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NITI Aayog

SCENARIOS TOWARDS VIKSIT BHARAT AND NET ZERO

SOCIAL IMPLICATIONS OF TRANSITION

(VOL. 11)

NITI Aayog

Government of India,
Sansad Marg, New Delhi–110001, India

Suggested Citation

NITI Aayog. (2026). Scenarios towards Viksit Bharat and Net Zero: Social Implications of Transition (Vol. 11)

Available at: https://niti.gov.in/publications/division-reports

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SOCIAL IMPLICATIONS OF TRANSITION

(VOL. 11)

डॉ. विनोद कुमार पॉल
सदस्य
Dr. Vinod K. Paul
MEMBER

भारत सरकार
नीति आयोग
संसद मार्ग, नई दिल्ली – 110001
Government of India
NATIONAL INSTITUTION FOR TRANSFORMING INDIA
NITI Aayog
Sansad Marg, New Delhi – 110001
Tele.: 23096809, 23096820
E-mail: vinodk.paul@gov.in

February 4, 2026

Foreword

India stands today at an unprecedented juncture in its development trajectory. As we advance toward our vision of Viksit Bharat by 2047, we simultaneously pursue the ambitious commitment to achieve Net Zero emissions by 2070. This dual objective presents both transformative opportunities and complex challenges. This report, *Pathways to Net Zero (Vol. 11): Social Implications of Transition*, emerges from a deep recognition that India's transition to a low-carbon economy is not merely a technical or economic undertaking, but fundamentally a social transformation that will touch the lives of every citizen.

The Inter-Ministerial Working Group on Social Implications of Transition, which I had the privilege to chair, was constituted with a clear mandate: to examine the human dimensions of India's climate transition. Our deliberations have been guided by a fundamental principle, that places human centric design at the heart of India's development to ensure inclusivity, equity and prosperity for all.

This report reveals crucial insights that demand our immediate attention. The transition will require substantial land and water resources for renewable energy deployment, with implications that extend far beyond simple statistics. The aggregate requirements for land and water appear manageable, however, both have competing uses arising out of the developmental needs. Renewable deployment often coincides with open natural ecosystems classified as wastelands that are often integral to rural livelihoods supporting grazing, fuelwood collection, and traditional practices. Further, more than half of India's solar installations are located in water-stressed zones, creating potential conflicts in regions already grappling with scarcity. When renewable projects are sited in these regions, they systematically concentrate development pressures on populations with low capacity to absorb them. These findings underscore the imperative of balancing our climate ambitions with the protection of community rights and ecological sustainability.

The employment landscape presents both challenges and opportunities. Over 150 districts across eastern and central India are significantly dependent on fossil fuel supply chains, supporting livelihoods for nearly one-third of our population. It is observed that informal sector engages at least twice as many as workers directly employed in coal mining, coal thermal power plants, and fossil-linked manufacturing and downstream industries. Further, while the Net Zero pathway promises net employment growth in the energy sector, it also demands a fundamental restructuring of skills and occupations. We must ensure that no worker, no community, is left behind in this transition. This requires comprehensive social protection, targeted reskilling programs, and economic diversification strategies tailored to regional contexts.

Climate change compounds these transition challenges, with more than 40% of India's districts facing high or very high climate risk. Climate change compounds these transition challenges, with more than 40% of India's districts facing high or very high climate risk. The report highlights health vulnerabilities are multifaceted arising from both direct and indirect impacts of climate change. The report further highlights that transition offers health co-benefits that could prevent thousands of premature deaths and reduce the burden of respiratory and cardiovascular diseases.

Individual and community behaviour plays a pivotal role in shaping this transition. India has built a robust foundation through Mission Lifestyle for Environment (LiFE), recognizing that sustainable development requires fundamental shifts in consumption patterns and daily choices. However, behavioural barriers rooted in social norms and structural constraints persist. Further, the report highlights the effectiveness of behavioural interventions varies significantly across India's diverse socioeconomic contexts, and addressing these barriers requires interventions that go beyond information dissemination to include visible leadership, social proof, strategic defaults, and bundled solutions that reduce complexity.

The policy recommendations in this report chart a comprehensive pathway forward. It recognises the need for adaptation measures and robust social protection systems, serving not only to shield vulnerable communities from climate shocks but also to ensure that the transition itself does not deepen existing inequalities. The report calls for decentralised renewable energy solutions that reduce land acquisition pressures, explicit recognition of energy needs in water allocation policies, comprehensive support packages for affected workers and regions, climate-ready health infrastructure and targeted behavioural interventions anchored in Mission LiFE. These recommendations are not aspirational, they are actionable, evidence-based interventions that can shape an equitable transition.

I commend the dedicated efforts of the working group members, technical experts, and NITI Aayog's team led by Dr Anshu Bharadwaj including Venugopal Mothkoor and Aastha Singh who have contributed to this vital work. Their rigorous analysis provides policymakers, researchers, and practitioners with the insights needed to navigate India's just transition. This report is not an end but a beginning a foundation for ongoing dialogue, adaptive policymaking, and collaborative action across ministries, states, and communities.

As we embark on this transformative journey, let us be guided by the principle that progress must be measured not only in gigawatts of renewable energy or tonnes of emissions reduced, but in the well-being, dignity, and opportunity afforded to every Indian. The path to Net Zero is, fundamentally, a path to a more just, resilient, and prosperous India.

(Vinod Paul)
Member, NITI Aayog
Chairperson,
Inter-Ministerial Working Group on Social Implications of Transition

बी. वी. आर. सुब्रह्मण्यम
B.V.R. Subrahmanyam
मुख्य कार्यकारी अधिकारी
Chief Executive Officer

सत्यमेव जयते

भारत सरकार
नीति आयोग, संसद मार्ग
नई दिल्ली - 110 001
Government of India
National Institution for Transforming India
NITI Aayog, Parliament Street,
New Delhi - 110 001
Tel. : 23096576, 23096574
E-mail : ceo-niti@gov.in

FOREWORD

Under the visionary leadership of our Hon'ble Prime Minister, India has set its aspirations on becoming a "Viksit Bharat", a developed economy by 2047. India has also pledged to achieve Net Zero emissions by 2070. This dual objective takes India on an unprecedented development journey. This transition transcends beyond energy system reforms. It entails a fundamental reimagination of our development paradigm, guaranteeing prosperity, equity, and sustainability for every Indian citizen.

At NITI Aayog, we have approached this transition with the understanding that policy effectiveness depends on addressing its social dimensions with the same rigour we apply to technical and economic analysis. This report provides a comprehensive examination of how the transition will affect land use, water resources, employment, migration patterns, public health, and individual behaviour across India's diverse landscape.

The analysis presented here reveals the complexity of the challenge ahead. Renewable energy deployment at the scale required will have implications on land, water and employment. In the long run, we will have to carve sustainable pathways to reshape regional economies, where mining and power have long been economic anchors. These are not abstract policy concerns, but they represent the lived realities of millions of Indian families.

This report illuminates pathways that can turn these challenges into opportunities. The transition can be a catalyst for job creation in new sectors, health improvements through cleaner air and reduced heat stress, and more resilient communities through decentralized energy solutions.

The recommendations in this volume are designed to be actionable across multiple levels of governance. They call for integrated, coordinated action across ministries and state governments. This report builds on extensive stakeholder consultations, data analysis, and scenario modeling to provide policymakers with the evidence needed for informed decision-making.

I sincerely appreciate Dr V. K. Paul's leadership in chairing the working group. I thank the contributions of all working group members and also our knowledge partners WRI, WHO, CEEW and iForest. I congratulate the NITI Aayog modelling team led by Dr. Anshu Bharadwaj, with Shri Venugopal Mothkoor, and Ms. Aastha Singh, for their outstanding efforts in finalising the report. This report will be an important guide for all stakeholders interested in a balanced transition.

Dated: 4th February, 2026

[B.V.R. Subrahmanyam]

स्वच्छ भारत
एक कदम स्वच्छता की ओर

Authors and Acknowledgement

Chairperson

Dr. V. K. Paul
Member, NITI Aayog

Leadership

Sh. Suman Bery
Vice Chairman, NITI Aayog

Sh. B. V. R. Subrahmanyam
CEO, NITI Aayog

Dr. Anshu Bharadwaj
Programme Director, Green Transition, Energy & Climate Change Division, NITI Aayog

Sh. Surender Mehra
Advisor, Environment and Climate Change, NITI Aayog

Core Modelling Team

NITI Aayog

Sh. Venugopal Mothkoor
Energy and Climate Modelling Specialist, NITI Aayog

Dr. Anjali Jain
Consultant Grade-2, NITI Aayog

Sh. Nitin Bajpai
Consultant, NITI Aayog

Authors

NITI Aayog

Sh. Venugopal Mothkoor
Energy and Climate Modelling Specialist, NITI Aayog

Ms. Aastha Singh
Young Professional, NITI Aayog

Knowledge Partners

Sh. Chandra Bhushan
CEO, International Forum for Environment, Sustainability & Technology (iFOREST)

Dr. Srestha Banerjee
Director, iFOREST

Sh. Nitin Bassi
Fellow and Team Lead, Council on Energy, Environment and Water (CEEW)

Ms. Akanksha Tyagi
Programme Lead, CEEW

Ms. Parineet Kaur Chowdhury
Research Analyst, CEEW

Ms. Ulka Kelkar
Executive Director, World Resources Institute (WRI), India

Ms. Gauri Atre
Senior Program Associate, WRI, India

Sh. Arpan Golechha
Program Manager, WRI, India

Ms. Payden
Acting Representative to India, World Health Organisation (WHO)

Dr. Pushpa Chaudhary Deo
Team Leader (RMNCAH), WHO

Dr. Richa Kandpal
SAMARTH National Officer, WHO

Dr. Nitish Dogra
Consultant, WHO

Dr. Sandeep Thacker
Consultant, UNICEF, India

Peer Reviewers

Sh. Priyavrat Bhati
Program Lead, Environment and Climate Change, NITI Aayog

Sh. Dilip Singh
Programme Specialist, UNDP, India

Ms. Somya Bhatt
Programme Analyst, UNDP, India

Ms. Srishti Dewan
Young Professional, NITI Aayog

Working Group Members

Ms. Gitanjali Gupta
Program Director, NITI Aayog

Sh. Neelesh Kumar Shah
Joint Secretary, Ministry of Environment, Forest & Climate Change

Sh. Nilambuj Sharan
Senior Economic Adviser, Ministry of Skill Development and Entrepreneurship

Sh. Rohit Mathur
Joint Secretary, Ministry of Petroleum and Natural Gas

Sh. Rajib Sen
Program Director, NITI Aayog

Dr. Sumita Ghosh
Officer on Special Duty, Health, NITI Aayog

Dr. Anuradha Guru
Economic Adviser, Department of Economic Affairs, Ministry of Finance

Ms. Santosh Agarwal
Deputy Director General, Ministry of Coal

Ms. Anshu Singh
Deputy Director General, Ministry of Tribal Affairs

Sh. Amit Verma
Joint Secretary, Ministry of Commerce (Former Director, NITI Aayog)

Sh. Shard Sapra
Scientist F & Director, Ministry of Environment, Forest & Climate Change

Dr. Shikha Anand
Director, Ministry of Labour and Employment

Sh. Rakesh Kumar
Joint Director, Ministry of Micro, Small & Medium Enterprises

Sh. V. Ramakrishnan
Deputy Director, Ministry of Micro, Small & Medium Enterprises

Sh. Chandra Bhushan
Chief Executive Officer, iFOREST

Ms. Sunita Narain
Director General, Centre for Science and Environment

Sh. Karthik Ganesan
Fellow, CEEW

Ms. Ulka Kelkar
Executive Director, WRI, India

Dr. K S Reddy
Honorary Distinguished Professor, Public Health Foundation of India (PFHI)

Sh. Aakash Shrivastav
Additional Director, National Centre for Disease Control

Ms. Nataliya Kulichenko
Lead Energy Specialist, World Bank

Dr. Soumya Swaminathan
Chairperson, M.S. Swaminathan Research Foundation

Dr. Anandajit Goswami
Research Lead, Senior Research Fellow, Ashoka Centre For People Centric Energy Transition (ACPET)

Dr. Anshika Singh
Former Young Professional, NITI Aayog

Editors

Ms. Aastha Manocha
Editor and Communication Consultant (Independent)

Ms. Rishu Nigam
Communication Specialist (Independent)

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List of Abbreviations

ABDM	Ayushman Bharat Digital Mission
APV	Agri-Photo Voltaic
ASI	Annual Survey of Industries
ASUSE	Annual Survey of Unincorporated Sector Enterprises
AVISTEP	Avian Sensitivity Tool for Energy Planning
BEE	Bureau of Energy Efficiency
CAP	Common Alerting Protocol
CEA	Central Electricity Authority
CIL	Coal India Limited
CO_2	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
CPCB	Central Pollution Control Board
CPS	Current Policy Scenario
CREA	Centre for Research on Energy and Clean Air
CSR	Corporate Social Responsibility
DRE	Decentralised Renewable Energy
ESIC	Employee State Insurance Corporation
FDI	Foreign Direct Investment
FPO	Farmer Producer Organisations
GVA	Gross Value Added
HAP	Heat Action Plan
IBAT	Integrated Biodiversity Assessment Tool
ICAP	India Cooling Action Plan
ICED	India Climate & Energy Dashboard
IDSP	Integrated Disease Surveillance Programme
IEA	International Energy Agency
IEEFA	Institute for Energy Economics and Financial Analysis
IPCC	Intergovernmental Panel on Climate Change
IPCC-AR5	Intergovernmental Panel on Climate Change Fifth Assessment Report
IPHS	Indian Public Health Standards
IREDA	Indian Renewable Energy Development Agency
LCOE	Levelised Cost of Energy
LPG	Liquefied Petroleum Gas

M&E	Monitoring and Evaluation
Mha	Million hectares
Mission LiFE	Mission Lifestyle for Environment
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest & Climate Change
MoHUA	Ministry of Housing and Urban Affairs
MoSPI	Ministry of Statistics and Programme Implementation
NABARD	National Bank for Agriculture and Rural Development
NAPCC	National Action Plan on Climate Change
NCAP	National Clean Air Programme
NDMA	National Disaster Management Authority
NHM	National Health Mission
NPCCHH	National Programme on Climate Change and Human Health
NSVA	Net State Value Added
NZS	Net Zero Scenario
PCF	Product Carbon Footprint
PIB	Press Information Bureau
PLFS	Periodic Labour Force Survey
PM JANMAN	Pradhan Mantri Janjati Adivasi Nyaya Maha Abhiyan
PM-ABHIM	Pradhan Mantri Ayushman Bharat Health Infrastructure Mission
PM-JAY	Pradhan Mantri Jan Arogya Yojana
PMKSY	Pradhan Mantri Krishi Sinchayee Yojana
PMMVY	Pradhan Mantri Matru Vandana Yojana
PMUY	Pradhan Mantri Ujjwala Yojana
PPA	Power Purchase Agreements
RE	Renewable Energy
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RESCO	Renewable Energy Service Companies
SAF	Sustainable Aviation Fuel
SAPCC	State Action Plan on Climate Change
SBTi	Science Based Target initiative
SCGJ	Skill Council for Green Jobs
SHG	Self Help Group
TB	Tuberculosis
ToR	Terms of Reference
TPP	Thermal Power Plants
UJALA	Unnat Jyoti by Affordable LEDs for All
VGF	Viability Gap Funding
WHO	World Health Organisation

Executive Summary

India is currently at a critical juncture in its developmental trajectory, navigating the dual ambitions of achieving the status of 'Viksit Bharat' by 2047 and reaching Net Zero by 2070. This transition occurs against the backdrop of intensifying climate risks, with India ranking among the countries most affected by extreme weather events. These climate impacts disproportionately burden vulnerable populations, making a socially informed approach not merely an environmental goal but a foundational requirement for sustainable and resilient development. A carefully sequenced, policy-driven transition is therefore required to address social considerations emerging from both climate change and the expansion of low carbon infrastructure. This report frames low-carbon development as a transformative opportunity for socio-economic realignment, integrating technological innovation with equitable growth outcomes.

