, 2024, https://www.globalreporting.org.

The Climate Reality Project, 2022. 'How the Climate Crisis Is Impacting India'. 2022. The Climate Reality Project. 21 November 2022. https://www.climaterealityproject.org/blog/how-climate-crisis-impacting-india.

The NAP Data Initiative, 2024. LDC Expert group. https://unfccc.int/sites/default/files/resource/NAP-Data-Initiative.pdf

IBM. 2023. 'What Is the Task Force on Climate-Related Financial Disclosures (TFCD)? | IBM'. 15 February 2023. https://www.ibm.com/think/topics/tcfd.

IFRS. n.d. "ISSB and TCFD." https://www.ifrs.org/sustainability/tcfd/.

IPCC. 2014. "Climate Change 2014: Synthesis Report" Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

IPCC. 2014. Noble, Ian R., Saleemul Huq, Yuri A. Anokhin, Jo Ann Carmin, Dieudonne Goudou, Felino P.

Lansigan, Balgis Osman-Elasha, et al. 2015. "Adaptation Needs and Options." Climate Change 2014 Impacts, Adaptation and Vulnerability: Part A: Global and Sectoral Aspects, 833–68. https://doi.org/10.1017/C-BO9781107415379.019.

IPCC. 2001. "Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change" [Houghton, J.T.,Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press. https://www.ip-cc.ch/site/assets/uploads/2018/03/WGI_TAR_full_report.pdf

IPCC. 1992. CLIMATE CHANGE: The 1990 and 1992 IPCC Assessments. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/05/ipcc_90_92_assessments_far_full_report.pdf

JSW. 2020. JSW Steel 2020-2021. https://www.jsw.in/sites/default/files/assets/downloads/steel/IR/Financial

Performance/Annual Reports Steel/jsw-steel-20-21/JSW-IR21.pdf.

Kumar, Nikhil, Manish Kumar Goyal, Anil Kumar Gupta, Srinidhi Jha, Jew Das, and Chandra A. Madramootoo. 2021. "Joint behaviour of climate extremes across India: Past and future." Journal of Hydrology 597 (2021): 126185.

Kennisportaal Klimaatadaptatie. n.d. 'Climate Adaptation Knowledge Portal of Netherlands' https://klimaatadaptatienederland.nl/en/.

LLOYDS. 2023. "LLOYDS STEELS INDUSTRIES LIMITED," no. 02524. https://www.bseindia.com/xml-data/corp-filing/AttachHis/79782eb2-a5f0-4b22-ab2f-d27538a29aa8.pdf.

Micale, Valerio, Bella Tonkonogy, and Federico Mazza. 2018. "Understanding and Increasing Finance for Climate Adaptation in Developing Countries." Climate Policy Initiative, no. December: 1–37.

Ministry of Environment, Forest and Climate Change (MoEFCC). National Action Plan on Climate Change (NAPCC). New Delhi: MoEFCC, 2008.

Mohanty, Abinash. 2020. Preparing India for Extreme Climate Events: Mapping Hotspots and Response Mechanisms. New Delhi: Council on Energy, Environment and Water.

Mohanty, Abinash, and Shreya Wadhawan. 2021. "Mapping India's Climate Vulnerability, A district-level assessment". New Delhi: Council on Energy, Environment and Water (CEEW). https://www.ceew.in/sites/default/files/ceew-study-on-climate-change-vulnerability-index-and-district-level-risk-assessment.pdf

Moreira, Luana Lavagnoli, Mariana Madruga de Brito, and Masato Kobiyama. 2021. "Effects of Different Normalization, Aggregation, and Classification Methods on the Construction of Flood Vulnerability Indexes" Water 13, no. 1: 98. https://doi.org/10.3390/w13010098

Moody's. 2021. "Moody's ESG Solutions - Critical Industries Have Substantial Exposure to Physical Climate Risks," November 2021.

Moody's. 2022. 'Quantifying Financial Impact of Climate Risk with Moody's Climate on Demand'. 12 December 2022. https://www.moodys.com/web/en/us/capabilities/esg/re-

sources/insights/quantifying-financial-impact-of-climate-risk-with-moodys-climate-on-demand.html.





MOSPI, Central Statistical Organisation Ministry of Statistics and Programme Implementation. 2008. 'National Industrial Classification (All Economic Activity)'. Government of India. https://www.ncs.gov.in/Documents/NIC_-Sector.pdf

MoSPI. ASI, 2024. Annual Survey of Industries (ASI) Introduction, Ministry of Statistics and Program Implementation 2024. https://www.mospi.gov.in/.

