सत्यमेव जयते

India's Long-Term Low-Carbon Development Strategy

Ministry of Environment, Forest and Climate Change
Government of India

India's Long-Term Low-Carbon Development Strategy

Submission to the United Nations Framework Convention on Climate Change

Ministry of Environment, Forest and Climate Change
Government of India

India's long-term low-carbon development strategy

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List of Units

GJ	Giga Joules
$GtCO_2e$	Gigatonnes of Carbon dioxide equivalent
GW	Gigawatt
km	Kilo meter
kWh	Kilowatt Hours
MT	Metric Tonnes
$MtCO_2e$	Million tonnes of Carbon dioxide equivalent
MW	Megawatt
tCO_2e	Tonnes of Carbon dioxide equivalent
TOE	Tonne of oil equivalent
TWh/BU	Terrawatt hour/Billion Unit

मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
और
श्रम एवं रोज़गार
भारत सरकार

सत्यमेव जयते

MINISTER
ENVIRONMENT, FOREST AND CLIMATE CHANGE
AND
LABOUR AND EMPLOYMENT
GOVERNMENT OF INDIA

भूपेन्द्र यादव
BHUPENDER YADAV

MESSAGE

India is a nation that has taken on its due share of responsibility for humanity and the planet and has committed itself to climate action. For the warming of the planet by 1-degree C that we are witnessing today, our responsibility is minimal, with our own scientific judgment echoed in the recent assessment reports of the Intergovernmental Panel on Climate Change (IPCC).

India has always been pro-active in its commitments to international cooperation and in keeping abreast of the requirements of the global climate regime that we have collectively agreed to under the United Nations Framework Convention on Climate Change and its Kyoto Protocol and Paris Agreement. In keeping with this commitment, it is now submitting its Long-Term Low-Carbon Development Strategy in accordance with the requirements of Article 4, para 19 of the Paris Agreement.

India's long-term strategy makes clear its commitment to equity and climate justice. In operationalizing these two inter-related principles, fair and equitable access to the global carbon budget is the key.

India's climate policies and actions are robust and adequate, in keeping with the requirements of the Paris Agreement, while seeking cooperation and collaboration, as in the pandemic, to find collective solutions to the challenge that faces us. As announced by Hon'ble Prime Minister Shri Narendra Modi at COP26 in Glasgow, India believes that the world needs to follow the mantra of LiFE, i.e. Lifestyle for the Environment - a global movement to effect a paradigm shift from mindless and destructive consumption to mindful and deliberate utilization.

The journey to a sustainable future is one in which all nations should participate on the basis of equity and in accordance with the principle of common but differentiated responsibilities and respective capabilities, with developed countries taking the lead as has been agreed by all in the United Nations Framework Convention on Climate Change.

The journey to net-zero at 2070 is a five decade long one and India's vision of low-carbon development is one that must be evolutionary and flexible, accommodating new developments in technology, the global economy and international cooperation, while mindful of the risks that such a journey inevitably entails. The imperatives of eradicating our development deficits and ensuring our energy security while rationally utilizing our natural resource endowment are therefore two themes that pervade our low-carbon strategy.

In presenting this submission to the UNFCCC, India once again affirms its commitment and dedication to the cause of fighting climate change.

Date: 1. 11. 2022

(Bhupender Yadav)

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Ashwini Kumar Choubey

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उपभोक्ता मामले, खाद्य और सार्वजनिक वितरण
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CONSUMER AFFAIRS, FOOD & PUBLIC DISTRIBUTION
GOVERNMENT OF INDIA

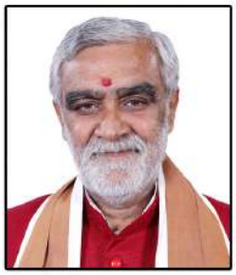
आज़ादी का अमृत महोत्सव

सत्यमेव जयते

आहारशुद्धौ सत्त्वशुद्धिः

स्वच्छ भारत
एक कदम स्वच्छता की ओर

October 31, 2022



MESSAGE

I am gratified to pen this message for the submission of India's Long-term Low-carbon Development Strategy in accordance with the requirements of the Paris Agreement.

India is a committed and pro-active player on the field of climate action. Under the able leadership of our Hon'ble Prime Minister, India has made rapid strides in matching its climate policies to the need of protecting people and the planet. Our renewable energy plans are challenging and ambitious. In areas such as the provision of LEDs for street lighting on a mass scale for domestic and street lighting under our Unnat Jyoti by Affordable LEDs for All (UJALA) and LED Street Lighting National Programme (SLNP), we are pushing forward the concept of development along a low-carbon pathway. Our UJJWALA programme has provided clean cooking fuel to millions of households, benefiting both the conservation of natural resources and the enhancement of women's health. More than 80 million LPG connections have been provided to rural households who were previously using wood or coal as cooking fuel. Initiatives like electric mobility and alternate fuels including biofuel and green hydrogen are being pursued and are at various stages of development.

It is notable that India has thus far undertaken its actions primarily with its own resources. India's submission to the UNFCCC in this document lays out our vision for an equitable and sustainable future. An integral part of this is India's call to all nations to join in **LiFE**, Lifestyle for Environment, a global movement for planet and the people.

The world will also need much more technological advancement and a serious effort at innovation to achieve a sustainable future. Hence, there is a specific emphasis on research and innovation in the long-term development strategy. With economic growth, technological advance, and radical improvement in the provision of the means of implementation by developed countries, India's long-term strategy for low-carbon development will no doubt evolve further and may be suitably revised as per emerging scenarios in future.

(Ashwini Kumar Choubey)

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FOREWORD

India has been at the forefront in taking action for combating climate change while meeting its development and growth aspirations. India's vision of a climate-resilient and sustainable world, is also one that embraces the values of equity and climate justice and upholds the motto of not leaving any one or any nation behind. With the right spirit, the right attitude and the right perspective, we can build international cooperation to successfully tackle the challenge of climate change. India has also updated its Nationally Determined Contribution (NDC) and communicated the same to the UNFCCC. The Long-term Low Greenhouse Gas Emissions Development Strategy (LT-LEDS) articulates India's strategy and action plan in the short and long-term for achieving its NDC goals by 2030 and the target of net zero emissions by 2070.

This document encompasses India's plan for its long-term low-carbon development strategy, laying out the pillars of the country's future growth and development. It has a visionary approach, including in its ambit policy interventions as well as futuristic research and innovation plans taking into account its common but differentiated responsibilities and its own capabilities in the light of its unique national circumstances. The perspective is one that has climate resilience as its core, while at the same time remaining connected with existing development gaps. The transition to a low carbon pathway will entail several costs pertaining to the development of new technologies, new infrastructure, and other transition costs in which climate finance by developed countries in the form of grants and concessional loans and as per the principles of UNFCCC will play a major role.

One of the key aspects of the country's strategy is the 'Lifestyle for environment' – LiFE philosophy, wherein it is envisaged that pro-planet people from across the globe would contribute in their individual and collective capacities by bringing changes in their lives and lifestyles, such that their actions benefit the environment. This is a key message that India brings to the world.

(Leena Nandan)

New Delhi, October 31, 2022

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Executive Summary

ES1. Introduction

India is currently one of the fastest growing economies in the world, home to almost one-sixth of humanity. Its growth momentum is an integral part of global development and is essential to meeting the world's sustainable development goals. A number of challenges confront India's development agenda including that of climate change. India's contribution to global warming is minimal. Nevertheless, India is committed to combating climate change, by making development choices that ensure growth and development of the economy along low carbon pathways towards net-zero by 2070. Recognizing that climate change is a global collective action problem, India is committed to addressing the challenge with firm adherence to multilateralism based on equity and the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC), as enshrined in the United Nations Framework Convention on Climate Change (UNFCCC).

Based on climate science, limiting global cumulative emissions within the global carbon budget is the key to limiting global temperature rise. India maintains that operationalizing the principle of equity and climate justice requires that this budget be equitably shared among all countries and used responsibly. Historical and future responsibility of countries is to be framed in terms of limiting their cumulative emissions within their fair share of this budget. The key principle that informs India's climate policy, therefore, is to pursue its development goals according to national circumstances while keeping within its fair share of the global carbon budget.

Parties agreed, under Article 4.19 of the Paris Agreement under the UNFCCC "to strive to formulate and communicate long-term low greenhouse gas emission development strategies (LT-LEDS), mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances." Accordingly, in this document India lays out its approach to its low-carbon development pathway, taking note of the development challenges facing it in the context of climate change and cognizant of its historical traditions and culture that seeks harmony and balance between human society and nature. India's LT-LEDS draws on a review of available quantitative and analytical studies, syntheses of official and academic materials, and the inputs of seven Task Groups established to deliberate on different dimensions of the LT-LEDS for India.

India's approach to low-carbon development

India's approach is based on the following four key considerations that underpin its long-term low-carbon development strategy:

1. India has contributed little to global warming

The Summary for Policy Makers (SPM) of the Working Group III contribution to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) [2022] has noted clearly that the contribution of entire Southern Asia is only about 4% of historical cumulative net anthropogenic emissions between 1850 and 2019, even though the region includes almost 24% of the global population. North America and Europe alone have contributed almost 10 times more to global cumulative emissions in this period, though they have only ~13% of the global population.

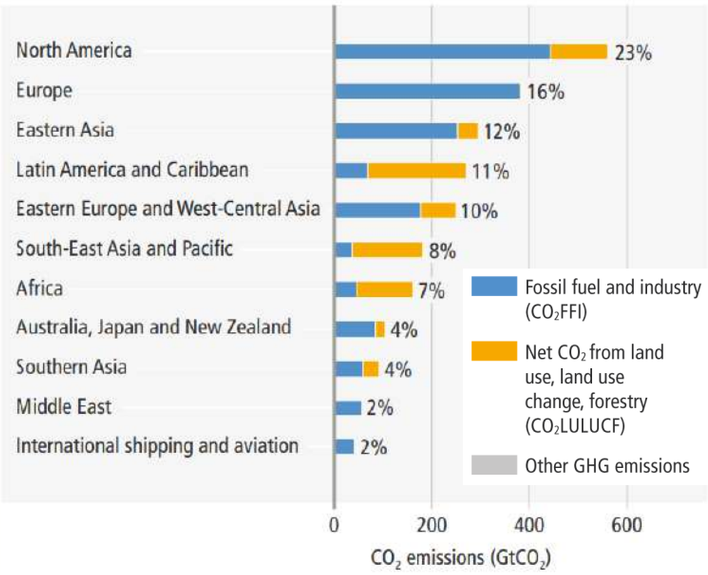


Figure ES.1 Historical cumulative net anthropogenic CO_2 emissions per region (1850–2019)

Source: *IPCC AR6 2022 Working Group III, Summary for Policymakers, Figure SPM.2*

India's historical contribution to cumulative global GHG emissions is therefore minuscule despite having a share of ~17% of the world's population. India's per capita annual emissions are about a third of the global average. From a global carbon equity perspective, India is justified in seeking that developed countries undertake early net-zero, well before 2050, by investing heavily in negative emissions, and providing adequate climate finance, technology transfer and capacity building support.

2. India has significant energy needs for its development

Energy is essential to erasing India's development deficits and meeting its developmental needs and aspirations. India's annual primary energy consumption per capita in 2019 was 28.7 gigajoules (GJ), considerably lower than both developed and developing country peers. Energy is needed for social development, to support India's demographic transition and consequent job creation needs, its agrarian and urban transition, and infrastructure development. India is actively pursuing energy efficiency as one of the key means of promoting low-carbon development. While the extent of decoupling of emissions from growth seen in developed countries is still insufficient in terms of the ambitious emissions reduction required by their historical and current responsibility, India's continued effort at increasing decoupling of emissions from growth proceeds, in contrast, from an already low baseline of emissions.

3. India is committed to pursuing low-carbon strategies for development and is actively pursuing them, as per national circumstances

India's mitigation efforts are driven not just by climate-specific policies, but also by broader development choices. India seeks to identify and explore opportunities to shift to low-carbon development pathways, while ensuring adequate access to household energy, energy security, and energy for the development of all sectors of the economy. Beginning in 2008 with the National Action Plan on Climate Change (NAPCC), the scope for co-benefits between climate and development is recognized by India, while also being mindful of the trade-offs and corresponding costs.

The social and transaction costs of making a low-carbon transition are considerable. While India will pursue low-carbon growth and development strategies, this transition will be in accordance with national circumstances and at a pace and scale that is nationally determined, without compromising development futures. Consequently, the need for climate finance for India's low-carbon transition is considerable.

The global and domestic context, including equity and the need for sustainable development, will guide India's national objectives in the rational utilization of fossil fuel resources, with due regard to India's energy security. India's per capita consumption of coal, its leading natural fossil fuel resource, when normalized for coal quality, was half the world average in 2019 and its natural gas consumption was 30-50 times lower than many OECD (Organisation for Economic Cooperation and Development) countries. Further, global oil and gas emissions are 25% higher than coal emissions, whereas, for India, coal is its main fossil fuel resource.

4. India needs to build climate resilience

India has a diverse geography that encompasses a wide range of ecosystems, from mountains to deserts, from inland to coastal areas, and from plains to jungles, and is vulnerable to impacts of climate change. Adaptation measures and building resilience to potential climate impacts are necessary to maintain India's development gains and human development outcomes and sustain its growth and development.

India's climate actions

India is already making considerable efforts at undertaking climate actions across its entire economy. India also has a long tradition of reverence and respect for Nature that provides broad societal support for India's pro-active climate policies and actions. India has achieved its pre-2020 voluntary contributions and its policies and actions are acknowledged to be compatible with the 2°C warming target of the Paris Agreement. India has consistently made ambitious commitments at the UNFCCC, the key multilateral forum for climate change, and under the Paris Agreement, and has a strong track record of meeting these commitments, despite its minimal responsibility. Building upon Hon'ble Prime Minister Narendra Modi's *Panchamrit* (five nectar elements) pledges at the 26th Conference of Parties (COP26) of the UNFCCC in Glasgow, including the target of net-zero emissions by 2070, India updated its NDC in August 2022 as follows:

i. Meet 50% of India's cumulative electric power installed capacity from non-fossil sources by 2030.
ii. Reduce the emission intensity of GDP by 45% below 2005 levels by 2030.
iii. Put forward and further propagate a healthy and sustainable way of living based on the traditions and values of conservation and moderation, including through a mass movement for LiFE – Lifestyle for Environment as a key to combating climate change.