Key Insights:

Power sector and green hydrogen land and water requirements are substantial under both scenarios: Under the Current Policy Scenario, which assumes continuation of policies and trends as of 2023, land requirements grow 6 times over 2030 reaching 4.2 million hectares by 2070 (equivalent to 7.5% of India's ~56 Mha wasteland capacity). While in a Net Zero Scenario, which assumes a strong policy push for renewables, the land requirements grow 7 times reaching 5.92 million hectares (equivalent to 11% of India's wasteland capacity). Under both scenarios, the water consumption in proportion grows only by 1.7 times in 2050 over 2030 levels due to higher renewables, which has lower water requirements. Further, water requirement declines by 2070, largely owing to technological improvements and efficiency gains post 2050.

As proportion of wasteland, renewable deployment on 7.5%-11% of wasteland seems modest, it masks community dependence and livelihood realities: Lands officially classified as wastelands are often used for grazing, fuelwood collection, and rural livelihoods, supporting pastoralism and cultural practices. Diversion of wastelands for renewable projects needs to be carefully managed.

Energy transition creates a geographic mismatch between fossil-fuel dependent regions and renewable deployment zones: States like Jharkhand, Chhattisgarh, and Odisha are heavily dependent on mining and thermal power generation. Renewable energy deployment, however, is concentrated in other states with 75% of installed solar and wind capacity in Rajasthan, Gujarat, Maharashtra, Tamil Nadu, and Karnataka. This geographic mismatch means fossil-fuel sustained communities face economic dislocation while renewable rich states experience intensifying competition for land and water resources among agriculture, energy infrastructure, and local livelihoods. Further, renewable expansion are largely located in arid and semi-arid areas that are water stressed.

Energy transition also has implications on employment: Over 150 districts across India are significantly dependent on fossil-fuel supply chains, directly or indirectly sustaining livelihoods for nearly one-third of India's population. It is observed that informal workers are at least twice as many as workers directly employed in coal mining, coal thermal power plants, and fossil-fuel-linked manufacturing and downstream industries.

Energy transition increases employment in the Net Zero Scenario compared to the Current Policy Scenario while reshaping job composition: Under the Current Policy Scenario, energy sector employment remains stable at around 6 million by 2050, with coal, oil, gas, and electricity accounting for the bulk of employment. Under the Net Zero Scenario, energy sector employment increases to about 7 million by 2050, around 1 million higher than under Current Policy Scenario, reflecting a change in the composition of energy jobs toward clean technology manufacturing and renewable energy infrastructure for both skilled and unskilled workers. Beyond the energy sector, the Net Zero Scenario generates large economy-wide employment gains, led by construction with approximately 4.6 million additional jobs in 2050. Trade also adds 5.2 million jobs over the period 2030–2070 in the Net Zero Scenario compared to the Current Policy Scenario.

Livelihood diversification strategies are essential in climate vulnerable and fossil-fuel dependent regions: Migration functions as a livelihood diversification strategy, particularly in agriculture dominant states. The share of male outmigrants is more compared to women. Migrants frequently settle in informal urban settlements and enter informal labour markets in construction, transport, and informal services. This can transform migration from a coping mechanism into a source of new vulnerabilities as both climate impacts and industrial restructuring intensify displacement pressures.

Climate change intensifies health burdens disproportionately affecting vulnerable populations: Healthcare systems in over 40% of districts in India face high climate risk, with escalating direct and indirect impacts through rising temperatures, frequent heat waves, increased transmission of vector-borne diseases and deteriorating air quality. These risks amplify cardiovascular, respiratory, and heat-related illnesses and impacts fall disproportionately on vulnerable groups including women, children, and the elderly and urban informal workers with low-adaptive capacity.

Energy transition presents health opportunities: Transitioning from fossil-fuel based system to low-carbon energy offers substantial health benefits including reduced respiratory diseases, cardiovascular diseases, premature deaths, heat-related illnesses, and improved air quality.

India has built a robust policy ecosystem for behavioural change, anchored by Mission Lifestyle for Environment: India has successfully deployed large-scale behavioural interventions across multiple sectors, establishing proven models through flagship programmes like Swachh Bharat Abhiyan, UJALA (Unnat Jyoti by Affordable LEDs for All), Jal Jeevan Mission, and the Bureau of Energy Efficiency's star labelling programme. These initiatives demonstrate how social proofing, choice architecture, defaults, and peer networks can drive voluntary adoption of sustainable practices at national scale. Mission LiFE (Lifestyle for Environment), launched in 2022, provides a comprehensive national architecture that unifies these sectoral efforts into a coordinated system, with the Ministry of Environment, Forest and Climate Change as the anchor player.

Behavioural changes and equity considerations are key to shaping the transition landscape: Behavioural barriers rooted in social norms, status perceptions, and structural constraints persist across sectors. For example, personal vehicle ownership remains a status symbol, landlords lack incentives to invest in building efficiency where tenants reap the savings, industrial procurement may prioritise cost over carbon footprint, and farmers may show aversion toward unfamiliar climate-smart practices.

The effectiveness of behavioural interventions varies significantly across India's diverse socioeconomic contexts, with groups facing constrained decision making authority such as women in many households and lower income families encountering material and social barriers that limit their ability to adopt sustainable behaviours.

Key Policy Suggestions

1. **Promote decentralised renewable energy solutions:** Prioritise decentralised solutions such as rooftop solar, mini-grids, and dual-use systems like agri-PhotoVoltaics that combine farming with solar panels. These approaches reduce large-scale land acquisition requirement and support local communities. These land-neutral solutions may be promoted through targeted Viability Gap Funding (VGF) or concessional debt.

   Further, the implementation of decentralised models can be scaled through adoption of business models such as Renewable Energy Service Companies (RESCOs). To be effective, RESCOs must operate within clear contractual frameworks supported by robust risk-mitigation instruments and revenue-sharing mechanisms. Additionally, to ensure tangible benefits for local communities, RESCO operators can adopt local employment quotas alongside targeted reskilling programs for skilled roles.

2. **Recognise energy-use explicitly in national and state level water allocation policies:** Safeguards include promoting desalination in coastal regions, wastewater circularity in groundwater-stressed areas, and prioritizing water-lean energy technologies through efficiency-based evaluation criteria.

3. **Improve planning and resource management:** Use mapping tools to avoid high conflict zones and ecologically sensitive areas. Explicitly include energy production in water allocation policies, encouraging water-efficient technologies, recycled water use, and desalination technologies especially in coastal areas.

4. **Create a comprehensive package for affected workers and regions:**

   (a) Creation of national policy framework followed by district level transition plans for worker retraining, relocation support, and economic diversification in affected districts. Further, in affected districts, leverage funds from District Mineral Foundations, Skill Council for Green Jobs and the Skill India Mission.

   (b) Accelerate development of sector specific transition skill roadmaps to identify at-risk occupations in fossil-fuel linked sectors.

   (c) Upgrade the e-Shram platform to track workers in fossil-fuel industries. Ensure access to social protection entitlements for all the impacted workers (informal and contractual).

(d) In fossil-fuel dependent regions and areas increasingly impacted by climate change, establish local facilitation units to help workers access benefits and navigate reskilling programs while accelerating implementation of new Labour Codes.

5. **Establish consistent risk assessment nationwide:** Adopt and integrate standardized vulnerability assessment framework into health surveillance systems to track of climate-sensitive diseases across states.

6. **Build climate-ready health infrastructure and workforce with adequate financing:**

   (a) Update Indian Public Health Standards (IPHS) to include climate-proofing requirements such as backup power, water security, and climate-resilient designs.

   (b) Integrate climate-health and emergency preparedness modules into medical training with mandatory refresher courses and preparedness drills.

   (c) Use earmarked National Health Mission (NHM) funding to attract larger investments from multilateral and philanthropic sources.

7. **Deploy targeted behavioural interventions across sectors:**

   (a) Leverage visible leadership and social proof through campaigns showcasing public officials and community leaders using sustainable practices.

   (b) Integrate behavioural nudges into digital platforms with sustainable defaults in mobility apps and smart building systems.

   (c) Deploy standardised Product Carbon Footprint labelling for industrial procurement

   (d) Build comparative energy reports with neighbourhood baselines for households to nudge energy-use behaviour.

   (e) Promote farmer-led demonstration plots with bundled climate-smart packages to reduce decision fatigue and risk aversion.

8. **Strengthen Mission Lifestyle for Environment (LiFE) implementation through integration and evidence-based monitoring:**

   (a) Accelerate the mainstreaming of Mission LiFE principles across existing government schemes in housing, energy, transport, agriculture, and livelihoods.

   (b) Establish outcome-oriented monitoring and evaluation frameworks with behavioural indicators, baseline data collection, and longitudinal tracking.

   (c) Strengthen inter-ministerial and center-state coordination while ensuring interventions are responsive to diverse socioeconomic contexts.

1

INTRODUCTION

Introduction

1

1.1 CONTEXT

India stands at a defining juncture in its development trajectory. It is aiming to become Viksit Bharat by 2047, a developed country, with a high per capita income, while doing so in a sustainable manner. Given the Net Zero by 2070 goal laid down by the Hon'ble Prime Minister, there are limitations on using purely fossil-fuel led growth path.

The challenge is particularly consequential as India simultaneously pursues the two national priorities: achieving developed-nation status by 2047 and reaching Net Zero emissions by 2070, as this has never been done or attempted before. Navigating this dual ambition demands a carefully sequenced, policy-driven transition that safeguards livelihoods, promotes inclusive growth, and ensures that the costs and benefits of the transition are equitably distributed. A socially informed approach to the energy transition is therefore not only an environmental imperative, but a foundational requirement for sustainable and resilient development.

At the core of this transition lie significant and unevenly distributed social pressures emerging from both the expansion of low-carbon infrastructure and long-term decline in the role of fossil-fuel-based systems. The fossil-fuel phase down affects not only formal mining employment but also extensive informal livelihoods across supply chains, transportation, and services concentrated in fossil-fuel dependent regions. These cascading socioeconomic affects risk undermining community stability through the erosion of municipal revenues, public services, and local economic ecosystems. At the same time, renewable energy deployment is spatially concentrated in arid and semi-arid states, geographically distant from existing fossil-fuel led economies (Mitra & Chandra, 2023). This spatial mismatch creates new regional inequities, as job creation, infrastructure investment, and economic opportunity do not naturally align with areas facing fossil-fuel decline in the long run.

The expansion of renewable energy infrastructure introduces additional social and ecological stresses. Large-scale renewable projects demand significant land and water resources, often intersecting with multifunctional landscapes that support pastoral grazing, rural livelihoods, biodiversity, and cultural practices (The Nature Conservancy India, 2020). Water requirements for construction and operation of low-carbon infrastructure further strain scarce resources in host regions, exacerbating vulnerabilities among local and marginalised communities (International Energy Agency [IEA], 2021). These pressures underscore that clean energy deployment, while environmentally necessary, is not socially neutral and requires deliberate policy safeguards.

These transition-linked challenges are further compounded by India's deep and escalating climate vulnerabilities, which amplify social risks across both fossil-fuel-dependent and renewable-intensive regions. Intergovernmental Panel on Climate (IPCC) stresses the need to enhance the understanding of climate risks that arise from the interaction of environmental hazards, socio-economic inequality, demographic pressures, and uneven adaptive capacity, especially at sub-national levels (IPCC, 2022). According to the Global Climate Risk Index 2026, India ranks ninth globally among countries most affected by extreme weather events over the period 1995–2024, reflecting high exposure and vulnerability to climate risks. It is exposed to flooding, tropical cyclones, and drought. According to the Central Water Commission's (2023) statistical report, the average annual damages to crops, houses, and public utilities from 1953 to 2021, as reported by states and Union Territories, totalled ₹6,972 crore. The highest recorded annual damage was ₹58,433 crore in 2021. Heatwaves have caused over 24,000 deaths between 1992 and 2015, with urban heat island effects intensifying risks in rapidly growing cities (Singh, 2025). In addition, a state-level assessment under the Global Burden of Disease Study 2019 found that air pollution contributed to 1.67 million deaths in India, accounting for nearly 18% of all deaths (Balakrishnan et al., 2021). The economic losses from premature mortality and morbidity were equivalent to 1.36% of national GDP in 2019 (Balakrishnan et al., 2021). These impacts disproportionately burden the already vulnerable communities: rural pastoralists, informal workers, women, children, the elderly, and indigenous communities (IPCC,2022).

The climate risk in India is therefore compounded by high levels of socioeconomic risk, leading to a high instance of social vulnerability. Studies show that more than 80% of India's population lives in districts that are vulnerable to climate disasters, with most of them having low adaptive capacities (Mohanty & Wadhawan, 2021). In this context, adaptation and social protection measures are indispensable, not only to buffer vulnerable populations from climate shocks, but also to ensure that the transition itself does not deepen existing inequalities. Addressing these intertwined challenges requires governance frameworks that translate technological and economic progress into tangible social security and local well-being. Evidence from other parts of the world (See Box-1) highlights the centrality of procedural equity, transparent consent processes, benefit-sharing mechanisms, and livelihood restoration, in reducing conflict and sustaining public support for resource-intensive transitions.

Box-1: International practices for managing social aspects of transition

Germany's Structural Development Act implemented in 2020, allocated up to 40 billion euros through 2038 to help coal regions through the phase-out (Federal Government of Germany, 2020). The plan supports investments in clean energy, infrastructure, science and innovation and labour market policies in the hopes of diversifying and boosting the regional economies.

South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), launched in 2011, attempted at equitable energy transitions via competitive bidding with socioeconomic safeguards. It imposed minimum local content thresholds of 40% for goods and services in initial rounds from 2011 to 2013, with compliance increasing steadily in subsequent rounds (Eberhard & Naudé, 2017). Concurrently, the programme required at least 2.5% equity shares for communities within 50 km of sites, however, bidders frequently offered higher shares of 8% to 12.5% through trusts. These measures comparatively reduced resource conflicts and secured 6,328 MW across 92 projects by 2015, driving tariff reductions and investment (Eberhard & Naudé, 2017).

China's agrivoltaics systems in the Kubuqi Desert integrate solar generation with ecological restoration and desert-adapted agriculture, enhancing soil and water outcomes while diversifying rural incomes (Asian Development Bank, 2024; Wang et al., 2024). Research documents that photovoltaic installations in the Kubuqi reduced ground wind speeds by up to 50%; when paired with sand-fixation grids, these systems achieved desert stabilization in only four years, significantly accelerating the traditional ten-year restoration timeline (Huawei Digital Power, 2023).

1.2 INSTITUTIONAL MECHANISM TO EXAMINE THE ISSUE: INTER-MINISTERIAL WORKING GROUP ON SOCIAL IMPLICATIONS OF TRANSITION

The objective of the Inter-Ministerial Working Group on Social Implications was to examine the social aspects of transition such as land and water, employment, migration, health, and individual and community behaviour. The terms of Reference (ToR) of the Working Group are as follows:

(a) Examine the issues of transition away from fossil-fuel assets on employment and indigenous communities.

(b) Examine the impact of transition on need for reskilling workforce for high value-added jobs especially among the most vulnerable sectors such as coal mining, fossil-fuel value chain etc.

(c) Examine the impact of various scenarios on land and water requirement.

(d) Examine the issue of migration for livelihood generation.

(e) Examine the implication of climate change on different sections of society for example, increase in vector borne diseases, coastal flooding due to sea level rise etc.

(f) Examine the role of behavioural nudges in pushing for efficient resource use.

Chairperson of the working group: Dr. V.K. Paul, Member (NITI Aayog).

Accordingly, this report frames low-carbon development as an opportunity for transformative socio-economic realignment, integrating technological innovation with inclusive growth. Section 2 quantifies land and water requirements across alternative transition pathways to identify critical pressure points. Section 3 examines the future of work, analysing employment shifts, skill transitions, and migration dynamics. Section 4 explores health equity and the co-benefits of mitigation and adaptation. Section 5 assesses the behavioural changes required to sustain the transition and concludes by outlining governance pathways that align India's climate ambitions with the broader goal of a prosperous, just, inclusive, and resilient Viksit Bharat.