Nastasijević, I, B Lakićević and Z Petrović 2017 IOP Conf. Ser.: Earth Environ. Sci. 85 012022 https://iop-science.iop.org/article/10.1088/1755-1315/85/1/012022/pdf

NIDM, and GIZ. 2019. 'Climate Risk Management Framework for India Addressing Loss and Damage (L&D)'. https://nidm.gov.in/PDF/pubs/GIZ_NIDM_Climate%20RiskManagementFramework.pdf

OSDMA 'ODISHA STATE DISASTER MANAGEMENT AUTHORITY | State Drought Monitoring Cell'. n.d. Accessed 8 January 2025. https://www.osdma.org/preparedness/state-drought-monitoring-cell/#gsc.tab=0.

Patankar, Archana. 2019. 'Impacts of Natural Disasters on Households and Small Businesses in India'. ADB Economics Working Paper Series. 0 ed. ADB Economics Working Paper Series. Manila, Philippines: Asian Development Bank. https://doi.org/10.22617/WPS190617-2.

PIB. 2024. "Disaster Preparedness and Climate Resilience". https://pib.gov.in/pib.gov.in/Pressreleaseshare.aspx-?PRID=2082745.

PIB. 2008. "Impact of Climate Change and National Action Plan on Climate Change". Press Information Bureau. https://pib.gov.in/newsite/erelcontent.aspx?relid=44098

RBI. 2023." Report on currency and finance 2022-23. Reserve Bank of India. https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/RCF03052023395FAF37181E40188BAD3AFA59BF3907.PDF

Rama Rao, C.A., Raju, B.M.K., Islam, A., Subba Rao, A.V.M., Rao, K.V., Ravindra Chary, G., Nagarjuna Kumar, R., Prabhakar, M., Sammi Reddy, K., Bhaskar, S. and Chaudhari, S.K. (2019). Risk and Vulnerability Assessment of Indian Agriculture to Climate Change, ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, P.124. http://www.nicra-icar.in/nicrarevised/images/publica-

tions/Risk%20&%20vulnerability%20assessment%20of%20Indian%20agriculture%20to%20climate%20chang e.pdf

Raghavan, Krishnan & Sanjay, J. & Gnanaseelan, C. & Mujumdar, Milind & Kulkarni, Ashwini & Chakraborty, Supriyo. (2020). Assessment of Climate Change over the Indian Region A Report of the Ministry of Earth Sciences (MoES), Government of India: A Report of the Ministry of Earth Sciences (MoES), Government of India. 10.1007/978-981-15-4327-2. https://www.researchgate.net/publication/342143482_Assessment_of_Climate_Change_over_the_Indian_Region_A_Report_of_the_Ministry_of_Earth_Sciences_MoES_Government_of_India_A_Report_of_the_Ministry_of_Earth_Sciences_MoES_Government_of_India

Ramya MA and Poojary, V, World Resources Institute (WRI), 2024. 'Small Businesses, Large Impacts: Effect of Extreme Rainfall on Chennai's MSMEs'. Accessed 29 May 2024, at: https://wri-india.org/blog/small-business-es-large-impacts-effect-extreme-rainfall-chennais-msmes#:~:text=In%202015%2C%20Chennai%20was%20 inundated,due%20to%20disruption%20in%20production

S&P Global. 2023a. "Corporate Sustainability Assessment." https://www.spglobal.com/esg/csa/.

S&P Global. 2023b. "Crunch Time: Can Adaptation Finance Protect Against the Worst Impacts from Physical Climate Risks?" https://www.spglobal.com/en/research-insights/special-re-

ports/look-forward/crunch-time-can-adaptation-finance-protect-against-the-worst-impacts-from-physical-climat e-risks.

S&P Global. 2021. "Corporate Physical Assets Increasingly in Harm's Way as Climate Change Intensifies". https://www.spglobal.com/esg/insights/corporate-physical-assets-increasingly-in-harm-s-way-as-climate-change-intensifies

S&P Global. 2023. 'Quantifying the Financial Costs of Climate Change Physical Risks for Companies'. 20 November 2023. https://www.spglobal.com/esg/insights/featured/special-edito-rial/quantifying-the-financial-costs-of-climate-change-physical-risks.

SASB 2021. Sustainability Accounting Standards Board. SASB Standards Overview.