ES2. Strategic Low-Emissions Development Transitions

India's LT-LEDS rests on seven key transitions to low-carbon development pathways. These transitions to low-carbon development pathways have already been initiated through various significant and specific policies, programmes, and initiatives. However, India's efforts so far have been overwhelmingly undertaken with its own resources. India's current climate actions are comprehensive, covering the entire economy, keeping in view India's development imperatives.

The key elements that constitute each proposed low-carbon development transition are first summarised. In subsequent sections, the domestic and international contexts, current policies and targets and elaboration of the long-term low-emissions development strategies follow. The relevant literature has been taken into account in elaborating the elements of these low-carbon development transitions, including available modelling studies. The output of global models cannot be readily applied to India for the lack of clarity on equity, climate justice and common but differentiated responsibilities and respective capabilities in their assumptions and structure. Various stakeholders, especially academia, are developing the necessary techniques and models with Government support and facilitation, and India is cognizant of the need for the appropriate modelling results.

Elements of Long-term Low-Emissions Development Strategies

Low carbon development of electricity systems consistent with development

Growth in the electricity sector is critical for enabling industrial expansion, enhanced employment and incomes, and achievement of *Aatmanirbhar Bharat* (Self Reliant India). Low carbon options are to be assessed in the context of inclusive growth and expansion needed in the sector.

- Expanding renewables and strengthening the grid
- Exploring and/or supporting other low carbon technologies
- Focusing on demand-side management
- Rational utilization of fossil fuel resources, with due regard to energy security
- Assessing enablers for low carbon development
- Determining green taxonomy and optimum energy mix (complementing national development scenarios)

Develop an integrated, efficient, inclusive low-carbon transport system

Transport is a major contributor to GDP directly and indirectly. Low carbon options are to be assessed in the context of significant expansion needed across transportation modes for passenger and freight mobility.

- Encouraging improved fuel efficiency
- Phased transition to cleaner fuels
- Modal shift towards public and less polluting modes of transport
- Electrification across multiple modes
- Demand side management
- Traffic management and intelligent transport systems

Promote adaptation in urban design, energy and material-efficiency in buildings, and sustainable urbanisation

Exploring and encouraging adaptation measures in urban design will be critical in the context of developing urban areas. This will be a major focus alongside measures to promote sustainable urban design in the context of expanding cities.

- Mainstreaming adaptation measures in the built environment and urban systems
- Promote resource efficiency within urban planning guidelines, policies, and bylaws
- Promote climate responsive and resilient building design, construction, and operation in existing and future buildings and in urban systems
- Promote low-carbon municipal service delivery through resource efficiency, management of water, solid, and liquid waste

Promote economy-wide decoupling of growth from emissions and development of an efficient, innovative low-emission industrial system

Industrial growth is a major objective in the near, medium, and long term with policies directed at increasing the share of manufacturing in the GDP, including *Aatmanirbhar Bharat* and Make in India. Due efforts will be undertaken to recognize the informal sector and the development of the Micro Small and Medium Enterprises (MSME) sector. Low carbon options will be explored in this context, recognizing that there are many hard-to-abate sectors.

- Improve energy and resource efficiency, with efforts to increase the use of natural and bio-based materials
- Process and fuel switching and electrification in manufacturing, as feasible and viable
- Enhance material efficiency and recycling, strengthening the circular economy
- Promote green hydrogen technology and infrastructure
- Explore options for sustainable growth of hard-to-abate sectors
- Low carbon and sustainable growth of micro, small and medium enterprises (MSMEs)

CO_2 removal and related engineering solutions

This is a new sector being explored the world over and may also be explored in the Indian context. This shall require substantial international support through innovation, technology transfer, climate - specific finance and capacity building.

- Training, capacity building and planning to minimize socio-economic, livelihood and ecosystem impacts
- Explore public-private partnership frameworks in view of intensive resource requirements

Enhancing Forest and vegetation cover consistent with socio-economic and ecological considerations

India's national commitment to the enhancement of natural resources, preservation of resource heritage and promoting biodiversity will frame the strategy in this sector. It will also be an inclusive approach taking note of livelihood, social and cultural dependence of the relevant population.

- Restoration, conservation, and management of forests and their plant, animal and microbial genetic resources
- Restoration, conservation, and management of trees outside forests
- Strengthening infrastructure of State forest departments, including upgradation of nurseries

Economic and financial aspects of low-carbon development

Given the priorities of poverty eradication, increasing employment and incomes, increasing resilience to climate change, and reaching a new level of prosperity, low-cost international climate finance is essential to achieve the objectives of low carbon development.

- Assessments of financial requirements
- Mobilizing, accessing and delivering climate-specific finance, especially multilateral climate finance
- Mainstreaming of climate finance
- International climate finance, technology transfer and capacity building
- Linkages to international trade
- New multilateral mechanisms for supporting innovation, and technology development

ES2.1 Low Carbon Development of Electricity Systems Consistent with Enhanced Development Benefits

Domestic and International Context

India's average per capita electricity consumption from utilities alone, ~800 kWh in 2020, is only about a fourth of the global average. The overall per-capita consumption of electricity for the year 2021-22 was 1255 kWh. Across sectors, the supply of electricity in India will grow to support domestic, agricultural, industrial, and other uses. India recently achieved universal household access to electricity, with efforts underway for strengthening the quality and reliability of supply. Enhanced electricity supply will therefore be a focus area for India to develop low carbon strategies as the energy sector contributed 75% of GHG emissions in India, of which electricity contributes more than half. India's development of its electricity system is also seeing a rapid increase in the deployment of renewable sources of electricity generation promoted actively through public policies.

Current Policies and Targets

- Ambitious RE target with 50% of non-fossil capacity by 2030.
- Support for RE through "must run" status for renewable sources and Renewable Purchase Obligations for distribution companies, open access consumers and captive power plants. Policy on Energy Storage Obligations (ESO) has also been introduced.
- Green energy corridors to strengthen transmission networks in eight RE rich States.
- Policy and financial incentives include solar park development, accelerated depreciation on investment, waiver on transmission charges, and capital subsidy for residential solar roof-top and agricultural solar pumps.
- Promotion of hydro power through several policy measures to tap hydro power potential in the country and promote its use through the introduction of Hydro Purchase Obligation.
- Rational use of fossil-fuel based capacity.
- A three-fold rise in nuclear installed capacity by 2032.
- Promoting competition and markets for green electricity and smoother grid integration of Renewable Energy.
- Energy management at household level, including star rating of appliances.

- India has been proactively shutting down inefficient thermal units. A total 241 Units with capacity of 17281 MW have been retired from 10th Plan onwards till September 2021.

Elements of a Long-Term Low-Carbon Development Strategy

1. Expanding renewables and strengthening the grid: India aims to rapidly expand its RE capacity in the short to medium term while strengthening the electricity grid and enhancing its flexibility.
2. Other technologies for low-emissions development: Explore a greater role for nuclear energy and enhance support for R&D into future technologies such as green hydrogen, fuel cells, and biofuels.
3. Appropriate demand-side measures: Strong energy efficiency measures can help meet the growing demand for energy services using less energy, while energy supply to the bulk of the population will increase.
4. Rational utilization of fossil fuel resources: While the share of coal in installed capacity and supply of power will decline, coal will be needed for power and energy, including, inter alia, for grid stabilisation, supply to industry and to guarantee India's energy security.
5. Enablers for a National Development friendly transition: Enabling measures for a development-focused transition include promoting local manufacturing, and fostering capable, agile, and responsive institutions at all levels.
6. Optimum energy mix (complimenting National development scenarios): The role of all non-fossil and fossil fuel sources will be key to supporting the long-term low carbon development strategy in different sectors.

ES2.2 Develop an Integrated, Efficient, Inclusive Low-Carbon Transport System

Domestic and International Context

The transport sector in India contributes around 10% to the GDP. It is an important sector that facilitates the overall development of industries and commercial activities in any economy. In India, therefore, development of the transport sector is a priority area for the Government. Emissions from the transportation sector are mainly driven by fossil fuel consumption in the road sector, even as vehicle ownership in India is far below the world average and much below the levels of other developed and emerging economies. However, the road transport sector accounts for about 87% of passenger traffic and 60% of freight traffic movement in the country and sustainable development of this sector is a critical element in India's long-term development strategy.

Indian Railways is one of the world's largest railway networks, spread over ~68,000 km. It carries nearly 23 million passengers daily, making it the largest passenger carrying system in the world. Other segments such as civil aviation and domestic navigation account for a relatively small but fast-growing share of India's transport mix. Given India's current growth and transport sector trends, the on-road freight segment is likely to be a significant driver of transport emissions in the long-term in a business-as-usual scenario. Emissions from heavy duty vehicles would account for the majority of such emissions. Addressing both passenger and freight transport will therefore be an important goal for India's low-carbon development.

Current Policies and Targets

- Indicative 2025 target: 20% ethanol blending in petrol, with a savings potential of approximately INR 30,000 crore/yr.
- Leapfrogging Bharat Stage V emissions to directly reach Bharat Stage VI emissions.
- Comprehensive package for electric vehicles, including domestic manufacturing in auto parts and batteries, investments in charging infrastructure and demand aggregation.
- Indian Railways to become net-zero by 2030, leading to annual mitigation of 60 million tonnes of CO_2.
- Multiple policies to enhance the share of public, non-motorized transport.
- A National Master Plan for Multi-modal Connectivity – PM Gati Shakti.
- Integrated and optimized freight networks through programmes such as Gati Shakti, Transit-oriented development, Bharatmala, Sagarmala, and dedicated rail freight corridors.
- National Logistic Policy aspires to reduce cost of logistics in India to be comparable to global benchmarks by 2030.

Elements of a Long-Term Low-Carbon Growth Strategy

1. Reducing fuel demand and GHG emissions through improved fuel efficiency: India will achieve this through raised standards, optimized networks, improved technologies, and fleet modernization.
2. Phased adoption of cleaner fuels: There will be continuation of a gradually increased blending of cleaner fuels while managing socio-economic and development of the skilling aspects required for the same. Hydrogen will be used as an energy carrier and alternate fuel in the transportation sector.
3. Modal shift towards public and less polluting modes of transport: India will seek to integrate transport with urban planning, multi-modal connectivity, and enhanced railway capacity.
4. Electrification across multiple modes: A comprehensive package of programmes, policies, and measures for the domestic manufacturing of electric vehicles and batteries and the electrification of railways will be taken up.

ES2.3 Promoting Adaptation in Urban Design, Energy and Material-Efficiency in Buildings, and Sustainable Urbanisation

Domestic and International Context

India is rapidly urbanizing. A sustainable, balanced, and integrated development of urban areas is a central theme in India's future urban growth paradigm. As per Census 2011, 31% of the country's population lived in urban areas. India's urban population is estimated to reach 37% by 2030, and 70% of India's GDP in 2030 is expected to be generated from urban regions. Due to the concentration of economic activity in urban agglomerations, energy consumption, and consequently emissions are higher in cities making these important regions for climate action. In India's current state of development, many initiatives across a wide range of sectors address key urban issues. These include cross cutting schemes and programmes such as those in renewable energy, energy efficiency and sustainable water management. At the same time, given the extent of vulnerable population in cities, climate adaptation and climate resilience are also key requirements for urban India.

Current Policies and Targets

- National Urban Policy Framework (NUPF).
- Town and country planning act and State planning regulations, local area plans.
- Provision of housing for low- and middle-income groups through the Pradhan Mantri Awaas Yojana (PMAY).
- National Building Code, Energy Conservation Building Code, Eco-Niwas Samhita (an energy conservation building code for residential buildings).
- Development Control Regulations (DCR) and model building bylaws.
- India Cooling Action Plan.
- Sustainable public transport including sustainable mobility through national mission on electric mobility and battery storage.
- National Solar Mission.
- National Mission on Sustainable Habitat.
- National Water Policy, National Environment Policy, National Urban Sanitation Policy.
- Jal Jeevan Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT).
- Construction and Demolition Waste Management Rules, Extended Producer Responsibility 2021, and Plastic Waste Management (Amendment) Rules 2021.

Elements of Long-Term Low-Carbon Growth Strategy

1. Adaptation measures will be mainstreamed in urban planning.
2. Measures will be promoted for enhancing energy and resource efficiency and low-carbon development within urban planning guidelines, policies, and bylaws.
3. Climate-responsive and resilient building design, construction and operation in existing and future buildings are to be promoted.
4. Low-carbon municipal service delivery through resource efficiency and management of water, solid and liquid waste will be pursued.

ES2.4 Promote Economy-Wide Decoupling of Growth from Emissions and Development of an Efficient, Innovative Low-Emission Industrial System

Domestic and International Context

The industrial sector contributed about 25.9% to India's GVA in 2020-21. Manufacturing alone, contributed 14.4% to GVA this year, with construction and energy and other supply utilities adding another 9.9% (DEA, 2022). The Government of India is focused on expanding the contribution of manufacturing to GDP as this is necessary in a developing country such as India to generate employment, enhance incomes, and create infrastructure and conditions for improved well-being of the population.

Continued growth, plus aspirations to boost domestic manufacturing, is expected to lead to enhanced energy consumption, and significant additional demand for steel and cement in the medium- and long-term and this has implications for emissions from this sector. Low carbon options for the industrial sector in India must be viewed within the overall context of the need for significant expansion of industrial

production, the fact that India's contribution to historical emissions is negligible, and that India remains well below its fair share of the carbon budget. Additionally, a shift away from fossil fuels in this sector would require viable fuel and technology alternatives to maintain a healthy growth of India's GDP and employment and repurposing of assets and transition planning in sectors such as mining, petroleum refining, and manufacturing, which may subsequently also lead to impacts in other sectors of the economy. Despite these challenges, India has taken significant strides in ensuring improved energy efficiency in the industrial sector creating the conditions for sustainable growth in this sector in the medium and long term.