2

LAND AND WATER: THE RESOURCE CONTEXT

Land and Water: The Resource Context

2

Land and water are fundamental to India's development, supporting food security, livelihoods, urbanization, industrial growth, and the transition to clean energy. These resources are increasingly under pressure from competing demands: expanding agriculture to meet the needs of a growing population, rapid urbanisation and infrastructure needs, intensifying industrialisation, and the impacts of climate change degrading soil and disrupting hydrological cycles. With just 0.11 hectares of arable land per person, India falls well below the global average of 0.172 hectares, reflecting the pressures of limited land resources (World Bank, 2023). Adding to this is the growing reality of land degradation arising from the combination of climatic, developmental, social and anthropogenic pressures. ISRO's Desertification and Land Degradation Atlas of India (2018), reports that, as of 2018-19, approximately 30% of India's total geographic area was degraded. Further, from 2011–13 to 2018–19, the affected area saw a modest cumulative increase of 1.45 million hectares (0.44% of total geographical area), reflecting ongoing monitoring and targeted interventions amid broader restoration efforts (Ministry of Environment, Forest and Climate Change (MoEFCC), 2023).

On the water availability side, assessments indicate that average annual per capita availability is projected to drop from 1,486 cubic meters in 2021 to 1,367 cubic meters by 2031, placing India in the "water-stressed" category, which is defined as having less than 1,700 cubic meters available per person (Ministry of Jal Shakti, 2024). While these figures remain above the 1,000 cubic meter threshold that marks a condition of "water scarcity," the consistent downward trend highlights increasing pressure on resources. NITI Aayog's Composite Water Management Index 2.0 (2019) highlights that 820 million people across 12 river basins face per capita water availability below the scarcity threshold. Further, groundwater supports 80% of domestic water needs and 63% of irrigation amid intensifying economic and urban growth demands.

Climate change further shapes these dynamics through erratic monsoons, increased rainfall variability, and rising temperatures. These factors impact crop yields, hinder groundwater recharge, and alter surface water flows. Such shifts particularly impact rainfed agriculture, which accounts for over 60% of India's cultivated land and supports a significant portion of the rural population (World Bank, 2013). Water pollution is a concern as well. However, over the past years there has been marked improvement. Only 46% of rivers monitored (279 out of 603) were identified as polluted. In comparison 70% of rivers(275 out of 390) were identified as polluted in 2015 (Central Pollution Control Board (CPCB), 2025).

Therefore, India's pursuit of being a developed economy by 2047 (Viksit Bharat) coupled with its commitment to achieve the Net Zero by 2070 is unfolding amid a land–water landscape already under strain. The large scale renewable energy deployment central to

India's Net Zero by 2070 carries a significant land footprint. Utility-scale solar installations typically demand 1.2 – 2 hectares per MW of occupied land, as the panels and infrastructure cover most of the site. (Mazumdar and Malik, 2025). In contrast, wind power parks utilie a much larger dispersed land area due to turbine spacing requirements, access infrastructure, and environmental buffers. Meanwhile, despite renewable energy sources' high water use during construction, they significantly reduce operational water use. However, the land they require is a challenge in a country with limited space.

Other components of the energy transition shift pressure onto water resources. Nuclear power, envisioned as a stable clean baseload, requires uninterrupted cooling water for safety and operation. Similarly, green hydrogen produced via electrolysis depends on substantial amounts of high-purity freshwater, raising competition risks in basins already stretched thin. Even conventional thermal power plants contribute to resource stress, needing land for infrastructure, ash disposal, and mining, being significant water users, mainly for the cooling purposes.

India's biofuel expansion, including ethanol blending, biodiesel, and sustainable aviation fuel (SAF), adds another layer to this complexity. The primary feedstock of sugarcane, rice, and maize are inherently water-intensive. NITI Aayog (2021) estimates that sugarcane-based ethanol consumes around 2,860 litres of water per litre of ethanol produced while maize ethanol may need over 4,600 litres per litre, and rice ethanol over 10,700 litres of water per litre. Scaling ethanol blending without efficiency improvements or feedstock shifts could impact water for agriculture and households.

These land and water pressures, intensified by climate change and energy transition demands, disproportionately burden vulnerable populations reliant on these resources. Smallholder farmers risk crop failure from erratic monsoons and land diversion; women, elderly, and children in low-income households face heightened vulnerability due to direct economic dependence on these resources. The following sections assess land and water use across the Current Policy Scenario and the Net Zero Scenario pathways, examine spatial impacts on these groups, analyse governance challenges, and propose inclusive strategies for India's low-carbon transition.

2.1 LAND & WATER USE IN DIFFERENT SCENARIOS

To assess how India's energy transition will shape future land and water needs, this report evaluates two scenarios, aligned with national development and climate goals (For details, refer to Volume IIE Power sector report):

- Current Policy Scenario (CPS): The scenario represents a level of effort that is realistically achievable based on historical trends and recent progress. It assumes that current policies (as of 2022) and past trends will continue, leading to a gradual adoption of low-carbon technologies in each sector.
- Net Zero Scenario (NZS): The scenario reflects an ambitious pathway aligned with India's commitment to achieve the Net Zero GHG emissions by 2070. It incorporates both existing and additional policy measures to accelerate technology deployment and significant behavioural and structural shifts across sectors. Key strategies include rapid electrification of end-use sectors, substantial gains in energy efficiency, adoption of circular economy practices, and high penetration of renewable and clean energy technologies.

This analysis is restricted to the power sector and green hydrogen production. Other land- and water-intensive components of the transition such as biofuels, industry, and non-power infrastructure are not modelled here. Results are based on average technology intensities (land required per MW, water required per MWh or per kilogram of hydrogen) applied to projected capacity mixes (Detailed land/water use factors are provided in Annexures A & B). They provide a directional assessment of future pressures but do not capture site-specific variations such as regional water stress, land quality, or competing livelihood uses. Capacity mixes for each scenario are drawn from energy system modelling, and aggregate land and water requirements are derived accordingly.

India's Net Zero pathways entail substantial land and water requirements for clean energy deployment in both scenarios. Figure 2.1 presents land requirements (in million hectares) for 2030, 2050, and 2070 under both the scenarios.

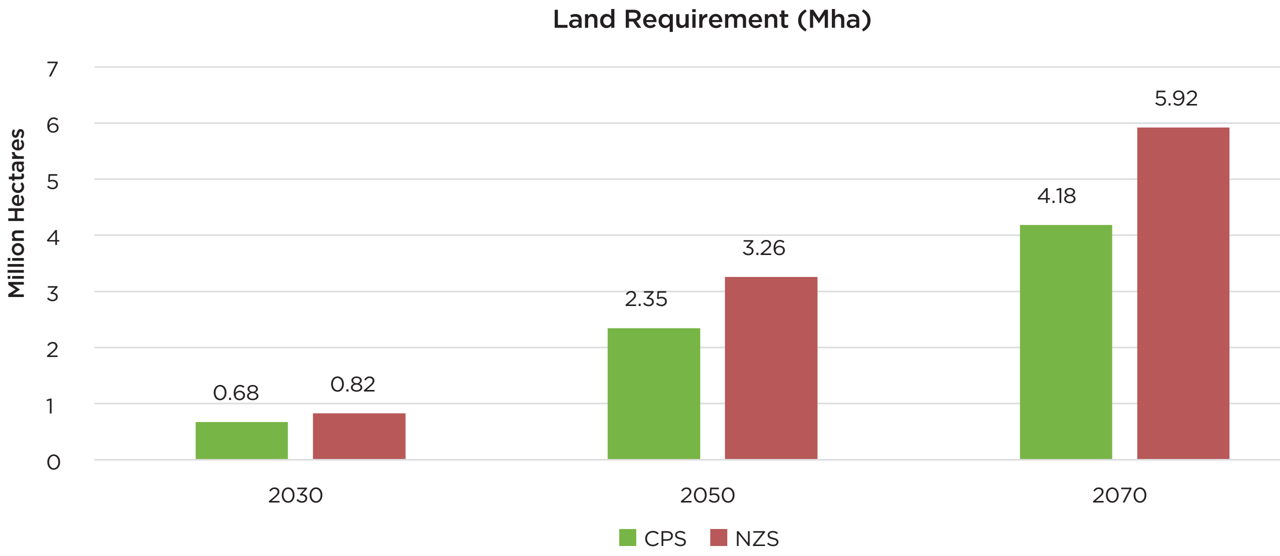

Figure 2.1: Land requirement under the Current Policy Scenario (CPS) and the Net Zero Scenario (NZS)

Land demand increases steadily under both scenarios as renewable capacity expands. Under the Current Policy Scenario, land requirements rise from 0.68 million hectares (Mha) in 2030 to 2.35 Mha in 2050, and 4.2 Mha by 2070. Under the Net Zero Scenario, land requirements are substantially higher, increasing from 0.82 Mha in 2030 to 3.26 Mha in 2050, and reaching 5.92 Mha by 2070. This reflects the extensive deployment of solar, wind, and nuclear energy required under a rapid Net Zero pathway. Future adoption of rooftop solar, floating solar, and agro-photovoltaic systems could, however, diversify deployment models and partially reduce land requirements.

At the national level, the aggregate land requirement for clean energy deployment appears manageable relative to India's total geographic area of approximately 300 million hectares. Recent land-use statistics indicate that net sown area constitutes 46.20% of the total area, while current and other fallow lands account for 8.35%. Pastures, tree crops, and culturable wastelands collectively represent 6.15% (Directorate of Economics and Statistics, Department of Agriculture & Farmers Welfare, 2024). Further, wastelands constitute only ~17% of the total land area, estimated at 55.76 million hectares in the Wasteland Atlas of India (2019).

A large part of this is India's open natural ecosystems (Vanak, and Madhusudan, 2022). Large-scale renewable projects are often set up on these wastelands. In reality, these open ecosystems often support grazing, biodiversity, and rural livelihoods (Vanak & Madhusudan, 2022).

As observed, land requirements for the power sector under both the scenarios is projected to increase over the years. This is majorly driven by the increasing share of renewables. Under the Current Policy Scenario, the land requirements are projected to reach 4.2 Mha by 2070, which is equivalent to about 7.5% of the assessed wastelands. Further, under the Net Zero Scenario the land requirements are projected to reach 5.92 Mha by 2070, which is equivalent to about 11% of the assessed wastelands. In both the scenarios the wasteland estimates for clean energy deployment constitute a substantial portion of the available wastelands. Given this, the diversion of such ecosystems for setting up large-scale renewable energy projects necessitates rigorous safeguards to mitigate socioeconomic and ecological impacts.

Concurrently, water requirements of the power sector evolve differently across scenarios as the generation mix shifts (see Figure 2.2).

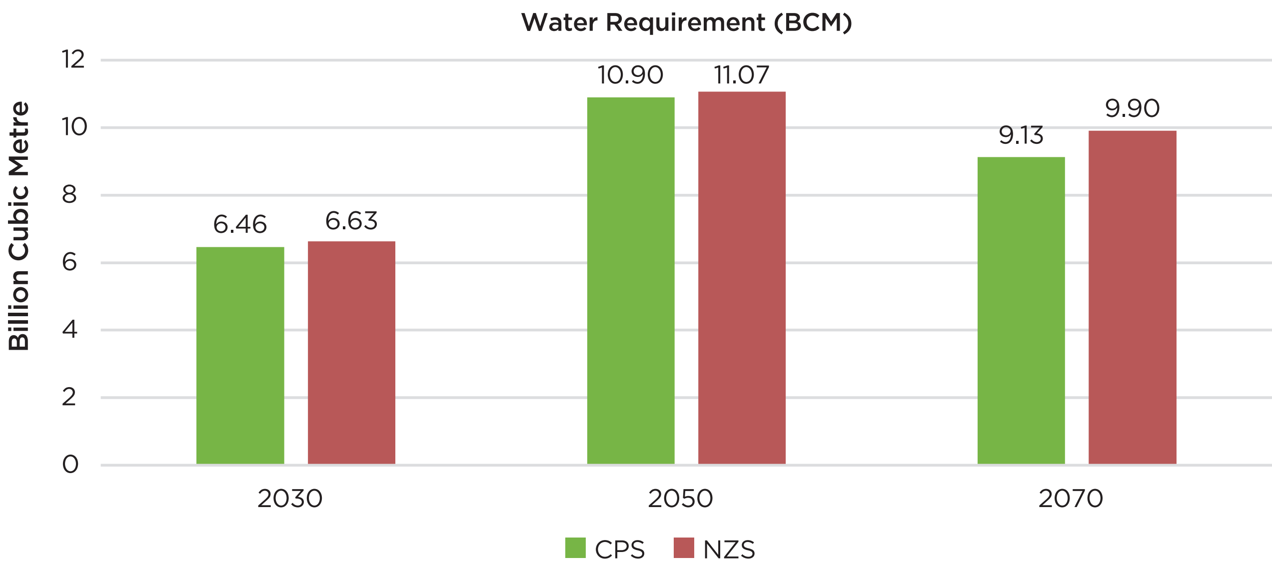

Figure 2.2: Water requirement under the Current Policy Scenario (CPS) and the Net Zero Scenario (NZS)

Under both scenarios, water consumption increases substantially by mid-century and declines thereafter. This is driven by the rising share of renewables which have low operational water requirements. It is further noted that the water consumption in the Net Zero Scenario remains higher than the water consumption under the Current Policy Scenarios throughout. This is due to greater nuclear capacity and the scaling up of green hydrogen production under the Net Zero Scenario.

Water use within renewable systems varies considerably by technology and practice. It ranges from 3 to 8 litres per module for traditional manual cleaning to less than 1.5 litres for optimised systems, with waterless robotic solutions now providing a zero-consumption alternative (Renewable Watch, 2020). Green hydrogen production typically has a water consumption intensity ranging from 17.5 to 22.3 litres per kilogram (IRENA and Bluerisk, 2023). However, when accounting for additional requirements like purification and process cooling, the total water withdrawal reaches approximately 32 litres per kilogram.

In addition, it is to be noted that despite lower aggregate water demand, local water stress does not disappear in renewables-dominated systems. Solar parks in arid and semi-arid states will continue to require water for maintenance. Similarly, large-scale green hydrogen production is likely to create new industrial water demand hotspots near refineries and industrial clusters.

Moreover, renewables create indirect resource pressures along their value chains. Grid expansion (transmission corridors and substations) adds to land footprints (besides the estimates in Figure 2.1), while battery storage depends on minerals such as lithium, cobalt, and nickel, whose extraction is water-intensive. Lithium extraction has significant water requirements, that is, extracting one ton of lithium requires approximately 5,00,000 gallons of water (Greenmatch, 2024). Further, every tonne of mined lithium results in 15 tonnes of CO_2 emissions in the environment. Nickel mining, often from laterite ores, can impact the natural ecosystem (Genchi et al.,2020).

Taken together, India's energy transition will reconfigure resource pressures. In both pathways, basin-level and region-specific planning will be critical to reconcile energy expansion with limited freshwater availability and competing land uses. Recycling, responsible sourcing, and integrated infrastructure planning will therefore be essential.

2.2 SPATIAL ASPECTS OF TRANSITION

India's land and water resource needs for renewable energy expansion needs to be seen in the context of demographic growth, ecological considerations, and multiple development priorities. This needs a closer examination of trajectories, including their geographic distribution, intersections with prevailing land uses, and other conditions.

India's renewable energy reforms have accelerated utility-scale solar deployment alongside wind and hybrids through several reform measures such as the Payment Security Mechanism, Waiver of Inter-State transmission charges, 100% FDI under the automatic route, the Green Energy Corridors programme etc. As a result, utility-scale solar constitutes ~100 GW of 130 GW total installed capacity, with 135 GW under construction. Wind power (including new onshore projects, repowering of ageing wind farms, and an increasing share of wind–solar hybrid installations) constitutes more than 50 GW of the installed capacity, with over 30 GW under various stages of development (PIB, 2025).

While these measures have facilitated rapid scale-up, they have also created conditions favouring large, contiguous sites in resource-rich zones. As per the Renewable Energy Statistics for 2024-25the RE capacity is geographically concentrated in five states: Rajasthan, Gujarat, Maharashtra, Tamil Nadu, and Karnataka as shown in Figure 2.3 (MNRE, 2025). These together account for nearly 75% of installed solar and wind capacity.