SASB n.d. "SASB Standards," Sustainability Accounting Standards Board, accessed December 7, 2024, https://www.sasb.org.

SEBI 2021. Securities and Exchange Board of India (SEBI). Business Responsibility and Sustainability Report (BRSR). https://www.sebi.gov.in/legal/circulars/may-2021/business-responsibility-and-sustainability-reporting-by-listed-entities 50096.html

Singh, Saumya, and R. K. Mall. "Frequency dominates intensity of future heat waves over India." Iscience 26, no. 11 (2023). https://www.sciencedirect.com/science/article/pii/S2589004223023404

Srinivasan, Pavithrapriya & RAMACHANDRAN, A & AHAMEDIBRAHIM, SN & Palanivelu, Kandasamy. (2022). Climate variability trend and extreme indices for the Thanjavur Delta region of Tamil Nadu in South India. MAUSAM. 73. 237-250. 10.54302/mausam.v73i2.5475.

Stern, Nicholas. 2007. "The Economics of Climate Change: The Stern Review". Cambridge: Cambridge University Press, 2007. https://doi.org/10.1017/CBO9780511817434

Tata Steel. 2023. "Integrated Report & 116." https://www.bseindia.com/xml-data/corpfiling/Attach-His/77fb8c12-ed57-4add-a4ff-397257889773.pdf.

TCFD 2017. Task Force on Climate-Related Financial Disclosures (TFCD). Recommendations of the Task Force on Climate-Related Financial Disclosures. Basel: Financial Stability Board, 2017. https://www.fsb-tcfd.org/

Tingey-Holyoak, J. L., Wheeler, S. A., Seidl, C., & Zuo, A. (2024). Understanding viticultural financial returns: A case study from the Riverland, South Australia. Journal of Rural Studies, 110, 103334. Accessed at https://researchnow-admin.flinders.edu.au/ws/portalfiles/portal/130286162/Tingey-Holyoak_Understanding_P2024.pdf

The World Economic Forum. 2023. The Global Risks Report 2023. The WEF. https://www.weforum.org/reports/global-risks-report-2023.





TMC and CEEW. 2024. Heat Action Plan for Thane City 2024. Thane: Thane Municipal Corporation, Thane; and New Delhi: Council on Energy, Environment and Water (CEEW). https://www.ceew.in/sites/default/files/how-can-thane-implement-heat-action-plans-to-tackle-heatwaves-risks.pdf

TVS. 2023. "31st Annual Report," 1–23. https://www.tvsmotor.com/api/InvestorDownloadD-ata?ItemId=7af88c54-9573-4947-8cd5-8a3e223fb4e1#page=26

UK, Gov of. n.d. "The King's Awards for Enterprise." https://www.gov.uk/kings-awards-for-enterprise.

UN. n.d. "Industry." United Nations Sustainable Development Goals. https://sdgs.un.org/topics/industry.

UNDRR. 2020. "Disaster Risk Reduction in India: Status Report 2020." United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific, 1–36. https://www.undrr.org/publication/disaster-risk-reduction-india-status-report-2020.

UNEPFI. 2023. "Climate Risks in the Industrial Sector." United Nations Environment Programme Finance Initiative (UNEP FI), April https://www.unepfi.org/wordpress/wp-content/uploads/2023/04/C-limate-Risks-in-the-Industrials-Sector.pdf

UNESCAP. 2019. "Asia-Pacific Risk & Resilience Portal 2.0." 2019. https://rrp.unescap.org/.

UNFCCC. n.d. "Adaptation and Resilience." https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction.

UNFCCC. 2024. "COP 28: What Was Achieved and What Happens Next?" 2024. https://unfccc.in-t/cop28/5-key-takeaways.

UNICEF and CEEW. 2024. Assessing Risks to India's Drinking Water, Sanitation, and Hygiene Systems from Extreme Climate Events. New Delhi, India: Council on Energy, Environment and Water (CEEW), India.

UNIDO. 2023. "International Yearbook of Industrial Statistics" December 2023. United Nations Industrial Development Organization. https://www.unido.org/sites/default/files/unido-publications/2023-12/UNIDO_IndustrialStatistics_Yearbook_2023.pdf.

Wadhawan, Shreya, and Aryan Bajpai. 2024. Accelerating investments towards Nature-based Solutions in the Global South - A Unified Framework for Mapping and Estimating Benefits. New Delhi: Council on Energy, Environment and Water.