The presence of a substantial MSME sector in India's manufacturing is noteworthy and special consideration is required to modernise and enhance the energy efficiency of this sector, especially because of its potential for growth, value addition and employment.

Current Policies and Targets

- National Missions for Enhanced Energy Efficiency and Sustainable Habitat, Standards and Labelling Scheme, and the Energy Efficiency Financing Platform.
- Fuel switching through promotion of natural gas and the National Policy on Bio-Fuels.
- Material efficiency through policies on resource efficiency, plastic and e-waste, and steel recycling.
- Green hydrogen technology and infrastructure promotion.
- Decarbonisation of hard-to-abate sectors such as steel and cement through R&D.
- National Solar Mission.

Elements of a Long-Term Low-Carbon Growth Strategy

1. Improve energy efficiency: Promotion of energy efficient/low carbon technologies, digitization of processes, and creation of trading schemes and other market-based enablers to achieve these goals will be pursued where relevant.
2. Process and fuel switching, and electrification in manufacturing: These will be pursued, as relevant, based upon availability and access to technology and the provision of climate finance.
3. Enhance material efficiency and recycling: Sector-specific material efficiency technologies and strategies will be enhanced through value chains, as material-demand trends shift.
4. Promote green hydrogen technology and infrastructure: R&D in technology and infrastructure for green hydrogen will be given a boost, ramping up electrolyser manufacturing capacity.
5. Explore low carbon options in hard-to-abate sectors: Best available technologies in the steel and cement sectors will be pursued
6. Low-carbon and Sustainable development of MSMEs: Strengthen financial support, knowledge sharing, and awareness of low carbon options and sustainable technologies.

ES2.5 CO_2 Removal and Related Engineering Solutions

The economic, technical and political feasibility of Carbon Capture Utilisation and Storage (CCUS) is highly uncertain. The emphasis in this aspect is on R&D and building human and infrastructure capacity to evolve technologies and methodologies that address issues related to high capital costs, safety, logistics and high auxiliary power consumption. CCUS technology at present is not matured and India can take

up only demonstration projects at this stage to assess the viability of the proposed solutions. Retrofitting of existing thermal power generating units for CCUS implementation is not a viable option, until the technology is cost effective and less energy intensive. India requires considerable climate finance and technology transfer with effective international collaboration to enter this arena on any significant scale.

ES2.6 Enhancement of Forest and Vegetative Cover Consistent with Socio-Economic and Ecological Considerations.

Domestic and International Context

In India, 24.62% of the total geographical area is under forest and tree cover. India has among the lowest rates of gross deforestation in the world, in absolute terms, in per capita terms, and in annual rates. The carbon stock in forests is estimated to be 7,204 million tonnes. The forest sector employs around 6.23 million people, and is a source of livelihood for several communities, especially tribal communities.

Current Policies and Targets

- NDC target: to create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent by 2030.
- Major policies and institutions: National Mission for a Green India, National Afforestation Programme, Compensatory Afforestation Fund Management and Planning Authority, Nagar Van Yojana, National REDD+ (Reducing Emissions from Deforestation and forest Degradation) Strategy 2018, National Rural Livelihoods Mission, Forest Fire Prevention and Management Scheme and AMRUT (Atal Mission for Rejuvenation and Urban Transformation).
- Other voluntary contributions: To restore 26 million ha degraded land by 2030; 12 National Biodiversity Targets, in line with 20 global Aichi biodiversity goals.
- Major greening efforts of the National Highways Authority of India (NHAI) and Indian Railways.

Elements of a Long-Term Low Carbon Development Strategy

1. Restoration, Conservation and Management of Forest Cover (including mangrove forests) Improving/ enhancing density and quality of forests; Improved protection and restoration of forest and green cover in biodiversity hotspots; Improved health of forest and forest hygiene; Improved climate smart monitoring and forest protection against forest fires.
2. Restoration, Conservation and Management of Trees outside Forests and Green Cover Restoration and increasing area under trees outside forests and green cover; Large scale enhancement of tree/ green cover in urban and peri-urban areas; Rural greening with a focus on One Forest – One Village; Promote agro-forestry to increase farming income and meet wood products demand.
3. Infrastructure development.

ES2.7 Economic and Financial Aspects of Low-Carbon Development

1. Assessments of Financial Requirements

A transition to a low-carbon development pathway will entail costs, pertaining to the deployment of new technologies, development of new infrastructure, and other transaction costs. In the longer term, such a transition will also have broader economic impacts. Several estimates regarding India's financial needs exist. Many of them focus on the energy sector, including industry, buildings, and transport. Estimates vary across studies due to differences in assumptions, coverage, and modelling approaches, but fall in

the range of trillions of dollars by 2050. In general, finance needs – and the domestic financing gap – are considerable, indicating a need for greater international support.

2. Mobilizing, accessing, and delivering climate specific finance, especially multilateral climate finance

Meeting finance needs require mobilising and scaling up financial resources internationally as well as mobilising domestic finance. International sources include multilateral and bilateral sources, dedicated climate funds, international institutional investors, and the private sector. There needs to be a significant enhancement in the scale, scope, and speed of climate finance from public sources to enable ambitious climate action in developing countries. In this regard, it is essential that developed countries should meet their commitments to climate finance, especially their long overdue commitment of USD 100 billion per year by 2020, while also enhancing their commitments under the New Collective Quantified Goals to enable the achievement of climate goals as mandated under the Paris Agreement. Ambition in climate action in developing countries requires ambition in climate finance under the Paris Agreement. Private finance can be channelled through equity investments, debt including loans and bonds, Foreign Direct Investment (FDI), risk mitigation instruments such as insurance and guarantees, and innovative forms of finance.

3. Linkages to International Trade

Financial aspects of the low-carbon transition can affect and in turn be affected by the international trade regime. India will seek to ensure that obligations in international trade agreements will not curtail the existing policy space to nurture domestic producers of environmental goods and services.

The domestic and foreign policies of developed countries, including the moves to address emissions through carbon border adjustment mechanisms, can also impact developing economies like India adversely, without achieving their stated objectives. There is a need to achieve the right balance between the requirements of development, trade, and low-carbon pathways.

ES3. Research and Innovation

India considers research and innovation in new technologies to be essential to meeting the challenge of climate action, including both adaptation and mitigation, either globally or nationally. There are many sectors where such innovation is especially critical for a developing country, for promoting low-carbon development, where the twin challenges of growth as well as the need for progressively decoupling emissions from such growth, must be met.

Chapter 3 of this report provides a detailed list of sectors and relevant technologies, a first list, where innovations are urgently required.

India also notes the example of the COVID-19 pandemic where the advantages of setting aside the intellectual property rights regime, particularly to meet global challenges, became very evident. Such an approach if adopted at the global level will promote research and innovation relevant to climate action.

ES4. Adaptation and Resilience

Development and growth are the first consideration in adaptation and resilience for developing countries. The impacts of climate change in India are multifold. Adapting to climate change will require an

understanding of risks and vulnerabilities, economic and infrastructural development, strengthened individual resilience through enhancing livelihoods and incomes, new governance capacities and improved coordination, raising resources for adaptation including in the form of adaptation finance, addressing loss and damage, and ensuring equitable and inclusive strategies. India's adaptation actions attempt to achieve all of these goals.

India's adaptation finance needs are challenging to quantify. While individual estimates are subject to uncertainty, it is clear that the adaptation finance required is significantly higher than current adaptation finance flows.

ES5. Mission LiFE – Lifestyle for Environment

Following from the announcement of LiFE that the Prime Minister, made in the National Statement delivered at COP26, India has updated its Nationally Determined Contributions and, inter alia, updated the first as follows: To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation, including through a mass movement for 'LiFE'– 'Lifestyle for Environment' as a key to combating climate change. LiFE is envisaged as a global movement to effect a paradigm shift from the mindless and destructive consumption to the mindful and deliberate utilization of national resources.

The three key phases of this pro-people and planet centric strategy to combat climate change are i) to promote globally the practice of simple yet effective environment-friendly actions by individuals in their daily lives; ii) consequent response by industry and markets, tailoring supply and procurement, following from large-scale transformation of individual demand; iii) through changes in demand and supply dynamics globally to promote long-term shifts in industrial and Government policies that can support sustainable consumption and production. The collective action towards mindful and deliberate utilisation of resources would certainly contribute in attaining the goal that India has set for itself under the Nationally Determined Contribution Targets namely, reduce the emission intensity of the GDP by 45% below 2005 levels by 2030.

ES6. International Cooperation

India's approach to international cooperation is founded on the principles and commitments of the UNFCCC that climate action should be on the basis of equity and in accordance with common but differentiated responsibilities and respective capabilities, as per national circumstances.

As part of its commitment to a leading role in climate action, well beyond its fair share of responsibility, India has developed several forward-looking and participatory global initiatives, partnerships, and coalitions to combat climate change and foster greater collaboration. These include:

- International Solar Alliance (ISA), launched by India and France, which is a dedicated platform for cooperation between Governments, multilateral organizations, and industry to strengthen global cooperation on solar energy.
- Coalition for Disaster Resilient Infrastructure (CDRI), a partnership of national Governments, UN agencies, multilateral development banks, the private sector, and knowledge institutions to promote the resilience of new and existing infrastructure systems to growing climate risks and disasters.
- India-UN Development Partnership Fund, which aims to contribute to developing countries' efforts to

realize the 2030 Agenda for Sustainable Development Goals, including Climate Action.

- Leadership Group on Industry Transition (LeadIT), co-led by India and Sweden, is a platform for the Governments and the private sector to identify low-carbon business opportunities, cooperate on net-zero technology innovation and exchange knowledge on sectoral roadmaps for hard-to-abate sectors.

India is committed to the principles of cooperation under the United Nations Framework Convention on Climate Change and the Paris Agreement negotiated under the Framework and reiterates the importance of meeting the Nationally Determined Contribution (NDC) under the Agreement. Joint projects, inter-ministerial dialogues, channels for sharing knowledge and experiences, joint development of global technology standards, building networks of research institutions, and strategic technology partnerships are some of the potential avenues for strengthening international cooperation.

India's stated climate goals can be fully realized only if financial assistance, low-carbon technology transfer and capacity-building needs are met under the UNFCCC and its Paris Agreement. Developed nations must take the lead not only in emissions reductions, but in developing international climate finance and technology arrangements that respond to gaps in available resources in the developing world.

India cannot deploy low-carbon climate technologies at a significant scale unless a facilitative global technology transfer regime is in place, and the incremental and associated costs of these technologies are met by international climate funds. A collaborative international mechanism needs to ensure that barriers, such as intellectual property rights, are lowered by developed countries to facilitate technology transfer from developed to developing countries.

India is committed to advancing common sustainable development goals. However, it also emphasizes that international cooperation is necessary to support developing economies through finance, technology and win-win strategies.

Chapter 1 INTRODUCTION

1.1 Outline and Approach for India's LT-LEDS

India is currently one of the fastest growing economies in the world, home to almost one-sixth of humanity. Its growth momentum is an integral part of global development and is essential to global advance in meeting the sustainable development goals. The centenary of India's independence offers a significant milestone to the national effort on sustainable development. The milestone will be met with the provision of basic services to all, the expansion of the economy to a scale appropriate to India's size, and the provision of large-scale productive employment, which together would decisively move India to the status of a developed country.

Alongside the number of challenges that confront India's development agenda, climate change is an unwelcome constraint thrust on India as it is on the entire world. This challenge is not of India's making. India's historical contribution to the accumulation of GHGs is about 4%, even though it is home to ~17% of the global population. Its per capita emissions are well below the global average. India has drawn far less than its fair share of the global carbon budget.

Global warming is a global collective action problem. Its solution, therefore, lies in international cooperation and multilateral processes which are embodied in the United Nations Framework Convention on Climate Change (UNFCCC). India is firmly committed to strengthening the efforts to combat global warming to the UNFCCC on the basis of equity and the CBDR-RC as laid down in the Climate Convention.

Climate science has clearly established that global surface temperature increase is directly proportional to cumulative emissions and limiting the rise in global temperatures requires global GHG emissions to be kept within a specific limit referred to as the global carbon budget. A disproportionately large part of the global carbon budget has been used by developed countries. The world, from 2020, has a remaining carbon budget of 500 gigatonnes of carbon dioxide ($GtCO_2$), to have a 50% probability of limiting global warming to 1.5°C relative to pre-industrial levels and a remaining carbon budget of 1350 $GtCO_2$ to have a 50% probability of limiting global warming to an increase of 2°C (IPCC, 2021).

Operationalizing the principle of equity and climate justice requires that this global carbon budget be equitably shared among all countries and used responsibly. Hence, historical, current and future responsibility of countries is to be framed in terms of limiting cumulative emissions within their fair shares of this budget. The key principle that informs India's climate policy is to pursue development goals along low carbon development pathways, while keeping within its fair share of the global carbon budget on the basis of equity and in accordance with the principle of common but differentiated responsibilities and respective capabilities. India will strive towards net-zero by 2070 through low carbon development in accordance with national circumstances.

As a developing country with a long coastline, vulnerability to monsoon disruption, high dependence on agriculture for livelihoods, and possible impacts on water systems, among other kinds of exposure to climate extremes and consequent hazards, India is likely to bear a considerable added development burden from the impact of global warming.

Nevertheless, in keeping with its responsibilities as a large nation, and in keeping with its traditions and culture, India is committed to a leading role in meeting the challenge of global warming. Hence it has been contributing far more than its fair share of the global effort at climate action. It is in this spirit that India in its National Statement at the 26th Conference of Parties in 2021 at Glasgow declared that it would reach net-zero emissions by 2070. Climate change presents a threat to people everywhere in the planet and a significant challenge to our collective development goals. It is in this context that India in its National Statement at COP26, called for a global movement, LiFE, or Lifestyle for the Environment. The goal of the movement is to push for a paradigm shift in the way the world deals with natural resources, from an attitude of "mindless and destructive consumption" to one of "mindful and deliberate utilization".