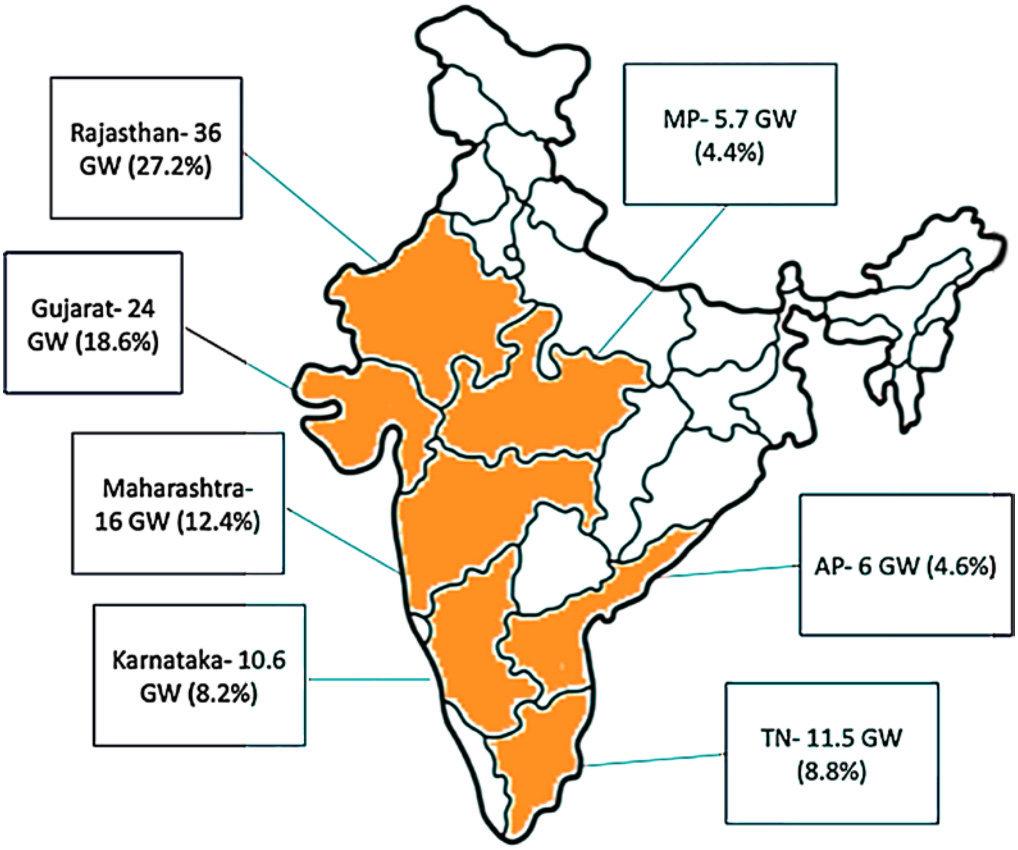

Figure 2.3: Solar capacity in various states in 2024 - 2025

These regions driving renewable expansion are largely located in arid and semi-arid areas, with 56% of all solar installations nationally located in water-stressed zones, amplifying ecological and hydrological risks for local communities (Gupta, 2019). This spatial overlap of renewable deployment intensity and vulnerable population concentrations creates distributional challenges that need to be addressed. When renewable projects are sited in these regions, they systematically concentrate development pressures on populations with low capacity to absorb them.

2.3 CHALLENGES

1. **Diversion of open ecosystems:**

   Government assessments identify ~55 million hectares as wastelands. A large part of this is India's open natural ecosystems (Vanak, and Madhusudan, 2022). Large-scale renewable projects are often set up on these wastelands. In reality, these open ecosystems often support grazing, fuelwood, and minor forest produce. The diversion of open ecosystems needs to be carefully managed to protect the livelihoods of people dependent on these areas.

2. **Ecological Disruptions and Biodiversity Impacts:**

   India's transition spans vulnerable ecosystems such as the Western Ghats, Thar and Kutch grasslands, and coastal wetlands, which host endemic and endangered species (Shivaprakash, 2022). Renewable installations often impact these habitats through land clearing, fragmentation, and construction of roads and transmission lines. The consequences include vegetation loss, increased soil erosion, and disrupted wildlife corridors. Further, these can impair ecosystem services like carbon sequestration, soil retention, and hydrological regulation. Climate change amplifies these vulnerabilities.

3. **Water Stress and Hydrological Competition:**

   The rapid expansion of renewable energy infrastructure unfolds within regions experiencing increasing hydrological constraints. Groundwater over-exploitation affects over 25% of administrative units in several states, with renewable zones increasingly coinciding with "Critical" and "Over-exploited" districts (Central Ground Water Board, 2025). Emerging low-carbon industries concentrate withdrawals near such areas, amplifying competing sectoral demands. Coordinated water allocation mechanisms are needed to manage this.

2.4 SUGGESTIONS

1. **Land-Neutral and Water-Efficient Pathways:** Technological innovation offers pathways to decouple renewable deployment from competing uses of land and water. Agrivoltaics, floating solar, and built-environment integration demonstrate that energy expansion need not displace existing productive land use while preserving agricultural output and reducing water consumption.

   To scale these models, there is a need to address the premium costs associated with these technologies. For example, Agri-Photo Voltaic (APV) systems typically cost upto 40% more than ground-mounted PV because of specialised structures and dual-use design (Pandey et al., 2025). Floating solar also exhibits higher levelized costs, with a Levelised Cost of Energy (LCOE) of ~₹4.32/kWh (US$0.052/kWh) compared to recent utility-scale solar tariffs of ~₹2.4–₹2.8/kWh (Mondragon Assembly, 2024). Accordingly, pursuing these options needs targeted viability-gap support or concessional debt to socialise the land-benefit while keeping retail tariffs stable.

   For floating solar, comprehensive reservoir mapping through the Central Water Commission and state irrigation departments may be undertaken to identify suitable areas. Further, complementing these approaches, building-integrated photovoltaics, railway-mounted solar, and highway installations can be supported through relevant ministries and departments.

2. **Strengthen Spatial Planning:** For projects that remain land-intensive, robust siting strategies are essential. Platforms such as the Integrated Biodiversity Assessment Tool (IBAT) and the Avian Sensitivity Tool for Energy Planning (AVISTEP) enable developers to avoid ecologically sensitive habitats. Coupled with accurate land records and structured community consultations, such tools can reduce contestation and improve the credibility of siting decisions. Importantly, these process can integrate local communities to ensure that mapping translates into legitimate outcomes on the ground.

   India's extensive stock of degraded and converted lands offers an underutilised opportunity for clean energy. These lands have limited agricultural value but can host solar and wind projects with relatively low social cost. Additionally, repurposing the 2,500 km^2 of land already mined for coal and lignite would serve dual goals:

advancing low carbon development while supporting a just transition in mining-dependent regions by creating new jobs and infrastructure.

3. **Scale implementation of decentralised models:** Decentralised Renewable Energy (DRE) represents another critical lever. Rooftop solar, mini-grids, solar pumps, and solar street lighting extend access without large-scale land acquisition, directly supporting rural livelihoods and last-mile electrification. Such models enable inclusive access, local ownership, and equitable benefit-sharing.

   Decentralised models implemented through Farmer Producer Organisations (FPOs) and cooperatives also provide economies of scale, wherein farmers not only retain land but also receive additional revenue from the sale of surplus power. While this model is important for inclusivity, only a small share of FPOs/Cooperatives currently has the institutional strength to manage large DRE projects at scale.

   The more scalable pathway lies in Renewable Energy Service Companies (RESCOs) and private developers, who can aggregate multiple sites, manage operations professionally, and access institutional capital. In such models, farmers or communities lease land, enter service contracts, or share revenues, while developers take on financing and operational risks.

   This aggregation model allows innovation like agrivoltaics or floating solar to be deployed at scale while still delivering steady livelihood benefits to landowners. To succeed, however, RESCOs must ensure farmers' and communities' interests are met through measures such as clear contractual frameworks and risk mitigation instruments that incorporate clear revenue-sharing. To ensure economic inclusion, employment quotas may require developers to source their workforce from host districts, with provisions for marginalised communities and dedicated training for skilled roles, moving beyond temporary casual labour.

4. **Developing Fit-for-Purpose Financing Models:** A fundamental barrier to the scaling of innovative renewable energy models and community participation is access to affordable and patient capital. Commercial lenders typically require collateral that farmer organisations and community entities cannot provide, while emerging technologies face higher perceived risks and longer payback periods. These constraints limit the participation of small developers, cooperatives, and landholders in the energy transition.

   To address these gaps, India requires a differentiated financing architecture anchored in public and blended finance. Development finance institutions such as IREDA, NABARD, and multilateral partners can provide concessional debt, first-loss capital, and partial credit guarantees to de-risk investments in agrivoltaics, floating solar, and decentralised renewable energy. Payment security mechanisms such as escrow accounts, state-backed guarantees, or pooled risk facilities should be established to mitigate off-take risk, particularly for community-linked and small-scale developers.

   While long-term power purchase agreements (PPAs) remain central, revenue diversification should be enabled through participation in emerging capacity markets and ancillary service markets that value firm capacity, storage, and grid services. Such mechanisms can improve project bankability while supporting grid stability.

Crucially, concessional finance and risk guarantees may be explicitly linked to social performance. Access to preferential capital must be conditional on compliance with procedural safeguards, including prior consent, transparent benefit-sharing and local employment commitments. Embedding social conditionality within financing frameworks ensures that public capital catalyses not only clean energy deployment, but also durable social outcomes and community trust.

5. **Water Resource Management:** Currently, energy production is captured under “industry” in national and state water policies. Bringing energy explicitly into these policies enables rational priority-setting and efficiency optimization. Safeguards while prioritizing allocation for energy may include:

   a. For coastal zones, the integration of desalination technologies offers a pathway to reduce freshwater requirements.

   b. In regions facing acute groundwater depletion, the focus may shift toward circularity utilizing treated wastewater for energy production.

   c. Prioritise water-lean technologies by incorporating efficiency as evaluation criteria, rewarding waterless cleaning or closed-loop recycling.

3

LIVELIHOOD, EMPLOYMENT AND MIGRATION ASPECT

Livelihood, employment and migration aspect

3

India's development and low-carbon transition unfolds along with shifts in work, livelihoods and migration patterns. Employment structures determine which households can absorb shocks from both climate impacts and clean energy deployment, and which are vulnerable. Patterns of migration, in turn, can act as social "shock absorbers" when they enable people to diversify income or move out of high-risk zones, or as "shock amplifiers" when migrants are channelled into precarious, climate-exposed settlements with limited protection. It is thus important to examine how employment and mobility will be reconfigured in a Net Zero economy, and how these changes intersect with existing structural inequalities in India's labour market.

India's labour force is vast with more than 640 million people employed in 2023–24 and contributing nearly 52% to Gross Value Added (GVA) (Reserve Bank of India, 2024). The labour force participation rate has risen steadily, from 49.8% in 2017–18 to 60.1% in 2023–24, driven largely by a surge in women's participation from 23.3% to 41.7% in the same period (Periodic Labour Force Survey (PLFS), 2024).

In terms of employment structure, according to PLFS 2023-24, agriculture employs 43.5% of workforce while contributing 14.7% of gross value added, while industry generates 21.9% of output and employs 24.9% and services account for 63.4% of output and employs 31.6%.

The employment landscape is defined by high informality with estimates differing due to methodological differences (Ministry of Statistics and Programme Implementation (MoSPI, 2024). PLFS (2023-24) further estimates that over 70% of non-agriculture workers are informally employed nationally with rural areas having a ratio of 79% and urban having 66% (MoSPI, 2024). Adding to this, the report further suggests that only 21.7% held regular wage jobs (MoSPI, 2024). Informality pervades both traditional and modern sectors.

Against this backdrop of high informality and uneven job quality, the employment impacts of India's low-carbon transition acquire particular significance. Energy systems are not only central to economic growth but also anchor livelihoods across regions, value chains, and skill levels. As the transition reshapes energy production, infrastructure, and supply chains, it will directly affect where jobs are created, which skills are valued, and which workers face displacement. Examining employment dynamics within fossil-fuel and clean energy sectors therefore provides a critical lens to assess how the Net Zero transition may redistribute risks and opportunities across India's workforce.

India's fossil-fuel supply chains, including coal, oil, and gas, remain major employers, but they are increasingly exposed to transition risks. The International Energy Agency (IEA) (2024) estimates that in 2023, India's energy sector employed 8.5 million workers, of which 3 million were in electricity generation and grid, and 2.4 million in coal, oil, and gas supply. These figures capture only direct employment; when indirect jobs are included, the scale expands substantially.

On other hand, clean energy is emerging as an important driver of job growth across the energy sector. In India, energy sector employment grew 3% year-on-year to 8.5 million, with clean energy jobs expanding by 5%, higher than the 2% growth in fossil-fuel jobs (IEA, 2024). However, vulnerabilities and opportunities of the Net Zero transition are deeply spatial in nature. The following section therefore undertakes a state-level analysis to examine how the energy transition is likely to reshape employment, migration, and livelihood outcomes across regions, and what this implies for targeted policy responses.

3.1 STATE-LEVEL ECONOMIC STRUCTURES AND THEIR IMPLICATIONS FOR EMPLOYMENT AND MIGRATION

India's transition to a developed economy by 2047 and subsequently to Net Zero emissions by 2070 will not unfold uniformly across the country. States enter this dual transition with markedly different economic structures, labour markets, and exposure to climate and transition risks. These structural differences shape how shocks are absorbed, where employment opportunities emerge, and which regions face the greatest risks of dislocation. A state-level classification of economic structure is therefore essential to move beyond a one-size-fits-all transition strategy and to identify differentiated pathways for development, employment creation, and low-carbon transition. Such a framework helps anticipate where labour displacement is likely, where clean energy and green industrial opportunities can be scaled most effectively, and where targeted policy support through skilling, social protection, or regional investment will be most critical.

In the analysis discussed subsequently, an attempt has been made to categorise states under broad economic profiles namely agriculture-dominant, industry-dominant, services-dominant, and balanced states based on their output and employment structures. This categorisation provides a lens to assess how India's development and climate transitions intersect at the sub-national level, and how policy responses must be sequenced and tailored across states rather than applied uniformly.

1. **Agriculture-Dominant States:** In the agrarian heartland, agriculture's share Net State Value Added (NSVA) and employment in many states is above the national average (17.3% Gross Value Added (GVA) and 43% of employment). As per PLFS and National Accounts 2022–23, this includes: Madhya Pradesh (37.1 % of NVSA and, 56% of employment), Uttar Pradesh (24.7%, 51.9%), Rajasthan (29.7%, 50.8%), Bihar (20.5%, 48.6%). Among these states, more than half of the workforce remains concentrated in agriculture in Madhya Pradesh, Uttar Pradesh, and Bihar.

   This concentration reflects persistent low labour productivity, limiting income growth and local absorption capacity outside farming. As a result, migration functions as a primary livelihood diversification strategy for working-age men and women, allowing households to offset seasonal income volatility, and climate-related shocks. According to the last comprehensive migration survey undertaken in 2020–21, male migration is overwhelmingly driven by employment (Migration in India, MoSPI, 2023), and Census 2011 highlights Bihar, Uttar Pradesh, Jharkhand, Odisha, and Rajasthan as the states with the highest shares of male outmigrants (Office of the Registrar General & Census Commissioner, India, 2011).

2. **Industry-Led States:** Among industry-led states, crucial distinctions exist between manufacturing-driven, mining-driven, and construction-driven industrial structures. These differences shape both employment outcomes and exposure to transition risks.

   (a) **Manufacturing-driven states:** Gujarat, Tamil Nadu, and Maharashtra account for the bulk of India's manufacturing output. Alongside these large manufacturing giants, a sizeable manufacturing base is also evident in smaller states. Goa, Sikkim, Uttarakhand, and Himachal Pradesh emerge as smaller but genuine manufacturing hubs. In these states, pharmaceuticals and chemicals dominate production, while in some cases automobiles and light engineering have developed under tax incentives and industrial clustering policies.