WEF. 2024. "Climate finance, carbon markets and more: 4 key takeaways from COP29". World Economic Forum. https://www.weforum.org/stories/2024/11/cop29-4-key-takeaways/

WEF. 2024. "Global Risks Report 2024 19th edition" World Economic Forum January 2024. https://www3.wefo-rum.org/docs/WEF_The_Global_Risks_Report_2024.pdf

WEF. 2023. "Accelerating Business Action on Climate Change Adaptation". World Economic Forum. https://wwww3.weforum.org/docs/WEF_Climate_Change_Adaptation_2023.pdf

WEF. 2021. "This is how climate change could impact the global economy". World Economic Forum. https://www.weforum.org/stories/2021/06/impact-climate-change-global-gdp/

WMO. 2024. "2024 Is on Track to Be Hottest Year on Record as Warming Temporarily Hits 1.5°C'. 2024. World Meteorological Organization. 8 November 2024. https://wmo.int/news/media-centre/2024-track-be-hottest-year-record-warming-temporarily-hits-15degc.

WMO. 2024. "State of the Climate in Asia 2023". World Meteorological Organisation. https://library.wmo.int/view-er/68890/download?file=1350_State-of-the-Climate-in-Asia-2023.pdf&type=pdf&navigator=1

Woetzel, Jonathan, Dickon Pinner, Hamid Samandari, Hauke Enge, Mekala Krishnan, Brodie Boland, and Carter Powis. 2020. 'Climate Risk and Response Physical Hazards and Socioeconomic Impacts'. McKinsey Global Institute. https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/climate%20risk%20and%20response%20physical%20hazards%20and%20socioeconomic%20impacts/mgi-climate-risk-and-response-full-report-vf.pdf

World Bank 2018 'Climate Change Could Depress Living Standards in India, Says New World Bank Report'. n.d. Text/HTML. World Bank. Accessed 7 January 2025. https://www.worldbank.org/en/news/press-re-lease/2018/06/28/climate-change-depress-living-standards-india-says-new-world-bank-report.

World Bank. 2019. "Adapt Now: A Global Call for Leadership on Climate Resilience." https://doi.org/10.1596/32362.

World Bank. 2022. "Physical Climate Risk Assessment: Practical Lessons for the Development of Climate Scenarios with Extreme Weather Events from Emerging Markets and Developing Economies." The Network of Central Banks and Supervisors for Greening the Financial System (NGFS), no. September. https://wwww.ngfs.net/sites/default/files/media/2022/09/02/ngfs_physical_climate_risk_assessment.pdf.

World Bank 2023. 'Climate Change'. n.d. Text/HTML. World Bank. Accessed 7 January 2025. https://www.world-bank.org/en/programs/south-asia-regional-integration/climate-change.

World Bank Group 2021. "CLIMATE RISK COUNTRY PROFILE- India" World Bank Group 2021 https://climate-knowledgeportal.worldbank.org/sites/defaulfiles/country-profiles/15503-WB_India%20Country%20Profile-WEB.pdf



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The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government and civil society through advisory and consultative processes.

For 130 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. With its extensive network across the country and the world, CII serves as a reference point for Indian industry and the international business community.

In the journey of India's economic resurgence, CII facilitates the multifaceted contributions of the Indian Industry, charting a path towards a prosperous and sustainable future. With this backdrop, CII has identified "Accelerating Competitiveness: Globalisation, Inclusivity, Sustainability, Trust" as its theme for 2025-26, prioritising five key pillars. During the year, CII will align its initiatives to drive strategic action aimed at enhancing India's competitiveness by promoting global engagement, inclusive growth, sustainable practices, and a foundation of trust.

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CESD works towards bringing local and global macro challenges to the centerstage; building policy consensus on critical issues; strengthening stakeholders' awareness and representation on policy & regulatory reforms and enabling actions that positively impact the environment, nature and communities.

With a vision to drive transformation towards sustainable development, CESD continues to play a focal role in Government-Industry dialogues on national regulations; articulating stakeholders' discourse on global policies; putting forth Indian Industry's stand on macro-economic issues and accentuating the need for sustainable and inclusive transformation.

CESD focuses on six transformational pathways: Advancing Creation of a Circular Economy; Facilitating an Enabling Ecosystem for ESG Reporting; Accelerating Nature Positive Actions; Enhancing Solutions for Clean Air; Building Climate Resilience and Low-Carbon Economy and Fostering Dialogues, Engagements & Knowledge Exchange.

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