As part of the efforts to achieve the goals of the UNFCCC, and its Paris Agreement (PA), all Parties agreed as per Article 4.19 of the PA, "to strive to formulate and communicate long-term low-emissions development strategies, on the basis of equity and in accordance with the principles of common but differentiated responsibilities and respective capabilities and in the light of different national circumstances". Consistent with this, India has prepared this document to lay out India's overarching approach to its low-carbon development pathway, taking note of India's development challenges as well as the necessity for climate action.

The process of preparing India's LT-LEDS included review of quantitative and qualitative studies, syntheses of official and academic materials salient to mitigation, adaptation, finance, and other relevant areas, and the inputs provided by seven inter-ministerial and stakeholder Task Groups to deliberate on long-term low-carbon development strategies for India. These groups reviewed existing policies, deliberated on emergent directions, and analysed linkages of these to development as well as assessed implementation considerations.

This report outlines the context and approaches that India will take toward the development and adoption of its LT-LEDS. The remainder of this section spells out India's framing and approach to its LT-LEDS, keeping in mind the foundation of equity and climate justice and the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC) in the global context. Chapter 2 brings together the extensive effort to examine key development transitions and their potential contribution to a low-carbon future, including through the efforts of the seven Task Groups. Chapter 3 of this report discusses research and innovation for India's low carbon development. This strategy document also includes a short discussion of India's adaptation needs in Chapter 4, in the light of its vulnerability to climate impacts. Chapter 5 of this report is about the global call for climate friendly lifestyles for environment. Chapter 6 focuses on India's approach and contribution to the global cooperation to address climate change.

1.2 National Development, Energy, and Emissions in Global Context

India's approach to the development of its LT-LEDS is underpinned by the following four key considerations, related to the national and context of its energy and emissions future, in a global climate and development situation:

1. India has only a minimal historical contribution to the consumption of the global carbon budget and its annual per capita emissions remains modest.
2. India is a developing country with low per capita energy use, and with considerable energy needs for development.

3. However, mindful of the need to combat climate change and the potential for continued technological and competitive opportunities from a low-carbon development pathway, India will pursue low-carbon development strategies within its fair share of the global carbon budget, aimed at meeting India's 2070 net-zero pledge, on the basis of equity and in accordance with the principle of CBDR-RC and national assessments of its development futures.
4. India's growth and development is also essential to build climate resilience and mitigate the climate risk and vulnerability that India will face with increasing global warming.

1.2.1 India has contributed little to Global Warming

In 2016, India's total greenhouse gas (GHG) emissions, excluding land use and land-use change and forestry (LULUCF), were 2,838 million tonnes of carbon dioxide-equivalent ($MtCO_2e$) (MoEFCC, 2021). India's per capita emissions of 2.46 tCO_2e in 2019 are well below the global average of 4.79 tCO2e. Most pertinently, India's historical contribution to global GHG emissions is about 4% against a share of ~17% of the world's population (Climate Equity Monitor, n.d.), and as such it has contributed little to the accumulation over time of greenhouse gases in the atmosphere.

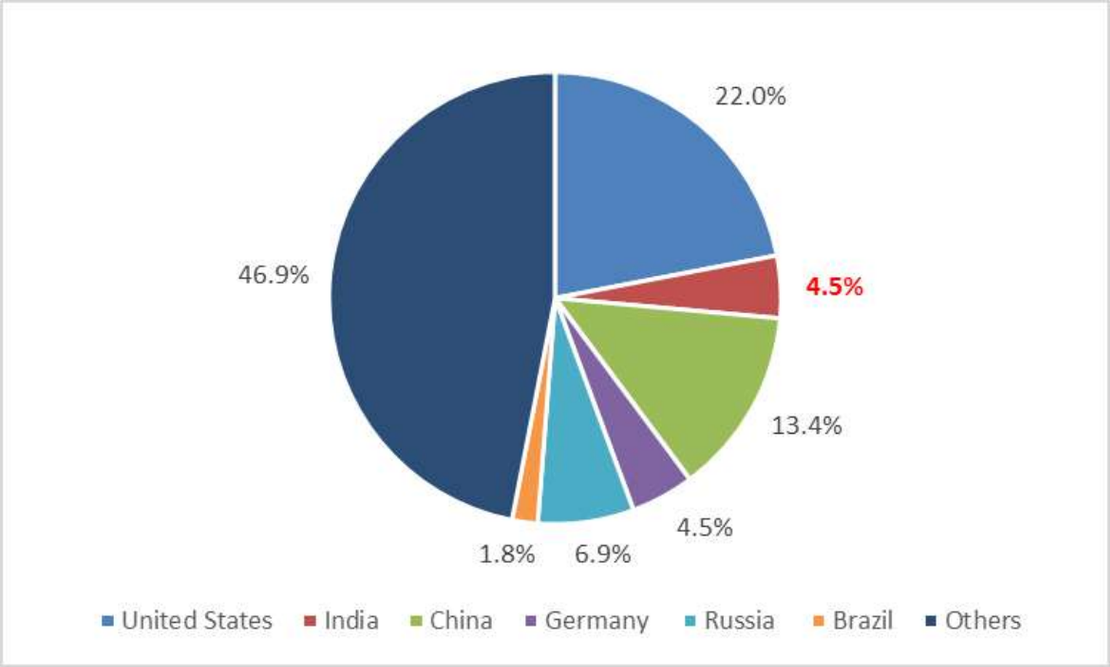


Figure 1.1 Share of Cumulative Emissions for Select Countries, 1850-2019

Source: *(Climate Equity Monitor, n.d.)*

In other words, India has used a far smaller part of its due share of the global carbon budget thus far, compared to developed countries who have exceeded their fair share very significantly, particularly when measured relative to its share of the global population.

From a global carbon equity perspective, therefore, India has adequate rationale to draw on its fair share of the carbon budget, as required for the future, as well as being adequately compensated, physically or otherwise, for its carbon credit from the pre-2020 period. Such compensation may be physically achieved by developed countries undertaking early net-zero, well before 2050, as well as undertaking negative emissions. It is well recognised that global net-zero does not mean that all countries must reach net-zero at the same time, more so for low emitters like India, South Asia, and Sub-Saharan Africa. Given India's

low base of emissions and development (for example, the per capita electricity consumption is about a quarter the world average), it is inevitable that its energy use and emissions will need to rise.

Box 1.1 - Climate Equity Monitor

The Climate Equity Monitor (CEM) is an online dashboard developed by various research organizations for assessing international equity in climate action in relation to climate mitigation, energy and resource consumption, and climate policy across the entire world. CEM is the first such initiative from a developing country, comparing the responsibilities and policies and actions of Annex-I and Non-Annex-I Parties from the perspective of equity and CBDR-RC. The Monitor estimates that India's fair shares of the remaining carbon budget for a 50% probability of staying within 1.5°C and 2°C temperature increase are 89.4 $GtCO_2$ and 241.3 $GtCO_2$, respectively. With respect to historical cumulative emissions prior to 2020, it finds that India has a carbon credit of 337.59 $GtCO_2$ due to its unutilized share of the part of the global carbon budget consumed till 2020.

Source: (Climate Equity Monitor, n.d.)

URL: https://climateequitymonitor.in/

Table 1.1 shows the estimates of India's fair share against the total and remaining carbon budget for the world. When historical responsibility is considered, India's fair share is estimated as the difference between the per capita share of the total carbon budget and the actual emissions. When only the remaining carbon budget is considered, ignoring all historical responsibility of developed countries, India's fair share is simply its per capita share of this remaining carbon budget.

Table 1.1: India's Fair Share of the Total Carbon Budget (With Historical Responsibility) and the Remaining Carbon Budget (Without Historical Responsibility) from 2020 to Net-Zero

	Total Global Carbon Budget (1850 to net-zero) ($GtCO_2$)	**Remaining Global Carbon Budget (2020 to net-zero) ($GtCO_2$)**	**India's Fair Share (2020 to net-zero) * [$GtCO_2$]**
1.5° C - 67% Probability	2790	400	71 - 441
1.5° C - 50% Probability	2890	500	89 - 458
2° C - 67% Probability	3540	1150	206 - 574
2° C - 50% Probability	3740	1350	241 - 609

* The lower end of the range is India's fair share without historical responsibility. The upper end is India's fair share if historical responsibility is considered, after deducting India's non-LULUCF CO_2 emissions from 1850 to 2019.

India emphasizes that its current emissions also reflect its commitment to the safety of humanity and the planet, as also revealed in the data on net anthropogenic GHG emissions per capita, by region in 2019. Figure 1.2 from the Summary for Policymakers (SPM) of the Working Group (WG) III contribution to Sixth Assessment Report (AR6) (IPCC, 2022) shows that Southern Asia has the lowest per capita emissions among all regions in the entire world. However, while responsibly staying within its fair share of the global carbon budget, India's current annual per capita emissions will increase to meet its developmental needs and aspirations.

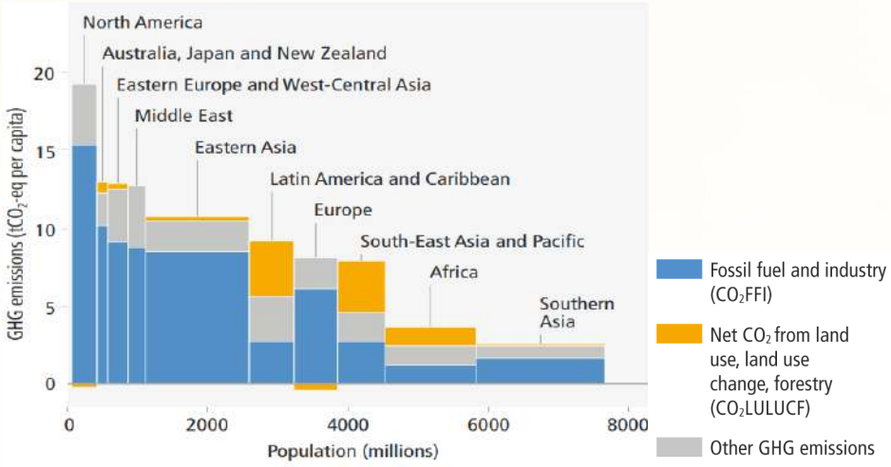


Figure 1.2: Net anthropogenic GHG emissions per capita

Source: *IPCC AR6 2022 Working Group III, Summary for Policymakers, Figure SPM.2*

1.2.2 India has Significant Energy Needs for Development

Through sustained growth and development, India seeks to move rapidly beyond its lower-middle income country status (World Bank, 2020). These and other challenges have been amplified by the socioeconomic impacts of the COVID-19 pandemic. In particular, immediate efforts need to be focused on the sections living below the poverty line (World Bank, 2020), and sizeable population employed in the informal sector (ILO, 2018).

Energy is essential to meeting the development needs and erasing India's development deficits while building for a prosperous future. However, India's primary energy consumption per capita in 2019 was 28.7 gigajoules (GJ), considerably lower than both developed country peers (e.g., 282.2 GJ for the United States, 340.4 GJ for Canada, 106.8 GJ for the United Kingdom) and comparative developing countries (e.g., 58.2 GJ for Brazil, 100.1 GJ for South Africa, 101.3 GJ for China) (IEA, n.d.). Meeting these development needs will require steep increases in overall and per capita energy use even as India implements an effective programme to enhance energy efficiency.

Social development as measured by the Human Development Index (HDI) is closely correlated with growing per capita energy consumption. India is well short of the threshold of per capita energy consumption required to reach an acceptable national level HDI.

Second, India is undergoing multiple transitions – a demographic transition that leads to demands for job creation, an agrarian and urbanisation transition, and rapid infrastructure growth. All three are energy intensive. As with HDI, historical evidence clearly shows that energy use per capita grows strongly during the early years of per capita GDP growth, and India is only beginning to exploit the positive linkages between energy consumption and GDP. The limited extent of decoupling emissions from growth seen in developed countries is still insufficient and their emissions continue to remain at high levels indicative of significantly higher consumption compared to developing countries. In contrast, India's trajectory reflects its low energy consumption and low emissions even currently, as well as the impact of its significant mitigation efforts, with its decoupling beginning at much lower emission levels.

India's growing energy needs are undeniable. The country is making strong efforts to increase the share of installed electric power capacity from non-fossil sources. While India is taking active steps in this

direction (See Chapter 2), the transition to a primarily low-carbon energy system is a long-term process that can extend up to 2070. The current energy capacity stock is predominantly fossil fuel based and the financial and transaction costs of a low carbon transition are considerable, as described in Chapter 2. India's emissions will have to increase in line with growing energy demand and overall development, eventually reaching the envisioned goal of net-zero in 2070. It is very clear that India's energy needs for development, which are substantial, cannot be deferred.

1.2.3 India will Pursue Low-Carbon Strategies for Development, as per National Circumstances

In this perspective, India is pursuing low-carbon strategies for development toward a net-zero emissions future by 2070. India recognizes that climate action must be based on multilateralism as well as firm adherence to the core principles of the UNFCCC, namely equity and CBDR-RC. India's approach is also informed by awareness of potential technological and competitive benefits arising out of a low-carbon transition in the long-term, as also the scope for financial and transaction costs in realising any benefits.

While ensuring adequate access to household energy, energy security, and energy for industrial development, India's approach seeks to identify and explore opportunities to shift to low-carbon development pathways. Beginning in 2008, India's National Action Plan on Climate Change (NAPCC) recognised the potential for co-benefits between climate and development, while also noting that there are trade-offs and corresponding costs. India's mitigation efforts are therefore driven not just by climate-specific policies, but also by broader development choices. For example, India faces other development challenges relating to access to critical services such as sanitation, housing, and transport, managing urban growth and rural opportunities, and other environmental issues. Thus, India's LT-LEDS is based upon an economy-wide multiple objectives approach, including integrating dimensions of gender equity and inclusion of marginalised and vulnerable groups, that consciously seeks to move to a low-carbon path of development. Accordingly, this LT-LEDS extends its scope across sectors from the perspective of its economy-wide goals to identify possible development-driven and equitable low-carbon development pathways, as outlined in Chapter 2.