   (b) **Mining-driven states:** Odisha, Chhattisgarh, Assam and Tripura, are characterised by mining- and metals-led industrial structures. These sectors generate substantial output but absorb relatively few workers, resulting in high output concentration without corresponding broad-based employment. Such structures heighten vulnerability to energy transitions, particularly as fossil-fuel–linked activities face long-term decline.

   (c) **Construction-driven states:** Arunachal Pradesh, Bihar, Kerala, Manipur, Nagaland, Chandigarh, and the Andaman and Nicobar Islands are the states where construction contributes more than 50% of industry Net State Value Added (NSVA). Construction functions as a labour sponge, particularly for migrants and low-skilled workers, but remains cyclical, highly informal, and weak in long-term productivity gains. The Internal Migration in Asia report highlights that such workers typically operate without adequate protections or safety nets, rendering them especially vulnerable to downturns in construction activity and climate-related disruptions.

3. **Service-Driven States:** A third pattern emerges in service-driven states, where services account for far more than the national benchmark of 54.9% Gross Value Added (GVA). Delhi (85.9% Net State Value Added (NSVA), 66.9% employment) and Chandigarh (90.4%, 84.8%) are the most extreme, dominated almost entirely by public administration and tertiary services.

   Karnataka (64.8% NSVA, 35% employment), Telangana (62.0%, 34.6%), and Kerala (64.9%, 49.4%) also far exceed the national benchmark, powered by IT, remittances, and tourism.

   The North-East similarly reveals service-led structures: Manipur (71.1% NSVA, 38.1% employment), Nagaland (65.7%, 38.4%), and Meghalaya (63.2%, 31.5%), though here much of the service activity reflects government administration.

4. **Balanced States:** A handful of states emerge as balanced giants, like Tamil Nadu, Gujarat, and Maharashtra who have substantial contributions from agriculture, industry, and services. These states exhibit diversification and resilience, absorbing labour effectively while exemplifying the structural transformation essential for nationwide replication (Table 3.1).

Table 3.1: Categorisation of states based on economic and employment structures

Category	States
Agriculture dominant	Madhya Pradesh, Uttar Pradesh, Rajasthan, Bihar
Manufacturing-led industry	Tamil Nadu, Gujarat, Maharashtra, Uttarakhand, Himachal Pradesh
Construction-led industry	NE-states
Services driven	Delhi, Chandigarh, Karnataka, Telangana
Balanced giants	Maharashtra, Tamil Nadu, Gujarat

This differentiation is particularly critical for understanding employment risks linked to fossil-fuel dependent sectors. States with mining- and metals-led industrial structures host a concentrated workforce tied to coal, minerals, and energy-intensive industries, making them disproportionately exposed to transition related job losses. As India advances toward the Net Zero, these sectoral and spatial concentrations will determine where labour displacement pressures are most acute and where proactive reskilling, diversification, and social protection measures must be prioritised.

3.2 FOSSIL-FUEL DEPENDENCE AND VULNERABILITY

India's economic structure, as reflected in the state-level typology above, is not only uneven across sectors and regions but is also deeply intertwined with the fossil-fuel economy. Coal, oil, and gas have historically underpinned industrialisation, electricity supply, and energy-intensive manufacturing, particularly in mining-driven and heavy-industry-oriented states. This legacy has produced pronounced regional concentrations of fossil-fuel dependence, where entire districts rely on coal mining, thermal power, refineries, steel, cement, and fertiliser industries for both employment and public revenues.

Box-2: Spatial distribution of fossil-fuel supply chains

An estimate suggests that over 150 districts across India are significantly dependent on fossil-fuel supply chains, directly or indirectly sustaining livelihoods for nearly one-third of India's population (Bhushan and Banerjee, 2021) (See Figure 3.1). This spatial clustering means that the transition away from fossil-fuel will be a lived reality in specific parts of India, where jobs, state finances, and induced economies are interwoven with fossil-fuel economy.

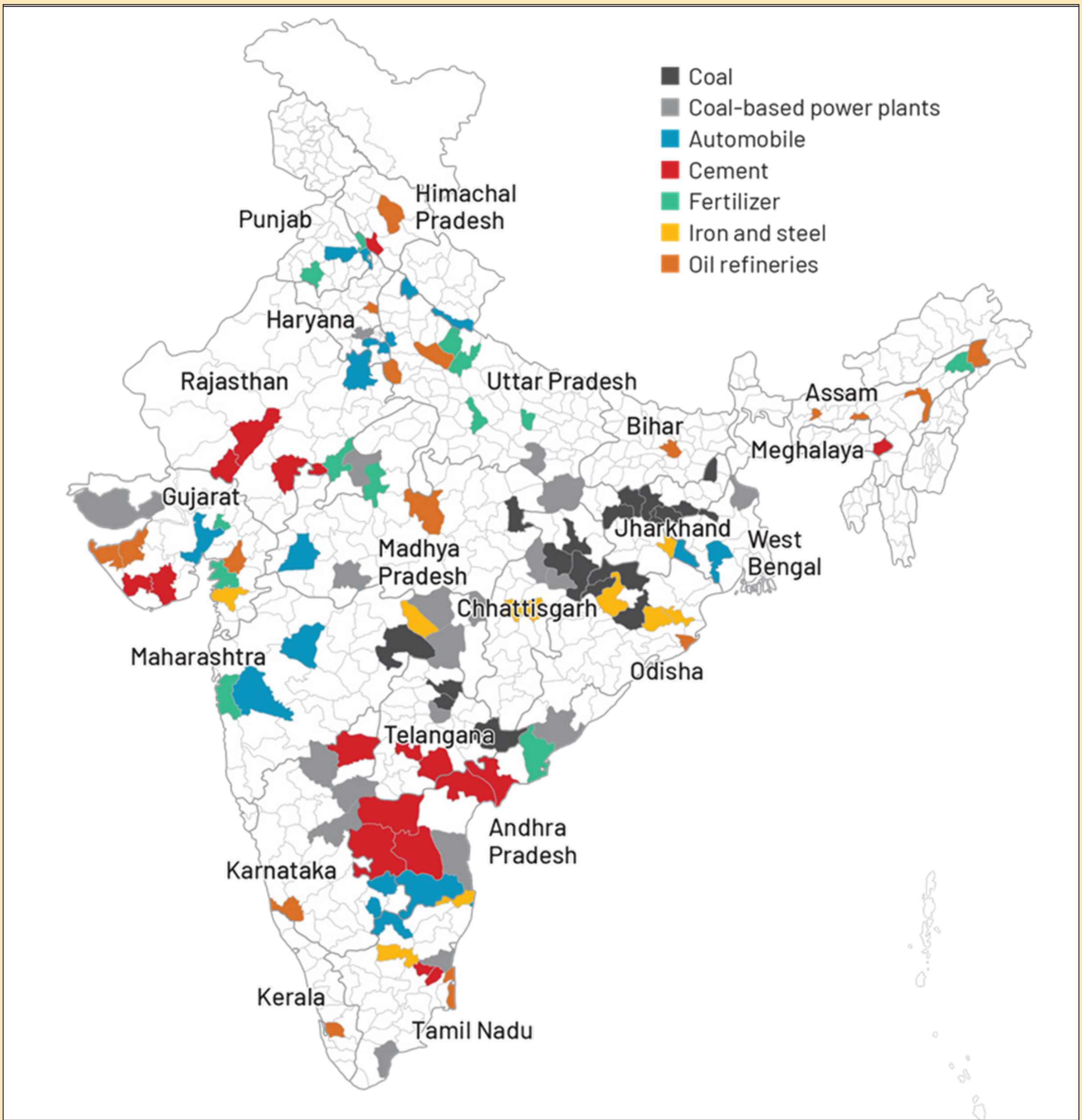

Figure 3.1 : Districts dependent on fossil-fuel economy

Coal mining remains the backbone of fossil-fuel employment. As of April 2024, Coal India Limited (CIL) employed 2,28,861 workers (regular and contractual) in its subsidiaries across Jharkhand, Odisha, Chhattisgarh, and Madhya Pradesh (Ministry of Coal, 2024). However, this number masks the wider reality: large numbers of contract, transport, loading, and ancillary workers operate outside CIL's rolls. According to this working group, formal coal mine employment is about 3,45,000 workers (See Table 3.2) (Working group analysis), while the informal workforce is at least twice as large. This implies that over 1 million people are directly dependent on coal mining.

While induced employment captures the wider local economy, the core of coal mining jobs remains concentrated in formal departmental and contractual workers employed directly by Coal India Limited and its subsidiaries. These workers form the backbone of coal's direct labour force and are distributed across a handful of key coal-bearing states. Table 3.2 provides a state-wise breakdown of this formal workforce, highlighting how employment is clustered in India, together accounting for well over half of total coal mine jobs.

Table 3.2: Workforce dependent on coal mining

State	Departmental workers	Contractual workers	Total formal workers (Departmental+Contractual)
Jharkhand	63,722	6,821	70,543
Telangana	35,469	23,166	58,635
Madhya Pradesh	31,677	21,224	52,901
West Bengal	40,702	4,111	44,813
Chhattisgarh	28,702	13,614	42,316
Odisha	18,692	21,823	40,515
Maharashtra	21,140	7,947	29,087
Uttar Pradesh	2,515	3,737	6,252
Assam	43	4	47
Total	**2,42,662**	**1,02,447**	**3,45,109**

Source: *Working group analysis. Mine-wise workforce data has been procured from CIL and its subsidiaries over the last two years (2022-2024).*

** Informal workers vary as per state. For example, in Odisha, it is nearly 1.6 times, while in Jharkhand it is as high as 3 times. Therefore, for estimation in the text, an average of nearly 2 times of the formal workforce has been considered.*

Yet the actual footprint of coal goes further. Surveys conducted in coal-mining regions reveal that each direct job generates multiple induced jobs in the surrounding economy. Within a 10 km radius of mines, retail, transport, food services, repair shops, and daily wage activities thrive on coal incomes. In Bokaro (Jharkhand), every direct job supports three induced jobs; in Korba (Chhattisgarh) the ratio rises to over four; and in Angul (Odisha) it is just above two. This multiplier effect underscores how coal sustains not only mine workers but also entire local economies (Table 3.3).

Table 3.3: Ratio of direct and induced jobs in coal mining areas

District	Direct jobs	Induced jobs	Ratio
Bokaro (Jharkhand)	44,230	130,884	3.0
Korba (Chhattisgarh)	25,441	105,159	4.1
Angul (Odisha)	37,002	78,671	2.1

Source: *Working group (Vol 11) analysis using 2023 mines data.*

Looking ahead: mine-level assessments suggest that by 2030, around 178,000 formal jobs could be impacted and at least double that informally. Without reskilling and social protection, this can generate acute dislocation in coal belts such as Bokaro, Korba, and Angul.

Coal-Based Thermal Power Plants: Coal-fired thermal power plants (TPPs) form the backbone of India's electricity system, accounting for the bulk of installed capacity and generation. As on 2024-25 the 221.8 GW of coal capacity exists across the country (Institute for Energy Economics and Financial Analysis (IEEFA), 2025). Applying the CEA's standard employment factor of 0.63 personnel per MW, this capacity supports ~1,40,000 formal workers in plant operations, spanning engineers, operators, technicians, and administrative staff.

However, the formal workforce represents only part of the picture. TPPs are embedded within extensive local economies of contractors, transporters, maintenance workers, loaders, and service providers. District-level assessments suggest that informal jobs are at least twice as numerous as formal jobs. On this assumption, the informal workforce associated with coal-based TPPs adds up to around 2,80,000 workers. In total, therefore, TPPs sustain close to 4,20,000 jobs nationwide making them one of the single largest sources of industrial employment in India. The state-wise distribution of coal TPP employment reflects the geography of India's power system (See Table 3.4). Major industrial states dominate:

Table 3.4: State-wise workforce dependent on coal-based thermal power plant generation

State	Total workers
Uttar Pradesh	52,986
Maharashtra	46,619
Chhattisgarh	44,770
Madhya Pradesh	41,580
Gujarat	30,414
Tamil Nadu	26,767
West Bengal	25,490
Andhra Pradesh	24,929
Rajasthan	20,374
Telangana	19,358
Odisha	18,144
Karnataka	17,917
Bihar	17,123

State	Total workers
Punjab	10,735
Jharkhand	10,527
Haryana	10,074
Assam	1,418

Source: *State installed capacity from ICED (2024-25)*

This concentration underscores both the economic weight and vulnerability of coal-fired power. States reliant on coal mining are doubly exposed, hosting not only mines but also large clusters of thermal power plants. Moreover, while formal jobs are relatively secure, the majority of TPP-dependent livelihoods are informal and therefore the first to be affected when units scale back, or switch fuels.

Looking ahead, the age profile of India's TPP fleet compounds the challenge. While over three-fourths of current capacity is under 20 years old, by 2040 almost two-thirds of the existing fleet will cross 25 years of age, approaching or exceeding their design life. Timely planning is needed to protect the affected workforce.

Fossil-Fuel-Linked Manufacturing and Downstream Industries: Beyond coal mining and power generation, India's manufacturing base hosts a set of industries structurally tied to fossil-fuels, either as feedstock or as dominant energy inputs. These sectors employ millions of workers, both formal and informal, and are geographically concentrated in states that also host coal mines and thermal power plants, thereby compounding their vulnerability to the energy transition.

The Annual Survey of Industries (ASI, 2022–23) records around 7 million formal workers across fossil-fuel-linked manufacturing sectors (textiles, paper & pulp, basic metals and non-metallic minerals, petroleum products, chemical products, manufacturing and maintenance of vehicles), while the Annual Survey of Unincorporated Sector Enterprises (ASUSE, 2023–24) shows an additional 9.9 million informal workers in the same sectors (see Annexure-1 for sector-wise breakup).

(a) Textiles remain the largest single employer, with 1.72 million formal workers and 3.41 million informal workers. Though not often counted as "fossil-fuel industries," textiles are highly energy-intensive, especially in synthetic fibres, dyeing, and processing, which still rely on coal-fired captive plants.

(b) Non-metallic minerals, driven by cement, employ 1.05 million formal workers and 2.61 million informal workers.. Cement production is one of the most coal-intensive manufacturing processes, with captive thermal units powering kilns.

(c) Basic metals including steel and aluminium employ 1.41 million formal and 0.27 million informal workers. These industries are structurally tied to coal, both for coking and as feedstock for captive power.

(d) In energy-linked sectors, petroleum products account for about 1,69,000 formal jobs and 51,000 informal jobs, clustered around refinery hubs. Chemical products, including fertilisers, add another 1.06 million formal and 176,000 informal workers, heavily reliant on natural gas feedstocks and petroleum derivatives.

(e) The automobile sector spans both manufacturing and downstream services. Motor vehicle manufacturing provides 1.26 million formal jobs and around 63,000 informal jobs. Downstream, the retail and repair of vehicles-entirely informal adds over 3.0 million jobs (710,000 in sales, 2.35 million in repair). Taken together, the auto economy remains one of the largest fossil-fuel-linked employment clusters, vulnerable to electrification and automation.

In total, these fossil-fuel-linked industries represent a labour force of 16.9 million, with well over half concentrated in the informal sector. Unlike coal mining and TPPs, where risks arise from plant closures, these sectors face gradual disruption from technological substitution: low-carbon cement, green steel, bio-based textiles, and electric vehicles. The challenge is sharper because the bulk of workers, small contractors, repair shops, unregistered cement kiln staff, and dyeing unit helpers are informal and thus most exposed to volatility.

3.3 GENDER DIMENSION

Employment patterns in India are uneven across states, sectors, and gender. Women are concentrated in agriculture (60.6% per PLFS 2022–23 vs. 35.6% men) and informal work, with limited presence in fossil-fuel linked industries exposed to transition risks. Only 16.2% of women work in the secondary sector (vs. 28.9% men), and 23.1% in services (vs. 35.6% men).