It is critical to recognize the inevitability of not only trade-offs and corresponding costs, but also the need for finance to harness low-carbon opportunities. In a developing country, with its high and continuing need for capital, the opportunity cost of capital is high.

The social and transaction costs of pursuing such a path are also considerable. This is particularly evident when exploring shifts in the primary energy mix, discussed in Chapter 2. Similar challenges also exist in transitioning away from conventional vehicles and many manufacturing and construction processes, among others, which bear implications for social equity and access in a growing economy.

Alongside social and transaction costs, the larger challenge is that of capital costs, and hence ongoing growth and development will need fossil fuel use for varying lengths of time up to 2070 in different sectors. The requisite technologies are for a significant part not available at scale, nor are available technologies deployable without incurring very significant costs. Full substitution of fossil fuels has not even been achieved in developed countries, with their enormous dependence on oil and gas, and hence India will need to transition the use of fossil fuels over an extended period. This is also the significance of India's need for an equitable share of the global carbon budget.

Box 1.2: Unnat Jyoti by Affordable LEDs for All (UJALA) and the Pradhan Mantri Ujjwala Yojana

These two programmes perfectly illustrate India's commitment to transformative developmental action wherever feasible, which also promotes low-carbon growth. Launched in January 2015, the Unnat Jyoti by Affordable LEDs for All (UJALA) scheme provides LED bulbs, LED tube lights, and energy efficient fans at highly subsidized prices. As of November 2021, over 367 million LED bulbs have been distributed, leading to energy savings of over 47,776 million kWh annually, cost savings of INR 19,110 crore, avoided peak demand of about 9.56 GW, and avoided CO_2 emissions of over 38 $MtCO_2$ (PIB, 2022a). The Pradhan Mantri Ujjwala Yojana (PMUY), was launched in May 2016, to make LPG, a clean cooking fuel, available to rural and marginalized households. These households have otherwise used traditional fuels such as firewood, coal, cow-dung cakes, which have severe negative health and local environmental consequences. India has met its target of providing 80 million LPG connections well before the time initially envisaged for this scheme. The Government has now extended the scheme to ensure 10 million more LPG connections and has increased the coverage to include migrant families as well. The PMUY has led to an increase in LPG coverage from 62% on 1st May 2016 to 99.8% as on 1st April 2021.

While India will pursue low-carbon strategies, this transition shall be in accordance with national circumstances and a pace and scale that is nationally determined, without compromising India's development future. Consequently, the need for climate finance for India's low-carbon transition is considerable as well as the need for technology transfer without barriers (See Chapter 6).

As elaborated in Chapter 2, going forward, India's energy and fossil fuel strategy will have several pillars including, inter-alia (i) Focus on electrification of energy services; (ii) low carbon electricity systems, including one of the world's most ambitious programmes for adding wind and solar; and (iii) energy efficiency, both in end-use and energy delivery.

1.2.4 India is a Climate-Vulnerable Country

India has a diverse geography that encompasses a wide range of ecosystems, from mountains to deserts, inland regions to coastal areas and from plains to jungles. A long coastline of over 8,000 kilometres (km) supports a rich variety of marine ecosystems. With varying geographical and topographical conditions, India experiences a range of climates, from tropical to alpine. Its climate is significantly influenced by the Himalayan mountain range and by the Thar Desert; the monsoon – one of the most prominent climate systems of the world – provides nearly 75% of the country's annual rainfall, significantly supporting livelihoods (MoEFCC, 2021).

As such, India is vulnerable to the impacts of climate change. More frequent droughts, higher temperatures, and variabilities in monsoon rainfall are expected by the end of the century (Krishnan et. al., 2020). These changes will challenge India's largely rain-fed and resource-constrained agricultural system, impacting crop yields and incomes (DEA, 2018). Climate change is expected to increase the frequency and intensity of heat waves, which may affect outdoor labour productivity and deepen exposure to adverse health outcomes in urban and rural areas (DST, 2016). In coastal areas, rising instances of climate-induced sea-

level rise and extreme flooding events could result in infrastructural losses (NDMA, 2019; Krishnan et. al., 2020). Building resilience to potential climate impacts is, therefore, critical to maintain development gains and human development outcomes.

1.3 India's Progress toward a Low Carbon Future

1.3.1 Current Commitments and Pledges

India has consistently made ambitious commitments at the UNFCCC and its Paris Agreement, the key multilateral platforms for climate change, and has a strong track record of meeting these commitments.

India's Nationally Determined Contribution (NDC) submitted to the UNFCCC in 2015, inter alia, committed to reducing the emissions intensity of its GDP by 33-35% below 2005 levels by 2030, to achieve a 40% share of cumulative electric power installed capacity from non-fossil sources by 2030, and to create an additional carbon sink of 2.5-3.0 $GtCO_2e$ through additional forest and tree cover by 2030 (MoEFCC, 2015).

In line with these commitments, the emissions intensity of India's GDP had already reduced by 24% from 2005 levels until 2016 (MoEFCC, 2021), and as of May 2022, the share of non-fossil fuel sources in the country's installed generating capacity had reached 41.4% (CEA, n.d.). This indicates that India has overachieved one of its Nationally Determined Contributions (NDCs) announced at Paris Climate Summit (2015) by already meeting 40% of its power capacity from non-fossil fuels as of November 2021 almost nine years ahead of its targeted commitment. The country is thus on track to meeting its NDC targets.

Further, building upon Hon'ble Prime Minister Modi's *Panchamrit* pledges (five nectar elements) at COP26 in Glasgow, including the target of net-zero emissions by 2070, India updated three of its NDCs in August 2022 with the following targets (MoEFCC, 2022; UNFCCC, 2022):

1. Meet 50% of India's cumulative electric power installed capacity from non-fossil sources by 2030.
2. Reduce the emission intensity of the GDP by 45% below 2005 levels by 2030.
3. To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation, including through a mass movement for LiFE–Lifestyle for Environment as a key to combating climate change.

The challenge of meeting India's emissions intensity reduction pledge is not inconsiderable and will be made more serious with shifts in the structure of the economy, especially in favour of manufacturing and industry (Kanitkar et. al., 2015).

Box 1.3: Nationally Determined Contributions (NDC)

India's Nationally Determined Contributions to the Paris Agreement, submitted as India's Intended commitment prior to its signature at COP21 in 2015, is a robust and fair contribution to global climate action, on the basis of equity and in accordance with the principle of common but differentiated responsibilities and respective capabilities. The NDC followed India's consistent and successful implementation of its voluntary contribution to pre-2020 climate action. In the light of India's minimal contribution to historical cumulative emissions prior to 2020, and its current per capita emissions that are about one third of the world average for a sixth of humanity, the NDC are fully aligned to the temperature goals of the Paris Agreement and do not fall short of this requirement.

Nevertheless, to reassure the world that is preoccupied with the lack of ambition of the developed countries, India further enhanced and updated its NDC in August 2022. This was undertaken subsequent to India's National Statement at COP26, which announced, inter-alia, the enhancement of India's target in the deployment of renewable energy and the year 2070 as India's target date for net-zero.

The elements of India's NDCs that were enhanced and updated are as follows*:

- To put forward and further propagate a **healthy and sustainable way of living** based on **traditions and values of conservation and moderation**, including through a mass movement for LiFE–Lifestyle for Environment as a key to combating climate change.
- **To reduce Emissions Intensity of its GDP by 45% by 2030, from 2005 level.**
- To achieve about **50 % cumulative electric power installed capacity** from **non-fossil fuel-based energy resources by 2030**, with the help of transfer of technology and low-cost international finance, including from Green Climate Fund (GCF).

*The full submission of India's updated NDC is available at https://unfccc.int/NDCREG

1.3.2 Institutional Framework

Preparing the institutional capacity to appropriately develop and implement policies that are also consistent with development needs is a foundational requirement. Appropriate institutions can help shape the context for development pathways and mainstream low-carbon growth considerations into policy, financial, and administrative process. This will enable India to take a bottom-up, all-of-society approach to low-carbon development.

For Institutional intermediation and execution of India's LT-LEDS, a strong foundation is in place through existing extant agencies – the Executive Committee on Climate Change (ECCC), the Apex Committee for the Implementation of the Paris Agreement (AIPA), and others. Going ahead, the LT-LEDS will be based on coordinated climate action across an economy that spans its several sectors and Ministries, as well as its 28 States and 8 Union Territories, operating in a predictable, federalized structure of governance. India will continue to promote States as engines of climate action further, especially considering States as actors, and to improve their scientific and policymaking capabilities.

Chapter 2 STRATEGIC TRANSITIONS

Chapter 2 discusses seven key low-carbon development transitions, which have been developed through an Inter-Ministerial Task Group process with stakeholders' participation. To support this process, the Ministry of Environment, Forest and Climate Change (MoEFCC) constituted an Inter-Departmental Steering Committee (IDSC) with representation from various relevant Ministries and Government Departments for oversight and a Technical Advisory Committee of Experts (TACE) from academia and research organisations to provide technical guidance.

Each Task Group was steered by a representative from the relevant Ministry. Other members of the Task Groups included representatives from relevant Ministries and Governmental Bodies, Academic and Civil Society Organisations, and the private sector.

Each Task Group was requested to provide through an iterative, consultative process a summary report on developing the perspective for the area of its responsibility. In particular, Task Groups were requested to provide the domestic and international developmental context for these transitions to low-carbon development to indicate the current policies and targets that were already supporting such transitions, to identify the key elements of the long-term strategy in each transition, and the opportunities and challenges in achieving them, as part of the developmental outcomes that these transitions might contribute to.

2.1 Low Carbon Development of Electricity Systems

India has one of the largest power systems in the world catering to a population of 1.3 billion. With a peak demand of about 206 GW (CEA, 2022), the total electricity generation for FY 2021-22 was under 1,500 TWh/BU. The industrial sector accounted for about 43% share of consumption, the residential sector 24% and the agriculture sector 18%. India has an installed generation capacity of 404 GW (July 2022), of which 168 GW (41.6%) is from non-fossil fuels. In India's total electricity generation in FY 2021-22, renewable energy was about 22% including hydro (MoP, 2022a; 2022b). Renewables (esp. wind and solar) have been growing very strongly in recent years (39 GW in 2015 to 110 GW by 2022). For the past seven years, RE is the fastest growing segment of generation capacity at an average CAGR of 15.6%. (Data sourced from CEA, 2022; MNRE, 2022).

India's average per capita electricity consumption from utilities alone, about 800 kWh in 2020, is only about a fourth of the global average. The overall per capita consumption of electricity for the year 2021-22 was 1,255 kWh. The following figure 2.1 illustrates the large gap between India and developed countries whose consumption is more modest than that of the United States which has the largest per capita consumption amongst them.

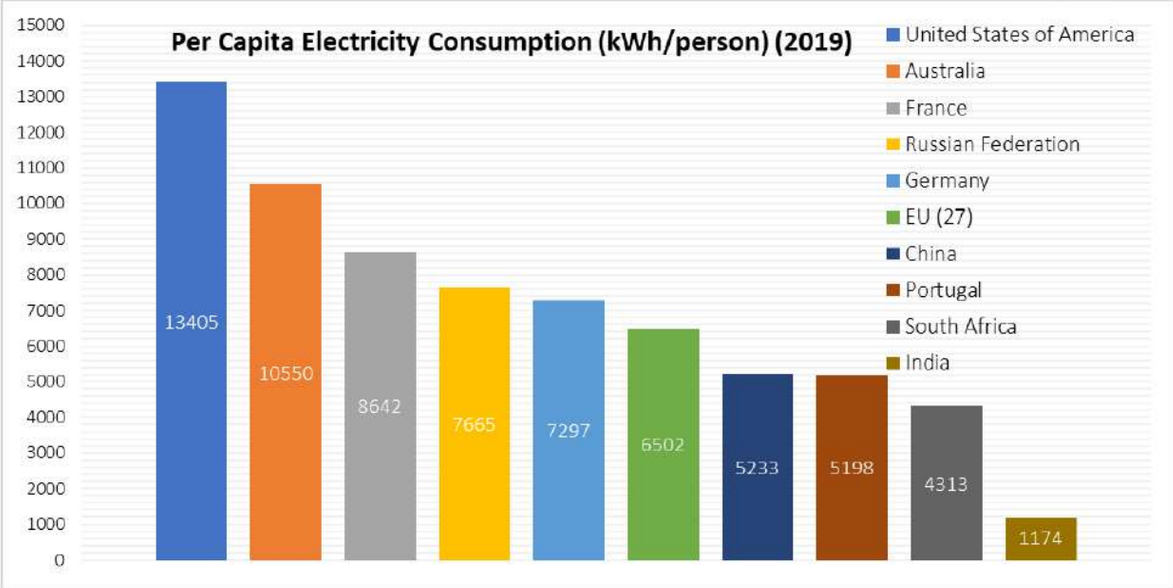


Figure 2.1 Country wise per capita electricity consumption *(Climate Equity Monitor, n.d.).* The year 2019 is chosen as it provides a better cross-country comparison from the year prior to the pandemic.

India recently achieved universal household access to electricity, (https://saubhagya.gov.in) with current efforts focused on further strengthening the quality and reliability of supply, especially in rural areas. However, with the need for further increase in electricity consumption, India's challenge is reaching optimal, though higher, energy consumption levels even while being mindful of a low-carbon path of growth. India has been proactively shutting down inefficient thermal power units. A total 241 Units with capacity of 17,281 MW have been retired from the 10th Plan period onwards till September 2021.

2.1.1 Current Policies and Programme

Since the initiation of National Action Plan on Climate Change (2008) and its missions on solar energy and energy efficiency, India's policy framework for growth in electricity generation and supply along a low-carbon development pathway has evolved comprehensively and is described here under three categories.