Annual Survey of Unincorporated Sector Enterprises (ASUSE, 2023–24) reveals informality's granularity: women dominate textiles (1.76 million vs. 1.65 million men) but are marginal in heavy industries like basic metals/petroleum (<25,000 each), vehicle repair (18,465 vs. 2.33 million men), and retail (49,000 vs. 661,000 men). Migration reinforces this. PLFS 2020–21 shows 42.9% of men migrate for work vs. 0.7% women (mostly marriage-related).

These vulnerabilities amplify transition risks (Nayak and Swain, 2023). Women are less represented in formal fossil-fuel jobs and associated benefits (compensation, retraining), while their informal livelihoods (coal collection, agriculture, textiles, construction) will be impacted first.

3.4 PROJECTIONS: THE SHAPE OF WORKFORCE TRANSITION

As India embarks on the Net Zero transition, the employment landscape will undergo fundamental changes. Global scenarios and country-level models converge on a key insight: clean energy investments will reshape jobs, but need careful planning to achieve equitable outcomes.

Employment impacts are assessed leveraging inputs from the report on Macroeconomic Implications (Vol. 2) to analyse labour market changes under both the Current Policies Scenario (CPS) and the Net Zero Scenario (NZS). In the Current Policy Scenario, the broad employment pattern in energy sector largely remains stable in 2022 with an employment of 6 million by 2050. Coal, Oil, Gas and Electricity account for the bulk of employment. By 2070, total jobs will be 4 million primarily due to improvements in energy efficiency and technological progress. As the economy becomes less energy-intensive, fewer workers are required both in direct energy production and in the upstream and downstream sectors that supply or depend on energy, leading to a gradual contraction in employment.

However, in the Net Zero Scenario, industry records higher employment than the Current Policy Scenario, for both skilled and unskilled workers, reflecting rising demand from clean technology manufacturing and renewable energy infrastructure. With rapid expansion in clean energy, energy sector jobs will be 7 million by 2050 (1 million higher than the Current Policy Scenario) and 4.5 million in 2070 (0.5 million higher than the Current Policy Scenario). These results are consistent with the IEA's World Energy Employment 2024, which projects India's energy jobs to grow by over 20% under its stated policies scenario, driven largely by clean energy deployment.

Beyond the energy sector, the Net Zero transition can deliver substantial economy-wide job gains under supportive policies. Job creation is concentrated in construction, road transport, and trade. Under the optimistic scenario[1], construction emerges as the single largest contributor, adding 4.6 million additional jobs in 2050 compared to the Current Policy Scenario. This is driven by the labour needs of utility-scale RE build-out, grid expansion, and low-carbon infrastructure. Road transport and trade also expand, with road transport adding 67,000 additional jobs in 2050 compared to the Current Policy Scenario. Trade contributes a cumulative 5.2 million jobs additional over the Current Policy Scenario during 2030–2070. This demonstrates that the Net Zero transition can be a major engine of employment outside the energy sector when combined with targeted complementary policies

Taken together, these projections show that the transition can be a net engine of job growth, not just in the energy sector but across the broader economy. However, geographic mismatches between fossil-fuel energy regions versus renewable energy potential areas will require deliberate policies for worker relocation, reskilling, and social protection to ensure that the benefits of transition are inclusive and equitably distributed.

While these projections suggest that the Net Zero transition can generate more jobs than it displaces, the gains are not automatic. Realising them will depend on two critical conditions: workers in fossil-fuel-heavy regions being reskilled for emerging opportunities, and investments flowing into the states where jobs are being lost. Current evidence points to sharp skill gaps particularly among informal coal workers who remain largely unskilled or semi-skilled and a geographic mismatch between fossil-fuel led economies and the locations where renewable energy investments are being deployed. Policies to bridge these gaps are needed so that projected green jobs at risk concentrated in a few states and sectors can benefit. These challenges, and the policies needed to address them, are discussed in the following section.

3.5 CHALLENGES AND SUGGESTIONS

Livelihoods are central to India's climate resilient development strategy and to its feasibility and legitimacy. There is a need to address spatially concentrated fossil-fuel dependence, informality, skills gaps, migration and institutional fragmentation. This will further determine whether jobs and mobility function as "buffers" that help households navigate climate and transition risks, or as "amplifiers" that may deepen vulnerability.

1. **Spatially concentrated fossil-fuel dependence and uneven emergence of green jobs:**

   Without deliberate spatial planning, coal and fossil-fuel belts may experience job loss and fiscal stress, while green growth benefits accrue elsewhere.

1 Net Zero Scenario wherein financing source is foreign, incremental finance is unproductive and subsidies are provided for deployment of clean energy protecting the low-income households. For details refer to report on Macroeconomic Implications (Vol. 2).

Suggestions:

(a) Create a national policy framework for worker retraining, relocation support, and economic diversification in districts affected by industrial decline. Dedicated funding mechanisms such as the District Mineral Foundation in mining regions can be leveraged alongside coordinated efforts by the Skill India Mission and the Skill Council for Green Jobs (SCGJ) to transition workers from declining industries into emerging green sectors.

(b) Using a national framework, integrated district-level transition plans may be developed for identified high-risk regions, combining economic diversification strategies, infrastructure investment, and workforce support, rather than addressing employment, skills, and investment in isolation. Within these plans, economic diversification can focus on building new, locally anchored sources of growth that reduce dependence on fossil-fuel–linked activities and strengthen long-term regional resilience.

2. **Informality and inadequate social protection for affected workers:**

A large proportion of workers in coal mines, coal logistics, construction and fossil-fuel-linked manufacturing are informal, employed through contractors or as casual labour, without written contracts and other benefits. Women are concentrated in precarious segments, such as coal picking, cleaning, auxiliary services and low-paid manufacturing, and are often invisible in official employment records.

Suggestions:

(a) Upgrade e-Shram to capture sectoral affiliation, contract type, geolocation including migration status, and skill levels, linking informal occupations directly to fossil-fuel-linked industries.

(b) Operationalise social protection entitlements for informal and contract workers in transition contexts, ensuring that existing schemes are effectively accessible to workers facing displacement or income loss due to industrial transition.

(c) Establish dedicated transition facilitation units at the local level, to support worker registration, benefit access, and coordination across schemes, with specific outreach to women and other invisible worker groups.

3. **Fragmented and supply-driven skilling systems:**

India's skilling ecosystem is fragmented across ITIs, the National Skill Development Corporation, state skill missions, company-led training and Sector Skill Councils. Curricula often lag behind rapidly evolving needs in renewable energy, storage, electric mobility, digital grids and green manufacturing. Regions with high fossil-fuel dependent supply chains have predominantly workers who have skills in manual and semi-skilled industrial tasks but limited exposure to new technologies, while women face additional constraints related to mobility, norms and care responsibilities. In this context, generic training programmes may not generate employment outcomes, while employers report difficulty finding workers with appropriate skills for green jobs.

Suggestions:

Accelerate development of sector-specific transition skill roadmaps to identify at-risk occupations in fossil-fuel–linked and carbon-intensive sectors and map pathways for reskilling into low-carbon roles, enabling workers and firms to adapt smoothly to decarbonisation pressures. Key elements of such roadmap to include:

(a) Align state-level skilling initiatives with sectoral decarbonisation roadmaps, identifying specific occupations and competencies required in renewables, grid modernisation, electric mobility, energy efficiency, and climate-resilient sectors.

(b) Strengthen employer participation in skilling systems, including curriculum design and on-the-job training, with incentives for firms that commit to hiring and mentoring workers from transitioning regions.

(c) Introduce targeted provisions for women and youth, including safe transport, childcare support, and flexible training schedules, to ensure equitable access to emerging employment opportunities in the low-carbon economy.

(d) Prioritise on-the-job training and practice-oriented skilling to upskill the existing workforce, particularly in emerging technologies and new production processes, ensuring that training leads to employable competencies rather than stand-alone certifications.

4. **Climate- and transition-induced migration:**

Migrants often settle in informal urban neighbourhoods without adequate housing, water, sanitation, waste management and health services. Labour markets at destinations frequently absorb them into low-wage work in construction, transport, informal services and gig platforms. These conditions can turn migration from a coping strategy into a driver of new vulnerabilities.

Suggestions:

(a) Local planning frameworks may recognise climate- and transition-induced migrants as a priority group for access to affordable urban housing, basic services and social protection, building on initiatives such as the One Nation One Ration Card to improve portability of entitlements.

(b) Implementation of the newly notified Labour Codes may prioritise high-migrant sectors through accelerated rollout, focused inspections, and enhanced compliance monitoring. This strengthens occupational safety, wage protection, and working conditions in construction, small manufacturing, logistics, domestic work, and gig-based services. Enforcement mechanisms may further adapt to informality, subcontracting, and platform-based employment models that disproportionately affect migrant workers.

4

HEALTH EQUITY AND WELLBEING IN INDIA'S NET ZERO TRANSITION

Health Equity and Wellbeing in India's Net Zero Transition

4

Over the past decade, the country has achieved significant progress in socio-economic development and health outcomes. Efforts to improve access to healthcare, sanitation, and nutrition have led to notable reductions in child and maternal mortality and a decline in communicable diseases, supporting the goals of inclusive growth and sustainable development.

India's healthcare transformation is guided by the vision of "Health for All". The government has made unprecedented strides in expanding access, improving quality, and ensuring affordability. Landmark initiatives like Ayushman Bharat- Pradhan Mantri Jan Arogya Yojana (PM-JAY), Ayushman Bharat Digital Mission (ABDM), PM-ABHIM, POSHAN Abhiyaan, and Pradhan Mantri Matru Vandana Yojana (PMMVY), PM JANMAN, eSanjeevani, and many others have strengthened healthcare systems, improved maternal and child health indicators, and enhanced nutrition security through community participation and technological innovation, particularly in rural and underserved regions (PIB, 2025; PIB, 2026). Investments in infrastructure, digital health, immunisation, and medical education have created a robust foundation for future health security. India's COVID-19 vaccination campaign marked a turning point in India's public healthcare journey, delivering over 2.2 billion doses through indigenous vaccines and the digital CoWIN platform at unmatched global scale and speed (PIB, 2025).

India's transition to clean energy presents significant health co-benefits. For instance, urban greening through trees, parks, and reflective surfaces reduces reduce heat stress, improve air quality, and lowers heat-related illness in cities (MoHUA, 2014, MoHUA, 2021). Complementary measures such as green buildings, reflective roofs, and permeable surfaces enhance indoor comfort, manage stormwater, and support urban biodiversity. Further, investments in public transport like metro rail, electric vehicles, Bus Rapid Transit (BRT) systems, and walking and cycling infrastructure are delivering better air quality, noise reduction, and physical activity benefits in Indian cities (NITI Aayog, RMI, 2022). These shifts improve safety and accessibility, especially for women, children, and the elderly, while contributing to long-term urban health and resilience.

The shift to cleaner fuels for cooking lowers rates of respiratory infections and eye irritation, particularly among women and children. It also lessens the burden of fuel collection, freeing time for education and livelihoods. India has made significant progress in expanding access to modern cooking energy, particularly through large-scale distribution of LPG connections under the Pradhan Mantri Ujjwala Yojana (PMUY) (PMUY, 2024; PIB, 2024).

Further, the transition to organic and climate-smart farming reduces chemical exposure, lowers emissions, improves soil quality, and improves nutrition security. Reduced crop residue burning further improves seasonal air quality (Patel et al., 2022). Health benefits are strongest for women farmers, rural households, and children. Renewable energy deployment strengthens health infrastructure by improving power affordability and reliability for clinics, vaccine cold chains, and emergency services, particularly in remote areas (Concessao et al., 2023). Better energy access supports maternal and child health outcomes and enhances healthcare equity.

While there are noticeable improvements and prospective benefits from transition to a Net Zero economy, climate change has emerged as a major challenge to public health. Rising temperatures, extreme weather events, and deteriorating air quality are affecting key determinants of health such as safe drinking water, nutritious food, and healthy living conditions. These impacts are particularly severe for vulnerable groups including women, children, the elderly, and socio-economically disadvantaged populations with limited adaptive capacity.

The following section deals with vulnerabilities that arise mainly from climate change. It elaborates on the impact on human health, the existing policy landscape, followed by suggestions to strengthen climate resilient health systems.

4.1 VULNERABILITY AND IMPACTS OF CLIMATE CHANGE AND ENERGY TRANSITION ON HEALTH

Vulnerability to climate change in India arises from the intersection of environmental hazards, social and economic inequality, demographic profile, and the capacity of local systems to absorb shocks. The section below discusses direct and indirect impacts of climate change.

I. Direct Impacts

(a) Extreme Heat

In India, about 57% of the districts, home to 76% of the country's population, are currently at high to very high risk from extreme heat (Centre for Science and Environment, 2024). Rising temperatures, intensified by recurring heatwaves, represent India's most immediate and escalating climate-related health threat. According to data from the National Centre for Disease Control (2024), there were 48,156 suspected heatstroke cases in 2024. A total of 430 heatstroke related deaths (comprising 161 confirmed and 269 suspected) were reported nationwide in the same.

Urban Heat Island effects, where cities trap heat during the day and release it at night, thus increasing nighttime temperatures further compound risks in densely populated cities. The rise in very warm nights is most noticeable in districts with a large population (over 10 lakh), which are often home to Tier I and II cities (Prabhu et al, 2025). Over the last decade, nearly 70% of districts experienced an additional five very warm nights per summer (March to June). In comparison, only ~28% of districts experienced five or more additional very hot days.

Table 4.1 shows few cities that have experienced additional very warm nights per summer in the last decade (2012-2022).

Table 4.1: Heat Island impact in major cities

City	Additional Very Warm Nights Per Summer
Mumbai	15
Bengaluru	11
Bhopal	7
Jaipur	7
Delhi	6
Chennai	4

By 2050, 50% of India's population is expected to live in urban areas (UN-DESA 2018). Heat island effects therefore pose a serious threat to the population as it can lead to a higher incidence of heat-related illnesses and cardiovascular morbidity, especially among infants, the elderly, and those residing in inadequately ventilated settlements (Romanello et al., 2025). National and local studies, including the Ahmedabad Heat Action Plan, have established a direct linkage between the intensity and duration of heatwave periods and spikes in mortality rates, underscoring the necessity for city-level adaptation planning (Hess et al., 2018; Azhar et al., 2014; Knowlton et al., 2014).

(b) Extreme Weather Events

Extreme weather events, including floods and cyclonic storms, are increasing and are known to inflict acute and large-scale health impacts. This often precipitates mass displacement, injury, loss of essential healthcare access, and outbreaks of water and vector-borne diseases, and economic losses (Roxy et al., 2017). The Assam State Disaster Management Authority (ASDMA) reports that Assam's 2022 floods impacted 8.85 million people, with a decade-high 181 fatalities in the same year. The Emergency Events Database (EM-DAT) pertaining to natural disasters and their related damage costs for the period 1990-2022 shows that India was among the worst affected countries in the world. The data further suggests that floods and storms featured as the top two natural disasters in India between the same period and accounted for the highest share of damage costs at 63.10% and 31.52% respectively (Goldar et al., 2024).

(c) Poor Air Quality

In 2019, air pollution was associated with approximately 1.67 million deaths, with ambient particulate matter acknowledged as a primary driver of both acute and chronic respiratory illness, leading to 0.98 million deaths (Pandey et al., 2019). Climate change is projected to increase this burden through longer pollen seasons, increased ozone and allergen production, and synergistic effects of heat stress and air quality.

II. Indirect Impacts

(a) Infectious Diseases

Climate change is expanding the spatial and temporal distribution of vector-borne diseases such as malaria, dengue, and chikungunya (MoEFCC, 2023). Incidents of malaria have been reported in the Himalayas, while dengue now spreads year-round, with a 13% and 53% rise in transmission potential for Aedes aegypti and Aedes albopictus mosquitoes, respectively (Lancet Countdown, 2024). Further, the report states that coastal Vibrio pathogen risk has surged by 66%, threatening 23 million people.

The spread and persistence of these infections are compounded by the constraints in vector control, fragmented surveillance systems, and changing human migration patterns. The intertwined vulnerabilities of agricultural-dependent communities reflect not only diminished food availability but also heightened exposure to pathogens through compromised sanitation infrastructures.

(b) Food and water insecurity

Climate variability threatens progress in food safety and nutrition across India (Basu et al., 2022). Altered rainfall and recurring droughts reduce crop yields and lower food quality. This has the potential to increase malnutrition and food insecurity among the socio-economically weaker households. Women and girls experience additional vulnerability, unequal resource access, and pressure from climate-related migration (M S Swaminathan Research Foundation, 2024). Further, there is heightened risk of foodborne and waterborne diseases. Children may face elevated rates of stunting, wasting, and micronutrient deficiencies.

(c) Mental Health and Psychosocial Wellbeing

The health burden of climate change extends to mental health and psychosocial domains. Direct exposure to cyclones, floods, and heatwaves creates immediate psychological trauma. Chronic stresses from environmental degradation, economic insecurity, and displacement, fuel longer-term psychopathology, including anxiety, depression, and trauma-related disorders. Among agricultural communities, drought-driven losses have been associated with increased suicide rates.

(d) Health System Strain

The growing frequency and severity of climate events threaten the operational resilience of India's health infrastructure. Healthcare systems in more than 40% of Indian districts are at high climate-induced risk (CEEW and UNICEF, 2025). The report states that over 2,00,000 public healthcare facilities are vulnerable to extreme climate events such as floods and cyclones.

(e) Displacement

Climate events are an increasingly important driver of internal migration. As per the Internal Displacement Monitoring Centre (IDMC, 2025), between 2015 and 2024, ~32 million people in India were internally displaced due to natural disasters, mostly floods and storms. In 2024, estimates suggest over 5 million people were displaced by floods, droughts, and storms (IDMC, 2025). Migrants from coastal, riverine, and drought-hit regions often lose access to public health entitlements and community health programs as they move into peri-urban or city locations. Children in migrant families experience disrupted vaccination schedules and schooling, leading to cascading long-term disadvantages in health and well-being (M S Swaminathan Research Foundation, 2024).

4.2 CURRENT POLICY LANDSCAPE

India's approach to managing climate and health risks is underpinned by an evolving policy framework and statutory mandates, supported by multisectoral missions and operational protocols.

(a) National Action Plans and programmes

India's legislative and policy architecture for climate adaptation and health is structured around the National Action Plan on Climate Change (NAPCC), which mandates multi-sectoral missions and integrates adaptation targets in water, agriculture, energy, sustainable habitat, and human health. This vision is operationalised through State Action Plans on Climate Change (SAPCC), which require each state to assess local vulnerabilities and delineate tailored interventions in line with national priorities.

A pivotal advancement is the creation and scaling-up of the National Programme on Climate Change and Human Health (NPCCHH) under the Ministry of Health & Family Welfare. NPCCHH establishes a national mandate for states to conduct district- and population-specific health vulnerability assessments, integrate climate risks into public health surveillance and planning, and develop cross-sectoral health adaptation strategies. The programme prioritises gender sensitivity, social inclusion, and migration, and issues specific technical guidance for climate-sensitive disease control, infrastructure resilience, and capacity-building within state and district health systems.

As NPCCHH becomes embedded in practice, all states are now required to develop dedicated State Action Plans on Climate Change and Human Health. This is to ensure systematic and locally responsive integration of climate-health adaptation across administrative levels and regions.

(b) Heat Action Plans and Multi-Hazard Early Warning

Heat Action Plans have been institutionalised in more than 20 states and over one hundred cities. These plans legally codify the procedures for issuing graduated, colour-coded public health alerts, with the India Meteorological Department responsible for real-time forecasting.

Under the Disaster Management Act, 2005, the National Disaster Management Authority (NDMA) requires district and local agencies to maintain readiness through mandatory drills and capacity-building. It utilises a Common Alerting Protocol (CAP) based integrated system, known as Sachet, to trigger public health surge protocols and disseminate real-time emergency warnings to the public.

Evidence suggests coordination across agencies remains uneven, with health surge protocols needing better integration amid data silos. The Ahmedabad Heat Action Plan is a success story where coordination challenges are overcome through combination of measures (See Box-3).

Box-3: Ahmedabad Heat Action Plan

The Ahmedabad Heat Action Plan (HAP) stands as South Asia's first comprehensive early warning system for extreme heat, in 2013 following a lethal 2010 heatwave. The plan uses a multi-tiered approach with color-coded alerts (Yellow, Orange, Red) based on IMD forecasts and temperature thresholds. The IMD provides a 7-day forecast which informs the activation of the plan. Beyond simple warnings, the plan integrates extensive public outreach to vulnerable slum populations, healthcare training for treating heatstroke, and infrastructure adaptations like the Cool Roofs Program, which uses reflective coatings to lower indoor temperatures. It is credited with preventing over 1,100 deaths annually and serving as a blueprint for dozens of cities across India to mitigate the rising threats of climate change and urban heat islands (Azhar et al., 2014).

HAP has evolved into a global benchmark. It demonstrates the power of low-cost, scalable interventions: early warning systems, inter-agency coordination, and public awareness campaigns to save countless lives at minimal expense. Further, more importantly, its approach shows that learning from past disasters, integrating scientific forecasts with indigenous coping practices, and maintaining flexible, community-centered plans is key to surviving a hotter future. Further, standardizing these behaviours into official action plans makes them easier to scale and implement.

(c) Air Quality Governance and Clean Air Policy

India's air quality management regime is structured around the National Clean Air Programme (NCAP), launched in 2019. It requires the preparation and implementation of city-level Clean Air Action Plans targeting PM10 reductions of up to 40% by 2026 from 2017 baselines. These plans include mandatory targets for particulate pollution reduction, vehicle emission controls, industrial compliance, road dust mitigation, and solid waste management. The opportunities for enhancement include prioritizing PM2.5 alongside PM10, accelerating source apportionment studies, optimizing fund allocation across sectors like industries and biomass, institute a formal process to review and update every two years the list of cities classified as "non-attainment" under NCAP, stricter emission standards, and airshed-based regional collaboration.

(d) Climate-Resilient Cooling and Infrastructure Codes

Sustainable cooling is institutionalised through the India Cooling Action Plan (ICAP), which aims to provide sustainable cooling and thermal comfort for all by FY 2037-38. The targets include reducing cooling demand, refrigerant demand, and cooling energy requirements, alongside training of service technicians. The policy mandates integration of passive cooling measures like enhanced insulation and natural ventilation, in new public and health sector buildings, leveraging the Energy Conservation Building Code. It prescribes technical standards for health system cold chains, including solar-powered storage at 2-8°C for vaccines and supplies under the National Cold Chain Management Programme, aligned with WHO guidelines.

(e) Agricultural Adaptation and Crop Residue Management

The National Mission on Sustainable Agriculture provides the policy anchor for climate-smart agriculture, resource conservation, and organic and natural farming. State-level regulatory approaches, including Sikkim's legislation for organic certification and targeted residue management protocols in Punjab and Haryana, have concretised mission objectives in law and operational practice.

(f) Disaster Management and Health Facility Preparedness

India's disaster preparedness framework is regulated through NDMA guidelines and statutory provisions in the Disaster Management Act. Annual simulation exercises, health and infrastructure resilience protocols, and capacity-building modules are now routine requirements for health system preparedness. The India Meteorological Department is mandated to provide seasonal and real-time impact forecasts, which serve as operational triggers for activating district- and health sector response plans.

4.3 CHALLENGES AND SUGGESTIONS

1. Inconsistent Vulnerability Assessment and Surveillance

In India, existing district assessments, such as those by the Department of Science and Technology, suggests the use of Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) framework to address climate vulnerabilities. However, this falls short of standardized, health-specific mandates across states. Methodological inconsistencies, the use of disparate indicators, limited inclusion of social determinants such as gender, and migration, and the absence of longitudinal monitoring or health-outcome validation restrict the comparability and effectiveness of vulnerability mapping.

Suggestions

(a) There is a need to develop and mandate a single, robust vulnerability assessment framework to establish a consistent national foundation for risk prioritisation. This framework may incorporate internationally recognised risk frameworks (e.g., IPCC AR5) customised to Indian district realities, under the leadership of NPCCHH, ensuring standardisation across states.

(b) The standardised framework may be integrated into district-level surveillance systems across the National Health Mission (NHM), Integrated Disease Surveillance

Programme (IDSP), and NPCCHH modules. This integration can ensure digital tracking of climate-sensitive diseases with mandatory gender, age, and migration disaggregated reporting.

2. **Lack of Climate-Resilient Health Infrastructure**

Large segments of public health infrastructure lack climate-resilient design and functionality, with significant deficits in backup power, reliable water and cooling, elevated construction in flood-prone areas, and disruption preparedness.

India's NPCCHH and NHM promote climate awareness and capacity-building in health facilities, yet public health infrastructure standards do not yet mandate comprehensive climate-proofing for high-risk districts, leaving gaps in retrofitting and real-time resilience monitoring.

Suggestions:

(a) There is a need to urgently revise Indian Public Health Standards (IPHS) to include mandatory climate-proofing specifications for all new and existing facilities in high-risk districts. These specifications may address backup power, water security, cooling systems, and elevated designs in flood-prone areas, building on NPCCHH's foundational guidelines.

(b) A real-time climate resilience monitoring system may be integrated with Integrated Disease Surveillance Programme (IDSP) and NHM to track infrastructure readiness and service continuity metrics. This will further ensure that NPCCHH can effectively safeguard healthcare functionality during extreme weather events.

3. **Unprepared Health Workforce**

Frontline healthcare personnel lack routine training in climate-health risks, emergency protocols, and gender- or migration-sensitive outreach, undermining preparedness in high-burden districts.

Suggestions:

(a) Mainstream climate–health and emergency preparedness modules across accredited medical and public health curricula, complemented by periodic refresher training and mandatory preparedness drills for in-service health workers and facility managers. These drills may be institutionalised as a routine operational requirement and linked to annual IPHS accreditation, shifting NPCCHH capacity-building from awareness to action-oriented preparedness.

4. **Financing Not Aligned to Climate Risk**

India's NPCCHH and NHM support climate awareness and infrastructure resilience, yet health and adaptation budgets lack vulnerability-based allocation formulas.

Suggestions:]

(a) Use earmarked NHM funding as a catalytic lever to blend multilateral and philanthropic finance and crowd in larger-scale investment for climate-resilient health infrastructure while linking allocations to performance-based monitoring and measurable resilience outcomes.

(b) Targeted climate-health insurance pilots may be launched for low-income, disaster-prone populations leveraging NHM administrative networks.

5

BEHAVIOURAL INSIGHTS FOR INDIA'S NET ZERO TRANSITION

Behavioural Insights for India's Net Zero Transition

5

This section focuses on why behavioural insights are critical to achieving India's long-term Net Zero transition. It first outlines key programmatic interventions undertaken by the Government of India, followed by an examination of sector-specific behavioural challenges and targeted, actionable suggestions. The section emphasises the need to integrate behavioural insights into broader climate and energy policy frameworks, highlighting how policy design must balance individual autonomy with collective action to deliver durable emissions reductions.

Accelerating climate impacts in India are coinciding with rapid economic growth and urbanisation, driving up energy demand and emissions in ways that cannot be addressed by technological solutions alone. The year 2024 was the hottest ever recorded globally, with several Indian states experiencing sustained temperatures above 40°C (Mohan, 2025). Beyond immediate health risks, extreme heat carries substantial economic consequences: recent estimates suggest that heat stress could reduce India's GDP by up to 4.5% by 2030, reflecting losses in labour productivity, rising cooling demand, and mounting stress on energy systems (Prabhu et al., 2025).

These climate pressures intersect with profound shifts in consumption patterns. Ownership of air conditioners owing to climate change and comfort has doubled in the last 4 years reaching 15 million by 2025 (Gokhale, 2025). Same is the case with other household appliances and private vehicles which have recorded strong growth.

This growth is occurring alongside continued urbanisation, with the urban population projected to reach nearly 65% by 2070. India's sustained nominal dollar GDP growth of 8% (1993-2025) has expanded middle-class aspirations for comfort, mobility, and convenience. Although per capita electricity consumption remains below the global average, it is projected to increase 4-5 times by 2050 (refer to Sectoral Insights: Power - Vol 7 report), driven by economy-wide electrification and rising demand from cooling, transport, and appliances. Regional disparities further complicate this trajectory: northern regions import significantly more power during peak summer months to meet cooling needs, while rural areas face the dual challenge of expanding energy access without entrenching unsustainable consumption patterns.

Taken together, these trends highlight a critical reality-India's energy transition is increasingly shaped by how energy is demanded and used, not only by how it is produced. Rising consumption linked to cooling, mobility, and appliances reflects everyday behavioural choices that aggregate into system-level impacts. As a result, supply-side expansion and efficiency improvements, while essential, are unlikely on their own to deliver the scale or persistence of emissions reductions required.

India's progress in deploying clean energy technologies and improving energy efficiency remains both necessary and significant. However, the effectiveness of these technological investments ultimately depends on behavioural responses on how households and firms adopt new technologies, adjust consumption patterns, and interact with evolving infrastructure. Behavioural barriers such as sensitivity to upfront costs, scepticism toward unfamiliar technologies, prevailing social norms, and entrenched habits frequently slow adoption or weaken impact. Moreover, rebound effects can erode efficiency gains when lower operating costs lead to increased usage. Embedding behavioural insights into policy design can therefore amplify the effectiveness of technological interventions by shaping demand, guiding choices, and sustaining low-carbon practices over time.

5.1 GOVERNMENT INITIATIVES

India has behaviour-centric schemes, which operationalise nudges through subtle cues leveraging social norms, defaults, and peer dynamics to foster mindful consumption and collective responsibility for sustainable development. These initiatives underpin the goals of Viksit Bharat@2047 and Net Zero emissions by 2070, transforming policy goals into scalable voluntary habits via emotional appeals, choice architecture, and real-time feedback. From Swachh Bharat Abhiyan's sanitation revolution to UJALA's LED penetration and Jal Jeevan Mission's water security, they establish blueprints amplified by Mission LiFE's national architecture of targeted interventions across flagship programmes.

The Swachh Bharat Abhiyan, serves as the foundational behavioural template exemplifying effective behavioural intervention at scale (UNICEF, 2020). By leveraging social proofing and emotional appeal, the mission transitioned sanitation from a government mandate into a "people's movement" driven by community ownership. It effectively utilized choice architecture and dignity-focused nudges to transform deep-seated habits, establishing a scalable blueprint.

The Bureau of Energy Efficiency's star labelling programme provides a core energy nudge through prominent star ratings displayed on appliances, acting as a visual shorthand that reduces decision complexity for consumers at the point of purchase. By translating technical efficiency information into an intuitive rating scale, the programme enables households to factor long term electricity costs into upfront buying decisions. According to the India Energy Scenario for the Year 2023-24 report, BEE's energy efficiency interventions delivered electricity savings of over 320 billion units and avoided more than 320 million tonnes of carbon dioxide emissions in that year, with the Standards and Labelling programme constituting a significant contributor.

Complementing this, the Ministry of Power's initiative to set default air conditioner temperatures at 24°C establishes energy efficient behaviour as the path of least resistance. While users retain full control to modify settings, the default embeds conservation as the effortless norm, reinforcing efficiency gains achieved through appliance standards and consumer information. Together, these measures demonstrate how well-designed institutional nudges can mainstream energy conservation by shaping everyday consumption choices while delivering measurable national scale energy and emissions savings.

In 2015, the Government of India introduced the UJALA scheme, successfully distributing over 36.87 crore LED bulbs as of early 2025 to over 9.2 crore households through a "demand aggregation" model that reduced retail prices by nearly 90% (Ministry of Power, 2025). This multi-channel nudge strategy featured kiosks highlighting bill savings, door-to-door swaps, social proof messaging ("neighbours switching to LEDs"), and celebrity endorsements normalising thrift.

Building on these principles, the Jal Jeevan Mission, launched in 2019, places nudges at the core of its water security strategy by providing functional tap connections to over 15.72 crore (81%) rural households as of late 2025 (Ministry of Jal Shakti, 2025). It fosters a Jan Andolan (people's movement) through community-led monitoring by village Jal Saakhis, hands-on chaupal demonstrations of conservation techniques, real-time peer-comparison dashboards on usage patterns prompting voluntary rationing, and Pani Samitis enforcing social accountability via village-level water budgets and rainwater harvesting competitions.