1. Promoting and supporting Renewable Energy and Nuclear

    a. Ambitious RE targets: Targets have been consistently enhanced (MNRE, 2019 & 2021).

    b. 'Must-run' priority dispatch status for renewables: Preference is given to RE power in the merit order despatch, despite costs, which is part of India's investment in mitigation, through increased cost of power, especially for supply from older sources.

    c. Renewable Purchase Obligations (RPO): These are obligations for the purchase of RE power, specified by State Electricity Regulatory Commissions for distribution companies, open access consumers and captive plants (MNRE, 2021).

    d. Promotion of Hydro Power: This is being undertaken through several policy measures to tap hydro power potential in the country, including the introduction of Hydro Purchase Obligation. This will also necessitate increased provision of climate finance.

    e. Energy Storage Obligations: These are being progressively introduced. However, their expansion will depend on decreasing cost of storage technologies, transfer of this type of technology and concessional finance.

f. Green energy corridors: These are being developed to strengthen transmission networks in eight RE rich States (MNRE, 2021).

g. Policy and financial incentives: These include solar park development, accelerated depreciation on investment, waiver on transmission charges, and capital subsidy for residential solar roof-top (MNRE, 2021).

h. A three-fold rise in nuclear installed capacity by 2032.

i. Agricultural solar pumps are being promoted (MNRE, 2021). The consumption of energy in the agriculture sector is an important aspect to ensure the food security aspect of the country and the globe, as large energy consumption is required for irrigation pumps.

j. Supportive policies are being introduced such as net metering, energy banking and waiver of duties and surcharges.

2. Policy and Programme Support

a. Manufacturing support such as production-linked incentives for solar, electric vehicles and battery storage systems (MNRE, 2021).

b. Establishment of a 'Renewable Energy Management Centre' for supervision, monitoring and control of RE.

c. Policy and financial assistance for promotion of waste to energy measures.

d. Enabling bundling of thermal and hydro power with RE to enhance flexibility.

e. Policies to support biomass use for power generation.

f. Roadmap of a sustainable and holistic approach to National Energy Efficiency (ROSHANEE) for Revised National Mission for Enhanced Energy Efficiency: This will enable alignment with the goals of the NDC, mainly through energy efficiency and conservation activities included under standards and labelling programme for appliances, building efficiency programme, industrial efficiency improvement under Perform, Achieve and Trade (PAT) scheme, and market transformation programmes such as UJALA (MoP, 2019).

g. Green hydrogen mission to incentivise green hydrogen production (MoP, 2022).

h. Support to R&D in carbon capture and utilisation.

i. Developing or deploying storage systems (Pumped Storage Plants, Battery Energy Storage Systems, Gravity, Thermal, Compressed Air, etc.).

3. Promoting Markets and Competition

a. Green Term-ahead Market to provide enhanced avenues for sale of RE (PIB, 2020).

b. Day-ahead market for trading of RE to meet green targets (CERC, 2020).

c. Real-time market to manage RE intermittency and demand variation (CERC, 2020).

d. Ancillary services to balance power and manage variation of intermittent RE and enable demand responsiveness.

e. Rules facilitating direct procurement of green energy by open access consumers.

f. Regulation for Renewable Energy Certificates trading and introduction of Renewable Energy Certificates multiplier for new technologies.

2.1.2 Elements of a Long-Term Low-Carbon Development Strategy

This section presents five elements that provide broad directional shifts for the Indian electricity sector, aimed at inclusive, low-carbon development in a manner consistent with India's developmental needs.

2.1.2.1 Expanding Renewables and Strengthening the Grid

Falling RE costs present an opportunity for RE expansion but realising this potential fully requires substantial investment in grid-strengthening in parallel and other enabling conditions.

1. Intermittency of RE: This is a major challenge for India as a developing country. This is particularly onerous for India as it does not have substantial oil and gas-based generation, which provides much greater flexibility in dealing with the intermittency. India will have to substantially rely on coal-based plants. It will also have to commission more storage systems, including pumped hydro, and cope with the challenge of enabling demand responsiveness in the medium/long-term. Flexible operation of thermal power plants (TPPs) to accommodate RE power needs to be developed as a potential strategy.
2. Rapid expansion of RE: India has adopted ambitious RE targets. India's 2022 updated NDCs includes a target of about 50% cumulative non-fossil fuel electric power capacity by 2030 (PIB, 2022b). Going forward, RE expansion will be facilitated by the promotion of offshore wind, centralized solar and onshore wind parks, floating solar photovoltaic installations, and decentralized solutions including rooftop PV, solar agricultural feeders and mini- and micro-grids. A priority will be simultaneous job creation. Offshore wind and greater uptake of other renewables and storage will also take place in the medium and long term as these technologies mature.
3. Hydro power is a significant renewable source of energy. India's policies for encouraging the development of hydropower include promoting hydropower obligations along with renewable power obligations. India envisages use of its hydroelectric potential at a faster pace, including promotion of small and mini hydel projects, strengthening the role of Public Sector Undertakings/State Electricity Boards for taking up new hydel projects and increasing private investment.
4. Assessing and planning for likely demand for green hydrogen (medium to long term): India has plans to promote green hydrogen, necessary for decarbonisation of hard-to-abate sectors. India aspires to expand annual production of green hydrogen several-fold.
5. India aspires to increasing electrolyser manufacturing capacity several fold by 2030 to become a global leader (NITI Aayog, 2022).
6. India envisages becoming a leading exporter of Green Hydrogen (GH) and Green Ammonia (GA) by 2030 (NITI Aayog, 2022). But this requires substantially enhanced RE capacity, which will require careful planning of capacity addition. The roadmap up to 2030 involves reduction of cost of production through technology development and bulk procurement, providing fiscal incentives to accelerate production, promotion of domestic manufacturing of electrolysers, issue of demand-side mandates to encourage adoption of green hydrogen and green ammonia in hard to abate sectors, and ensuring availability of low-cost green electricity for green hydrogen.
7. Promote co-firing of green ammonia in thermal power plants (TPPs). Beyond 2030, this would entail:
    a. Enhancing industrial demand for green hydrogen and green ammonia (fuel switching – GH/GA replacing coke and natural gas).

b. Expanding infrastructure for transporting and storing hydrogen, including pipelines, and storage tanks.

8. Several of the above strategies will require research and development, while all of them would require considerably enhanced provision of climate finance and technology transfer.

2.1.2.2 Other Low-Carbon Technologies

1. Exploring a significantly greater role for nuclear power: Presently (2020-21) nuclear power is saving 41 million tonnes of CO_2 emissions annually, compared to the emissions that would be generated by equivalent electricity generation from coal based thermal power plants. Nuclear power currently provides 3% of electricity generation (PIB, 2021f). Sufficient production and share of nuclear power are highly significant for ensuring country's energy security.
2. The potential for establishment of small modular nuclear reactors is to be explored, and this will require sharing and transfer of relevant technologies.
3. Expanding this share is possible, for example for utility distribution, captive use in industries and for green hydrogen production, but carries challenges.
4. Promoting R&D for frontier technologies: Emergent technologies include coal gasification, carbon capture, utilization and storage systems, biomass co-firing, beneficiation technologies, offshore wind, high efficiency fuel cells, advanced solar materials, methanogen and organo-assisted biological gasification, advanced chemistry cells, off-shore wind, tidal power, small modular reactors, and smart demand response systems. India will promote the R&D of such technologies to be ready to capitalise on such expertise as and when the opportunity arises.

2.1.2.3 Focusing on Demand-Side Measures

India's per-capita electricity consumption is very low by global standards and many Indians need to avail of more energy services from electricity. Per capita consumption, as an overall aggregate measure that also incorporates the use of electricity for production, will rise steadily as India is a developing country. This will also include electricity use in hard-to-abate sectors, or in the informal and MSME sectors, where demand-side measures have little scope in the current and future scenarios. Yet, while India will pursue demand-side measures in select sectors and contexts, such as the large-scale shift to LED lighting in meeting public lighting requirements, the scope for demand-side measures in low-carbon development in India will be circumscribed by socio-economic constraints.

Under the National Mission for Enhanced Energy Efficiency, the Bureau of Energy Efficiency, a nodal institution under the Ministry of Power, has undertaken significant work to improve energy efficiency. Under the ROSHANEE plan, ambitious energy efficiency programmes, spanning multiple sectors are being implemented. These include Standards and Labelling programme for appliances, Energy efficiency in Buildings, and PAT scheme for Industries.

2.1.2.4 Role for Coal

Coal has a predominant role in India's electricity system contributing about 75% of generation currently (MoC, n.d.). While the share of coal in the Indian electricity sector will reduce in the coming years, this will be a gradual process taking due note of its socio-economic implications.

Ensuring adequacy of supply of energy is paramount. India needs to guard against a lack of adequate and reliable energy to meet its economic and developmental needs. This could only be achieved through a judicious mix of supply resources including reliance on coal-based generation. Planning for low-carbon development in the electricity sector must ensure that India's growing electricity demand continues to be met.

Hence, as the overall strategy, the key elements are:

1. Rational utilisation of fossil fuel resources: The management of the share of coal in India's electricity sector will be undertaken in a careful manner to meet multiple objectives, including the deployment of ultra-super critical; meeting the growing demand for electricity; managing the intermittency of renewables; enhancing efficiency outcomes; and avoiding lock-ins as India develops towards net-zero in 2070. It is re-emphasized that India's coal consumption per-capita in 2019 was only half the world average (Tongia & Sehgal, 2016; Tongia, 2020). In contrast, India used only ~22% of the global average of oil and gas. Global oil and gas emissions were 25% more than from coal, even after factoring coal-based emissions from cement. Thus, it is inconsistent to focus disproportionally on lower coal use instead of lower total emissions. Key factors will be the price reduction trajectory of electricity storage systems and financial support and technology transfer from developed countries.
2. Reskilling and redeployment of manpower: This is a crucial requirement. Experienced human resource from fossil fuel sector could be retrained to meet the requirements of non-fossil sector in future, thereby making the transition just, smooth, sustainable and all inclusive.
3. Closing inefficient thermal power: India has been proactively shutting down inefficient thermal units. A total 241 Units with capacity of 17,281 MW have been retired from the 10th Plan onwards till September 2021.

2.1.2.5 Enabling Low-Carbon Development

1. Promoting local manufacturing of clean energy technologies (ongoing): India is promoting manufacture of clean energy technologies at scale. Existing Production-Linked Incentive (PLI) schemes support solar, energy storage systems and electric vehicle technologies. In the medium term, support may be considered for green hydrogen, offshore wind, smart demand-response systems and so on, as these are likely to be the technologies of the future. The aim is to promote indigenous growth and employment generation alongside a green transition.
2. Robust institutions to enable a smooth electricity transition (ongoing): Enabling an equitable, development-friendly low-carbon electricity transition has multiple linkages to other sectors of the economy, including, inter alia, transport, buildings, industry, forestry, and finance. It also requires coordination and planning across levels of Government ranging from the Centre to States to District and local authorities. Consequently, an important requirement is robust and capable institutions to address these complex tasks and associated effective coordination processes.
3. Green taxonomy for India's electricity sector: Considering that the time frame for medium- and long-term actions are 30 and 50 years away from now, India has a clear identification of all non-fossil sources viz., hydro, solar, wind, nuclear and biomass. This is key to supporting evidence-based and actionable policy making. It helps to define the direction/pace of transition, thereby sending reinforcing policy signals to industry and investors, providing clarity regarding which actions are to be considered as sustainable in the longer term.

4. Optimum energy mix: Considerations of optimal energy mix in the near, medium, and long term with the proportion of each energy source including fossil fuels, will be a part of India's low-carbon development strategy in the energy sector. This will enable policy signals that will assist in making informed investment decisions in different sectors over varying time scales and assist in the low carbon development transition.

2.1.3 Potential Benefits and Challenges

Large-scale expansion of RE will depend on the continued availability of critical rare earth minerals for solar, wind and non-fossil fuel technologies, both globally and for domestic production. Large scale RE expansion will also depend on increasing availability of specialised steel, cables and other critical strategic materials and equipment, especially through domestic manufacture under *Aatmanirbhar Bharat* and Make in India.

1. Increase in the contribution of modern energy sources, such as electricity by increasing the share of electricity in industry and transport.
2. Reduced cost of electricity, as the cost of newer technologies such as solar and wind continues to fall and distributed generation can lead to lower transmission and distribution losses, but with implications for consumer pricing and social welfare redistribution. However, an important pre-requisite is a fall in the cost of storage technology and its practical realization. The development of pumped storage facilities using hydro is the world's most widespread storage system by far. The scope of pumped storage in India is acknowledged as part of the country's larger hydro power policy.
3. The possibility of having decentralized, grid-connected renewables can further reduce costs by reducing transmission and distribution losses. However, these considerations do not extend to electricity supply for industry and transport. Current national and global experience shows the key importance of large-scale deployment of RE installations in areas where conditions are favourable.
4. Developing the electricity sector with progressively lower share of fossil fuels, in a just and equitable manner requires significant investments. Resources will be required for investment in high capex, large scale renewables capacity, enhancing the transmission grid and introducing energy storage systems. In addition, financing a just transition will require supporting social and physical infrastructure, ecological restoration of affected areas, building capabilities of communities, and to seed new livelihood generating activities. The challenge is compounded by high capital requirements of other sectors and the relatively high cost of capital in India.
5. India heavily taxes all fossil fuels at various stages from extraction to final consumption. This amounts to an effective carbon tax, higher than many developed countries.

2.2 Develop an Integrated, Efficient, Inclusive, Low-Carbon Transport System

The transport sector in India contributes around 10% to India's GDP (BERPD, 2018). It is an important sector that facilitates the overall development of industries and commercial activities in any economy. In India therefore, the development of the transport sector is a priority area for the Government. Emissions from the transportation sector are mainly from fossil fuel consumption in the road sector, though vehicle ownership in India is far below the world average and much below the levels of other developed and

emerging economies. In 2018, the total vehicle penetration per 1000 people in India was 32, in contrast to 134 in China, 619 in Germany, and 804 in the USA (MoRTH, 2021). The road transport sector accounts for about 87% of passenger traffic and 60% of freight traffic movement in the country and the sustainable development of this sector is a critical element in India's long-term development strategy (MoRTH, n.d.).

Overall, transport sector contributes to about 12.1% of India's energy-related CO_2 emissions (MoEFCC, 2021) and 9.7% of the country's total Greenhouse Gas emissions.