The GiveItUp campaign mobilised voluntary LPG subsidy relinquishment among affluent households through emotional appeals tied to national service, public leaderboards creating bandwagon effects, and patriotic messaging that redistributed resources equitably (GiveItUp Campaign, 2015). PM Surya Ghar Muft Bijli Yojana exemplifies procedural simplification with a single-window digital portal that slashes adoption hurdles, paired with "Apna Bijli, Apne Ghar" framing that taps pride in self-reliance to overcome rooftop solar inertia.

Community-level initiatives like the National Energy Conservation Awards and Gram Urja Swaraj Abhiyaan amplify social proof by spotlighting local champions such as farmers with solar pumps or energy-efficient panchayats, fostering emulation within peer networks (Bureau of Energy Efficiency, 2025; Panchayati Raj Institutions, 2022). Meanwhile, the Smart Meter National Programme delivers real-time usage feedback alongside neighbourhood benchmarks, turning abstract consumption data into immediate, actionable insights that prompt household-level self-correction (Economic Times EnergyWorld, 2024).

India launched Mission LiFE in 2022 as its largest-ever behavioural intervention, creating a comprehensive national architecture that unifies sectoral behaviour change initiatives into a coordinated system. Recently, the nodal ministry MoEFCC created a compendium that recommends embedding targeted nudges into flagship programmes for mass-scale behavioural change (Ministry of Environment, Forest and Climate Change, 2025). The strategy targets 80% of villages and urban local bodies achieving LiFE compliance by 2028 and one billion global pledges through voluntary adoption. For instance, under the Jal Jeevan Mission, it is proposed to establish village-level water usage dashboards and focus on RO reject water reuse campaigns. The Mid-Day Meals programme is suggested to adopt millet-based menu defaults with integrated nutrition education for 12 crore schoolchildren. For AMRUT, the suggestions include SHG-led water quality testing, "Drink from Tap" awareness drives, and waste segregation incentive systems across 4,000 cities. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) programme is suggested to include farmer irrigation audits promoting "More Crop Per Drop" efficiency. Indian Railways is envisioned to consider station-wise waste management rankings and single-use plastic bans at 7,000 stations. Further, the Ujjwala scheme is suggested to explore SMS and app-based LPG refill reminders for 10 crore beneficiary households.

Beyond scheme-level interventions, the compendium further recommends policy measures to standardise behaviour change across government institutions. Corporate Social Responsibility (CSR) guidelines can prioritise LiFE-aligned projects in waste reduction, energy efficiency, and sustainable agriculture. Blue and Green Star Ratings are suggested to certify water and energy-efficient restaurants and hotels, guiding consumer preferences. Further, adoptions of green procurement standards are suggested across government institutions. Finally, the Meri LiFE portal is suggested to facilitate real-time tracking via competitive individual and village leaderboards, with data aggregation drawing from participating ministries' scheme implementations. It is suggested that sustainability metrics be integrated into existing monitoring and evaluation frameworks.

Together, these interventions showcase India's evolving behavioural policy ecosystem, where nudges harness social norms, defaults, and peer dynamics to complement regulatory and fiscal tools. This approach not only scales voluntary sustainable actions across diverse populations but also ensures equitable transitions, embedding mindful resource use as a cultural cornerstone for development.

5.2 CHALLENGES AND SUGGESTIONS

India's energy transition demands a comprehensive approach addressing both supply and demand dimensions alongside systemic behavioural barriers. This section examines specific challenges in implementing behavioural interventions across demand sectors like transport, buildings, industry, agriculture, and supply considerations, and cross-cutting systemic issues. Each challenge is paired with targeted suggestions that focus specifically on behavioural nudges informed by India's Long-Term Low Emissions Development Strategy and Mission LiFE principles.

1. **Entrenched Travel Habits and Status-Driven Vehicle Ownership**

   The transport sector faces deeply embedded behavioural barriers to modal shift. Personal vehicles remain symbols of status and autonomy, while public transport is associated with inconvenience and lower social standing. Commuters exhibit strong habitual preference for private vehicles, reinforced by social norms that equate car ownership with economic success. Electric vehicle adoption encounters behavioural obstacles including range anxiety, technology scepticism, and reluctance to change established routines despite improving performance metrics and government incentives.

   Suggestions:

   (a) Leverage visible community leadership and peer endorsements through campaigns showcasing respected community members, technology executives, and public officials using public transport regularly. The Personal2Public campaign in Bengaluru demonstrated how Ministers and corporate leaders taking metro services twice weekly catalysed a broader modal shift, creating social proof that sustainable transport choices are compatible with professional success (The Hindu, 2024).

   (b) Address misconceptions through targeted testimonial campaigns featuring peer experiences to counter scepticism about public transport reliability and EV performance. Focus messaging on addressing specific concerns like comfort, safety, time efficiency rather than generic environmental appeals.

   (c) Integrate behavioural nudges in digital platforms by designing ticketing applications with default options favouring sustainable modes. Mobility apps could display public transport options first, require additional clicks to access private vehicle alternatives, and show comparative journey times with externalities factored in.

The broader suggestions are further discussed in the Report on Sectoral Insights: Transport (Vol. 3).

2. **Behavioural Inertia and Information Gaps in the Building sector**

Building occupants and owners display pronounced inertia in adopting energy-efficient practices due to established habits, unclear information, high upfront cost, and perceived inconvenience. The split incentive problem compounds behavioural barriers, particularly in rental settings where efficiency investment costs fall on landlords while energy savings accrue to tenants.

At the same time, efficiency improvements can generate rebound effects consistent with the Jevons Paradox. As appliances and buildings become more energy-efficient and affordable, households may increase usage intensity or shift toward larger or more energy-intensive options, partially offsetting expected energy savings. Moral licensing further weakens outcomes, as individuals who adopt one pro-environmental behaviour may feel justified in engaging in less sustainable practices elsewhere.

Suggestions:

(a) Enable transparent energy performance disclosure through BEE Star Ratings or other suitable indicators to empower market participants with energy cost and efficiency information. These disclosures create market signals by making efficiency costs salient to prospective buyers and tenants.

(b) Deploy personalised efficiency nudges using smart building systems to deliver contextualised reminders prompting energy-saving actions, adjusting thermostat settings (proposed target of 24 degrees as default option), switching off unused equipment, optimising natural lighting. Promoting the use of Time-of-Day tariffs can also incentivize the efficient energy use.

(c) Introduce green defaults in affluent contexts by implementing automatic opt-in for low-carbon building materials. Given income disparities, careful calibration is required, with initial focus on higher-income segments before broader deployment.

(d) Efficiency programmes should be paired with consumption-awareness messaging that highlights appropriate usage norms and the cumulative impact of individual consumption choices to address rebound and moral licensing effects. Messaging should move beyond single-technology efficiency to address overall energy demand patterns.

The broader suggestions are further discussed in the Reports on - Sectoral Insights: Buildings (Vol. 5) and Power (Vol. 7).

3. **Weak Behavioural Signals for Sustainable Procurement in Industry**

Hard-to-abate sectors including steel and cement lack strong behavioural cues for low-carbon choices. Procurement decisions prioritise cost over carbon intensity, with social and reputational factors playing minimal roles. Absence of standardised carbon footprint labelling makes informed low-carbon choices difficult for procurement.

Suggestions:

(a) Deploy standardised Product Carbon Footprint (PCF) labelling with clear, comparable carbon labels on industrial end-use products, especially targeting emission-intensive materials like cement, steel, aluminium, textiles and chemicals. Focus initially on business-to-business contexts such as procurement portals and construction tenders, where label visibility enables comparison and promotes informed low-carbon choices.

(b) Expand recognition and benchmarking platforms by creating detailed, sector-specific carbon intensity benchmarks (currently being undertaken under Carbon Credit Trading Scheme for select sectors). Enhance peer comparison tools with features such as gamification and public recognition to boost industry engagement.

(c) Facilitate voluntary public pledges through commitment frameworks (Science Based Target initiative- SBTi, RE100) enabling industries to publicly pledge specific carbon reduction targets, creating accountability through stakeholder scrutiny and competitive pressures.

4. Risk Aversion and Limited Social Proof in Agriculture

Farmers exhibit behavioural reluctance toward climate-smart practices due to risk aversion, limited exposure to successful implementations, and entrenched traditional methods. Social proof and trusted networks significantly influence agricultural decisions, yet visible demonstrations of climate-smart benefits remain scarce.

Suggestions:

(a) Design bundled discounts on climate-smart packages to facilitate uptake of efficient agricultural practices (Drip and Sprinkle, use of drones etc) by offering them as single packages through cooperatives or government schemes. Bundling reduces decision fatigue while improving affordability.

(b) Encourage and recognise public commitments by creating structured platforms via farmer producer organisations, gram sabhas, or digital pledges for farmers, especially women-led groups, to publicly commit to climate-resilient practices. The JEEViKA programme in Bihar exemplifies how women self-help groups can champion clean energy adoption through social networks. This has included facilitating access to solar lighting and cooking technologies, training local entrepreneurs and technicians, and creating livelihood opportunities linked to clean energy supply chains. The programme has leveraged its extensive SHG network to promote clean energy use and improve livelihoods, demonstrating the effectiveness of women-led groups as catalysts for sustainable energy adoption in rural areas.

(c) Enable farmer-led demonstration plots (Agri-PV) to establish visible success stories within specific agro-climatic contexts, using peer educators and local agricultural leaders to communicate benefits through trusted relationships.

5. Limited Consumer Engagement and Awareness of Impact in the Electricity sector

In the National Smart Grid Mission, consumer engagement with demand response and efficiency measures remains inadequate. Households and businesses underestimate their capacity to influence consumption patterns, leading to behavioural inertia. The complexity of energy systems obscures connections between individual actions and broader environmental impacts.

Suggestions:

(a) Deploy comparative energy reports with neighbourhood baselines through monthly household reports comparing consumption against neighbourhood averages. The VidyutRakshaka intervention in Bengaluru achieved 7% reduction in average monthly consumption across 2,000 participating households, savings equivalent to avoiding 604 million kilowatt hours annually if scaled citywide (Malaviya, et al. 2019).

(b) Create smart meter feedback loops providing real-time usage insights via mobile applications, including personalised tips and alerts when consumption spikes. Real-time feedback empowers users to self-correct and build energy-conscious habits more effectively than delayed monthly bills.

(c) Implement default green appliance scheduling by automatically setting smart appliances to operate during periods of high renewable energy availability, making sustainable energy use the effortless default choice for consumers.

(d) Highlight collective achievements to foster sense of community impact by communicating aggregate community savings in concrete terms, tonnes of CO_2 avoided, equivalent households powered. Messages emphasising community achievement prove more motivating than individual impact statistics.

6. Weak Implementation Architecture and Limited Scalability

Mission LiFE's implementation architecture is not yet aligned with the social realities required for large-scale behavioural transformation. Progress toward mobilising one billion citizens by 2028 remains difficult to assess. There is a need for clear metrics, accountability mechanisms, and outcome-oriented monitoring systems. Equity concerns are often structural rather than incidental: many promoted behaviours reflect middle- and upper-income consumption norms, while low-income households face material constraints, social risks, and limited decision-making power that shape what behaviours are feasible or desirable.

These limitations are evident in energy-use practices that remain deeply embedded in cultural meanings and social identities. For instance, the continued use of traditional cooking methods despite LPG availability illustrates how taste preferences, ritual significance, and identity can override economic incentives and technological access. Such dynamics highlight the inadequacy of behaviour-change strategies that focus narrowly on information provision without engaging underlying social norms and power relations.

These challenges are further compounded by weak systems for learning and adaptation. Behavioural interventions under Mission LiFE need to be supported by baseline data, control groups, or longitudinal tracking. This will enable to distinguish symbolic participation from sustained behavioural change.

Suggestions:

(a) Mainstream Mission LiFE across government programmes: Integrate Mission LiFE principles into existing government schemes by aligning policy objectives, institutional responsibilities, and funding mechanisms. Embedding behavioural nudges within housing, energy, transport, water, agriculture, and livelihoods programmes will enable scale and durability, avoiding treatment of Mission LiFE as a standalone or peripheral initiative. The proposed interventions should recognise women's central role in household energy use while addressing constraints on their decision-making authority.

(b) Institutionalise outcome-oriented monitoring and evaluation: Establish a dedicated Mission LiFE monitoring and evaluation (M&E) framework with clearly defined measurable behavioural indicators across sectors. This framework should track adoption, persistence, spillovers, and distributional impacts, and be implemented in partnership with research institutions using experimental and quasi-experimental methods. Behavioural indicators should complement conventional energy, emissions, and environmental metrics to capture full programme impact.

(c) Promote baseline data collection, appropriate control or comparison groups, and longitudinal tracking as minimum requirements for behavioural interventions. Develop standardised yet flexible evaluation protocols that can be adapted to diverse regional and sectoral contexts. Establish a national repository of behavioural intervention evaluations to document both successes and failures and enable systematic evidence synthesis.

(d) Leverage social norms, leadership, and collective influence: Systematically engage trusted community leaders, influencers, and early adopters as advocates for sustainable behaviours. Experience from Swachh Bharat Abhiyan demonstrates how public commitments, visibility, and role modelling can shift social norms and accelerate behaviour change at scale.

(e) Facilitate peer learning networks such as farmer-to-farmer extension programmes, community energy champions, and neighbourhood sustainability groups. These networks reduce social risk, provide practical knowledge, and create social support systems that sustain behavioural change over time.

Strengthen inter-ministerial and centre–state coordination: Create an inter-ministerial coordination mechanism to review progress and ensure policy coherence. The demand, supply, and cross-cutting behavioural interventions articulated above exemplify how behavioural insights serve as vital complements to technological and infrastructure measures in India's pathway towards sustainable energy. Pivotal to their success is an astute understanding of diverse local contexts, equity considerations, and a clear distinction between voluntary nudges, which preserve individual choice, and structural mandates, which may restrict it.

Strengthening the implementation of Mission LiFE, systematically addressing societal resistance, mitigating rebound effects associated with efficiency gains, and establishing robust frameworks for monitoring and evaluation will be essential in scaling effective behavioural strategies. Such foundational efforts will enable India to achieve a resilient, inclusive energy transition that aligns with development aspirations and climate commitments alike.

ANNEXURES

Annexure A:
Land Use Factor

Land-use factor (Acres per MW)			
	2030	2050	2070
Coal Power Plant	0.80	0.80	0.80
Gas Power Plant	0.12	0.12	0.12
Nuclear Power Plant	0.60	0.60	0.60
Large Hydro Power Plant	4.99	4.99	4.99
Solar PV Plant	2.97	1.98	1.98
On-shore wind Power Plant	3.46	3.46	3.46
Biomass Power Plant	5.98	5.98	5.98

Annexure B: Water Use Factor

Water-Use Factor	
Coal Power Plant (MCM/Mtoe)	40.64685
Gas Power Plant (MCM/Mtoe)	14.3049
Nuclear Power Plant (MCM/Mtoe)	44.4266
Green Hydrogen Plant (litre/kgH2 or MCM/Mt)	25

Annexure C: Employment in Fossil-Fuel Linked Manufacturing Industries

NIC code	ASUSE Code		Formal workers	Informal workers
13	M5	Textiles	17,22,672	34,10,714
17	M9	Paper and Pulp	3,50,482	2,77,547
23	M15	Non-metallic minerals (including Cement)	10,49,399	26,08,269
24	M16	Basic metals (including Steel, Aluminium)	14,11,577	2,73,300
19	M11	Petroleum Products	1,68,852	50,701
20	M12	Chemical products (including fertilizers)	10,58,217	1,75,616
29	M21	Manufacturing of Motor vehicles, trailers and semi-trailers	12,64,272	63,237
45	T1	Wholesale and retail trade of motor vehicles and motorcycles		7,10,533
	T2	Maintenance and repair of motor vehicles and motorcycles		23,48,172
		Total	70,25,471	99,18,089

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सत्यमेव जयते

NITI Aayog