In the previous decade, increasing sales of internal combustion engine (ICE) vehicles have more than doubled the fuel consumption and related GHG emissions from the transport sector, even as vehicle ownership in India is far lower than in other developed and emerging economies. Figure 2.2 below shows the growth in total number of registered vehicles in the country between 2000 and 2019, with the two-wheeler and car segments growing at a CAGR of ~10%. Much of this growth has been driven by rapid urbanization. This trend is expected to continue, as urban population is projected to increase from about 370 million in 2011 to 600 million by 2030 (DEA, 2021). India is also home to a thriving domestic auto manufacturing industry.

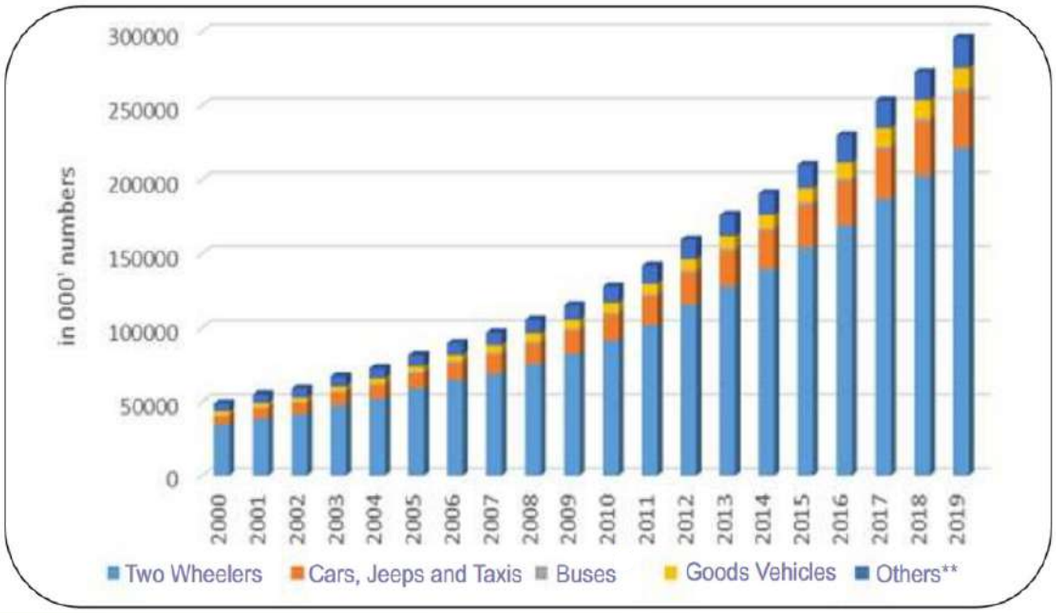


Figure 2.2 Total Number of Registered Motor Vehicles (Category Wise). ***Source:*** *(MoRTH, 2021).*

Note: ** Includes Tractors, trailers, 3-wheelers/LMV and other miscellaneous vehicles

Indian Railways is one of the world's largest railway networks, extending over 68,000 km (MoR, 2022). It carries nearly 23 million passengers daily, making it the largest passenger carrying system in the world (MoR, 2018). Other segments such as civil aviation and domestic navigation account for a relatively small but growing share of India's transport mix.

Given India's current growth and transport sector trends, the on-road freight segment is likely to be a significant driver of transport emissions in the long-term in a business-as-usual scenario. Emissions from heavy duty vehicles would account for the major part of such emissions. Addressing both passenger and freight transport is an important goal for India's low-carbon development.

2.2.1 Current Policies and Programmes

Achieving Improved Fuel Efficiency

1. Vehicle emissions: Leapfrogging from Bharat Stage IV emissions standards for vehicles directly to Bharat Stage VI emission standards.
2. Vehicle scrappage policy: Mandatory scrapping of old, unfit polluting vehicles subject to fitness and emissions tests and replacement of end-of-life vehicles (ELVs) can result in a 15-20% reduction in vehicular air pollutants and increased fuel efficiency (MoRTH, 2022).
3. Corporate average fuel economy norms: Standards imposed upon vehicle manufacturers to ensure fuel efficient design across their portfolio of products.
4. Others:
    a. Three-Phased mainline electric multiple unit (EMU) trains.
    b. Flexible usage of airspace, single engine taxing, continuous descent approach, airport carbon accreditation programmes in the aviation sector, carbon offsetting and reduction scheme in International Aviation.
    c. Green shipping and IT enabled management of ports in the maritime sector.
    d. Behavioural interventions and public awareness programmes.

Use of Cleaner Fuels

1. Use of biodiesel, green diesel, compressed natural gas and liquefied natural gas as fuel alternatives.
2. Natural gas as short-term fuel alternatives: Target to increase the share of natural gas in the country's energy mix to 15% by 2030.
3. National Policy on Biofuels 2018: Indicative 2025 target of 20% blending of ethanol in petrol, with an annual savings potential of INR 300 billion of foreign exchange.
4. For increasing feedstock and augmenting availability of bioethanol Government of India has announced Pradhan Mantri JI-VAN Yojana in March, 2019 for providing financial support in the form of VGF to 12 Integrated Second-Generation Bioethanol Projects using lignocellulosic biomass and other biodegradable feedstock. Under this scheme financial support to 10 demonstration units is envisaged to promote development of new technologies.
5. National Green Hydrogen Mission: The mission is expected to generate a production capacity of five million tonnes of green hydrogen per annum. Phase I of the Mission is focused on demand generation, while Phase II aims at accelerated production of green hydrogen.
6. Others:
    a. Natural Gas Infrastructure Development Plan.
    b. Bio-based Sustainable Aviation Fuel (SAF) programme coupled with:

        (i) short rotation oilseed cultivation as a second crop on existing irrigated mono-cropped land holdings feeding into hydro processed esters and fatty acids (HEFA) based SAF production;

        (ii) integration of gas fermentation technologies with alcohol-to-jet (ATJ) SAF plants. One semi-commercial scale plant of each type is expected to be operational by 2025.

c. Sustainable Alternative Towards Affordable Transportation (SATAT) scheme: Initiative encouraging entrepreneurial ventures in the setting up of compressed biogas (CBG) plants, and production and supply of CBG to OMCs. Significant additional decarbonization is expected as biogas purification systems mature so that biogas can be purified to bio-PNG / biomethane standards, injected directly into existing natural gas pipelines and compressed at the point of use.

Initiatives to Induce Mode Shift

1. Portfolio of urban transport policies and schemes: National Urban Transport Policy 2006, Smart Cities Mission, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Green Urban Mobility scheme, National Transit Oriented Development Policy.
2. Metro Rail Policy 2017: Target of constructing metro rail services in 27 cities across India by 2025 (MoHUA, n.d.).
3. National Rail Plan 2030: Target of increasing modal share of the railways in freight to 45%.
4. Indian Railways to become net-zero by 2030, leading to 60 million tonnes of annual mitigation of CO_2.
5. Gati Shakti National Master Plan: A GIS based digital platform to bring together 25 Central Ministries/Departments and all States/UTs for integrated planning and coordinated implementation of infrastructure projects.
6. Dedicated freight corridors by the railways.
7. Setting up of the National High-Speed Rail Corporation Ltd. to finance, construct and maintain high speed rail corridors.
8. National Logistics Policy providing for adoption of efficient, economical and environmentally sustainable modal-mix.
9. Sagarmala Programme – an initiative by the Government of India for enhancing the performance of country's logistics sector and comprising four pillars, namely, port modernisation, port connectivity, port-led industrialization and coastal community development.

Electrification

1. Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME India) scheme, Stage I and II.
2. National Mission on Transformative Mobility and Battery Storage.
3. Production-Linked Incentive Scheme (PLI) for advanced chemistry cell and advanced automotive technology.
4. Draft National Energy Storage Mission.
5. Charging infrastructure for electric vehicles: Publication of the revised consolidated guidelines and standards, 2022.
6. Alternate Fuels for Surface Transportation Programme.
7. Exemption of electric, ethanol and methanol vehicles from requiring permits to carry passengers/ goods.
8. Mission Electrification by the Railways: A 100% electrified broad-gauge network, transition to head-on generation (MoR, 2021).
9. Green Ports Initiative.

2.2.2 Elements of a Long-Term Low-Carbon Development Strategy

The elements of long-term low carbon growth in the transport sector, are already embedded within the current portfolio of policies and actions to a large extent. These are synthesized and elaborated upon below.

2.2.2.1 Improving fuel efficiency

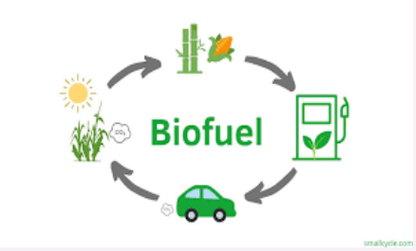
Fuel efficiency regulation, combined with electrification and expanding the adoption of clean fuels, can prove crucial in slowing down the rise in oil demand in the country. Fuel efficiency is also an important tool for achieving India's Nationally Determined Contribution (NDC) commitment. It is also pivotal in reducing oil import costs and enhancing energy security. Improving fuel efficiency can reduce overall growth in demand for fuel and consequently help in reducing GHG emissions as compared to scenarios where such actions for efficiency improvement are not embedded in plans and policies for the sector.

2.2.2.2 Phased adoption of cleaner fuels

The large imbalance between domestic supply and demand of fuels can be filled by boosting the development of alternative fuels. Alternative fuels are considered a promising replacement for conventional fossil fuels and can help in meeting India's energy security needs and reducing dependence on GHG-intensive fuels. They can help reduce reliance on crude oil imports and contribute to reducing CO_2 emissions in the sector. Alternative fuels are gaining popularity due to their advantages in terms of reduced CO_2 emissions, possibility of being produced using renewable energy, high energy quality, and potential contributions to economic growth.

The expanded use of cleaner fuels comprises of three broad phases:

1. Usage of ethanol, compressed natural gas (CBG), biodiesel and liquified natural gas (LNG) as short-term fuel alternatives.
2. Biodiesel and methanol/dimethyl ether (DME) supplemented by pipeline biogas (Bio-PNG) as medium-term fuel alternatives. For encouraging use of such fuels, the following measures would be adopted:
    a. Boost annual ethanol procurement.
    b. Increase ethanol production facilities and ensure availability of sufficient feedstock.
    c. Augment ethanol storage, handling, blending and dispensing infrastructure.
    d. Support manufacturing and adoption of higher ethanol compatible vehicles through incentives, tax breaks, and such other measures.
    e. Introduce sustainable aviation turbine fuel, and biodiesel at commercial scale.
3. Hydrogen as a long-term alternative: green hydrogen is expected to become a significant fuel in India's transport sector in the medium term, although the scale of its use will be contingent on the availability of low-cost finance to spur innovation in this sector. India is also aiming to emerge as a green hydrogen fuelling hub for maritime transport, with connectivity between ports and hydrogen producing facilities.



Box 2.1: Ethanol blended fuels for transport

India introduced the National Policy on Biofuels in 2018, which aims to achieve 20% blending of ethanol with petrol and 5% blending of biodiesel with diesel, by 2030. With the well-coordinated efforts of India's public sector Oil Marketing Companies, the target of 10% blending of ethanol with petrol has already been achieved, much faster than its envisaged timeline. Considering this encouraging performance, the target date of 20% ethanol blending has been advanced from 2030 to 2025-26. The total reductions in CO_2 emissions achieved in the last seven years due to the programme for Ethanol Blended Petrol are estimated to be 22.6 $MtCO_2$. In 2020-21 alone, a reduction of 6.44 $MtCO_2$ was achieved due to this program.

2.2.2.3 Expanding the availability of and access to public transport

As India rapidly urbanizes, vehicle ownership is expected to grow significantly. Studies have shown that a focus of the development of the Indian transport sector through fuel efficient modes of transport and a focus on expanding public transport can have the maximum impact on avoiding CO_2 emissions in the sector. Understanding the composition of different modes is essential in crafting appropriate policies to induce a modal shift.

India has introduced several initiatives to encourage a modal shift in both passenger and freight transport. The goal is to avoid higher per-capita emissions by encouraging public transport. Within public transport, the goal is to expand the use of less polluting modes with the order of preference being rail over road over airways.

2.2.2.4 Electrification across multiple modes

In a fast-growing country like India, electrification is critical to support low carbon development of the transportation sector. By 2050, both the rail and road transport will be encouraged to achieve high rates of electrification through policies designed to encourage electrification in this sector. Electrification of railways is already well on course with over 80% of the broad-gauge network already electrified till March 2022 (CORE, 2022). With the expansion of electricity generation through non-fossil fuel sources, electric transportation will also become less carbon-intensive in the medium and long term.

2.2.2.5. Increasing adoption of electric vehicles

India has a key goal to significantly expand the market share of electric vehicles (EVs) for passenger transport.

In addition to increasing the domestic manufacturing of EVs and batteries through production-linked incentives (PLI) schemes, India will explore the implementation of vehicle-grid integration options, to enable planning of increased load on the electricity grid (Das & Deb, 2020; FICCI, 2020). Increasing decarbonization of the grid and establishment of off-grid renewable hybrid charging / swapping stations for batteries are planned to keep pace with increasing electric mobility. In the short to medium-term, India will also consider policies related to the management of EV-related waste, and circular economy principles for the EV sector. As the EV industry grows, there will be a requirement for re-skilling of the workforce for manufacture and operation of new technologies and related infrastructure.

2.3 Promoting Adaptation in Urban Design, Energy and Material-Efficiency in Buildings, and Sustainable Urbanisation

According to Census 2011, approximately 377 million Indians comprising 31.1% of the country's population lived in urban areas (Bhagat, 2018). The country had 53 city agglomerations with over a million people, and six city agglomerations with over 10 million population. The urban population is projected to grow to about 600 million by 2030 (DEA, 2021).

There has been an increase in the number and intensity of extreme weather events. India's cities are susceptible to their effects, especially at their current stage of development. Cities are also engines of economic growth and it is estimated that 75% of India's GDP in 2030 will be generated from urban regions (CBRE, 2019). It is evident, therefore, that these will contribute more to total emissions. Currently, the major part of India's emissions are from cities, even as energy consumption in cities is more efficient as compared to rural areas Further, buildings account for more than 40% of India's total energy consumption in cities (Ahuja & Soi, 2020).

Therefore, as hubs of population and economic activity, cities are susceptible to the impacts of climate change, with varying degrees of risk to essential services, infrastructure, housing, livelihoods and health, but also have the potential to reduce vulnerability through increased incomes. Due to the concentration of economic activity in urban agglomerations, energy consumption, and emissions are higher in cities making these important regions for climate action.

2.3.1 Current Policies and Programmes

India already has a comprehensive policy framework for sustainable urban design. The relevant policies and initiatives are described here under three categories.

Urban Planning

1. Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines
2. Town and Country Planning Act
3. National Urban Missions such as the
    a. Atal Mission for Rejuvenation and Urban Transformation (AMRUT),
    b. Pradhan Mantri Awaas Yojana (PMAY) – Housing for all (Urban), providing housing especially for low- and middle-income groups.
    c. Smart Cities Mission (SCM)
    d. Swachh Bharat Mission (SBM)
4. Local Municipal Laws
5. Local Area Plans (LAPs)

Buildings

1. National Building Code, Energy Conservation Building Code, Eco-Niwas Samhita (energy conservation building code for residences)
2. Model building bylaws
3. National Mission on Sustainable Habitat

4. National Mission for Enhanced Energy Efficiency
5. Energy Conservation (EC) Act
6. Development Control Regulations (DCR)
7. Rating systems such as Green Rating for Integrated Habitat Assessment (GRIHA), Leadership in Energy and Environmental Design (LEED) and the Indian Green Building Council (IGBC)

Municipal Services

1. State planning regulations
2. Water Prevention and Control of Pollution Act
3. National Water Policy
4. National Water Framework Bill
5. National Environment Policy
6. National Urban Sanitation Policy
7. Central Public Health & Environmental Engineering Organization (CPHEEO) guidelines
8. Jal Jeevan Mission
9. Construction and Demolition Waste Management Guidelines
10. Extended Producer Responsibility (2021)
11. Plastic Waste Management (Amendment) Rules (2021)
12. Solid Waste Management Rules (2016)

2.3.2 Elements of a Long-Term Low-Carbon Development Strategy

This section presents three elements that provide broad directional shifts to promote adaptation in building design, energy and material efficient buildings and low-carbon urbanisation. These elements, namely city planning, buildings, and municipal services, are identified as focal areas to ensure that urban design in rapidly growing cities in India is climate resilient and can also contribute to India's overall efforts in sustainability.

2.3.2.1. Mainstreaming adaptation measures in urban planning and measures for enhancing energy and resource efficiency within urban planning guidelines, policies and bylaws

Cities are complex systems of natural and built environments. With over 4,000 urban centres and some of the fastest-growing cities, Indian cities face urban planning challenges, with climate impacts posing an additional risk to critical infrastructure. It is therefore important for cities to adopt a climate-sensitive approach to urban planning.

This can include increasing the amount of green space per capita. Conserving, rejuvenating, and increasing blue and green cover in a city can play a critical role in decreasing local temperatures, increasing carbon sequestration, building flood protection, and recharging groundwater.

Subcomponents of this element may include the preparation and revision of regional development master, and zonal level plans and guidelines, as well as introducing regulations and bylaws that are flexible, adaptive, and climate responsive.

2.3.2.2 Promoting climate-responsive and resilient building design, construction, and operation in existing and future buildings

Buildings construction and operations account for 36% of global energy use and 39% of energy-related emissions annually (UNEP-IEA, 2017). In India, the building stock accounts for more than 40% of the country's total energy consumption, and energy use from buildings is increasing by 8% annually (Khosla & Janda, 2019; Ahuja & Soi, 2020). With the urban population projected to increase to 60% by 2050, India's residential electricity demand will likely triple (IEA, 2021). Further, urban India is expected to build 700 to 900 million square meters of residential and commercial spaces (McKinsey Global Institute, 2010).

Buildings rated by voluntary green building rating programmes constitute approximately 5% of the Indian building market share. However, national power demand can be reduced significantly by 2030, by improving the energy efficiency of buildings design, construction, and operations. Subcomponents of this element may include improved building envelope design, choice of sustainable construction materials, methods of construction and other allied strategies such as adaptive reuse of buildings, energy-efficient building systems, usage of renewable energy, and green carbon sinks.

Box 2.2: Energy Conservation Building Code (ECBC)

The ECBC covers all important aspects of energy use in buildings, including the building envelope, comfort systems and controls (heating, ventilation, air conditioning, hot water systems), lighting and controls, and electrical and renewable energy systems. It prescribes standards in accordance with the five major climatic zones of India. The minimum level of energy efficiency that an ECBC compliant building achieves is 20% compared to a standard baseline, by adhering to the mandatory and prescriptive requirements. Buildings achieving energy efficiency of 30-35% are labeled as ECBC Plus and those achieving 40-45% energy efficiency are labeled as Super ECBC Buildings (BEE, 2017). The code is implemented by State Governments, which can make necessary modifications to suit local requirements. Countrywide implementation of ECBC is expected to achieve a 50% reduction in commercial building energy use by 2030, translating into energy savings of 300 billion units and peak demand reduction of over 15 GW in a year, and 250 million tonnes of CO_2 reduction (PIB, 2017).

2.3.2.3 Promoting low-carbon municipal service delivery through resource efficiency and management of water, solid waste, and liquid waste

Stresses on natural resources, unauthorised land use, untreated waste disposal, and problems of access to basic services, are intensifying with the growing urban population. Further, with extreme weather, most cities face the twin challenges of meeting increased demand for potable water, and management of excess water during extreme precipitation events.

A significant increase in Municipal Solid Waste (MSW) generation has been recorded globally, with average waste generated per capita per day at around 0.74 kilogram. Global MSW generation is expected to grow to 3.40 billion tonnes by 2050 from the current 2.01 billion tonnes annually (Kaza et. al., 2018). Waste accumulation and improper disposal severely affect the environment causing air, water, and soil

pollution, which affects public health and causes ecological damage. In India, 147,613 metric tonnes (MT) of solid waste are being generated per day as of January 2020. Smaller towns and cities face challenges in managing waste effectively (Singh, 2020).

With city governance determined by Urban Local Bodies (ULBs), rapid urbanisation will require interventions from ULBs to be able to manage resources and deliver municipal services efficiently. These can include mainstreaming efficiency within municipal service delivery through resilient water management, improved water use efficiency, demand management policies and conservation of water sources, circularity in waste management, and recycling and reuse of wastewater.

Box 2.3 – Climate Smart Cities Assessment Framework

To enable a holistic assessment and benchmarking of urban development from a climate lens towards a roadmap for embedding climate change within urban planning, the Ministry of Housing and Urban Affairs has developed a Climate Smart Cities Assessment Framework (CSCAF). The framework aligns with the National Mission on Sustainable Habitat and is intended as a tool for cities to inform investments, showcase evidence of climate actions, and monitor impact. It covers five thematic areas: urban planning, green cover & biodiversity; energy & green buildings; mobility & air quality; water management; and waste management. As of July 2022, 126 cities are using CSCAF to report on their climate actions; this number is expected to grow in the next phase of CSCAF.

2.3.3 Potential Benefits and Challenges

Embarking on a sustainable urbanisation strategy would lead to potential benefits and challenges, with an impact on other developmental indicators.

1. Integrating climate measures into urban planning instruments can potentially contribute to tackling

other local environmental and developmental problems in cities and providing benefits such as reduced air pollution, and improved public health. Additional gains may include energy savings. However, climate-responsive urban planning and building practices (e.g., passive design or efficiency standards) require large investments in innovation and low-carbon technologies. For a developing country with multiple claims on its public finances, mobilising these financial resources can be a significant challenge. The primary focus, therefore, will be in creating climate resilient infrastructure that will ensure the best possible protection from climate impacts in the future.

2. Energy-efficient buildings reduce negative impacts on the environment by utilizing less water, energy, and natural resources.
3. Improving the efficiency of municipal services, which include water supply, waste management and sewage treatment, reduces energy usage associated with processing and delivery. This also, in turn, helps in improved public health and quality of life. Improving the efficiency of municipal services involves an increase in expenditure for service delivery, which can eventually lead to higher tax rates. In early stages of urban development, with a large section of informal workers in the urban economy, this can be challenging for Governments to implement.
4. Implementation of early warning systems and frameworks for addressing impacts from extreme events within urban design and municipal service provision can have many benefits in protecting lives and economic activity in the future and will be a priority for the Government.
5. The use of new and emergent technologies and materials in building construction, ICT and SCADA tools for streamlining efficient municipal service delivery can have the advantage of reducing the costs of these technologies for use in other sectors of the economy.
6. Efficient waste management can potentially provide employment opportunities in areas deploying innovative technologies instead of the current predominance of informal work in the waste sector. The Government will focus on supporting innovative start-ups and models that can address the issue of waste and recycling in cities that have multiple benefits of employment generation, energy production, and waste reduction.
7. Many of the initiatives of efficient and resilient urban design will require a significant enhancement of technical and financial resources at the municipal level. In growing urban agglomerations, peripheries of which are largely dominated by informal settlements and economic activity, enabling processes for climate resilient urban design will be challenging. The Government will focus on building capacities of municipal departments and other regional administrative bodies.
8. Increasing number of private sector start-ups working in the waste sector, including e-waste.

2.4 Promoting economy-wide decoupling of growth from emissions and development of an efficient, innovative, low-carbon industrial system

The industrial sector contributed about 25.9% to India's GVA in 2020-21. Manufacturing alone, contributed 14.4% to GVA this year, with construction and energy and other supply utilities adding another 9.9% (DEA, 2022). The Government of India is focused on expanding the contribution of manufacturing to GDP as this is necessary in a developing country to generate employment, enhance incomes, and create infrastructure and conditions for improved well-being of the population. Continued economic growth and aspirations to boost domestic manufacturing, through initiatives like Make-In-India, are expected to lead to enhanced energy consumption, and significant additional demand for steel and cement in the medium-

and long-term. This has implications for emissions from this sector. Low carbon options for the industrial sector in India must however be viewed within the overall context of the need for significant expansion of industrial production, the fact that India's contribution to historical emissions is negligible, and that India remains well below its fair share of the carbon budget. The Industrial Processes and Product Use (IPPU) sector contributes approximately 8% of GHG emissions (MoEFCC, 2021) currently. An analysis of industrial emissions by NITI Aayog suggests an expectation of increase in energy consumption in the sector and consequently of emissions until 2070.

A shift away from fossil fuels in this sector could have a negative impact on India's sustained growth and rise in GDP and a negative impact on employment due to contraction in sectors such as mining, petroleum refining, and manufacturing. These may subsequently also lead to impacts in other sectors of the economy. India also faces the challenge of achieving higher energy access and energy security for its population.

Despite these challenges, India has taken significant strides in ensuring improved energy efficiency in the industrial sector, creating the potential conditions for sustainable growth in this sector in the medium and long term.

2.4.1 Current Policies and Programmes

Energy and material efficiency, process and fuel substitutions, circular economy approaches, electrification and the adoption of low-carbon fuels are important elements of establishing a productive and low-emissions industrial system. Current policies and programmes under these elements are outlined below. These include many listed in other sections of this chapter, but are included here as part of the overall contribution to energy efficiency and the economy-wide decoupling of growth from emissions.

Energy efficiency

1. National Mission on Enhanced Energy Efficiency
   - Perform, Achieve Trade (PAT) Scheme: This energy efficiency scheme for notified industries and industrial units is envisaged to widen its coverage to other energy intensive industries such as ports, chemicals, ceramics, sugar, and mines.
2. Energy Efficiency Financing Platform for capacity-building on energy efficiency.
3. Standards & Labelling Scheme for Industrial appliances and equipment.
4. Industrial processes and fuel switching.
5. Raise in the share of natural gas in energy mix.
6. Target of 20% blending of ethanol in petrol by 2025-26 under the National Biofuels Policy Adoption of Sustainable Mobility Technologies.
7. National Electric Mobility Mission Plan, the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) Scheme, the National Mission on Transformative Mobility and Battery Storage, and production-linked incentives for domestic manufacturing.
8. PLI ACC Battery Storage Scheme, the Battery Swapping Policy and new interoperability standards.
9. India aspires to significant EV adoption over the next few decades.

Material efficiency and recycling

1. Waste management policies for e-waste and single-use plastic
2. Circular economy approaches for 11 economic focus areas

Green hydrogen technology and infrastructure

1. National Hydrogen Mission
2. R&D on hydrogen production, storage and application is being supported by concerned Government departments and research institutions (NITI Aayog, 2022).

Low carbon technologies for hard-to-abate sectors

1. Planned mission on green steel to lay out a green expansion plan for steel
2. Ministry of Steel projects with global partners for technology, capital, and R&D

Micro, Small and Medium Enterprises (MSMEs)

1. Energy conservation and efficiency guidelines for MSME sectors
2. National Programme on Energy Efficiency and Technology Upgradation to address challenges of MSMEs
3. Promoting further investment in energy-efficient and renewable energy use by MSMEs

2.4.2 Elements of Long-Term Low-Carbon Development Strategy

Industrial activities and infrastructure feature a wide range of processes, materials, and technology. This section presents six elements of a long-term low-carbon development strategy towards a productive industrial system in India that can contribute to meeting its development goal and contribute to the global effort for climate change mitigation.

2.4.2.1 Improving Energy Efficiency

Energy efficiency remains a cornerstone of India's overall strategy for low carbon development. India will build on existing policies such as the PAT scheme and will continue R&D on energy efficient technologies, particularly for MSMEs in the short to medium term. It is proposed to widen the PAT scheme to cover significant part of industrial energy consumption by 2030 to eventually reach its maximal potential subsequently. It is also aimed to achieve 100% market penetration of energy efficient appliances mandated under the Standards and Labelling programme. Other components of this element include pursuing electrification, encouraging the use of electricity generated from non-fossil fuel sources, digitisation of processes, creation of a carbon pricing programme to incentivise energy efficiency, and alliances and collaborations across sub-sectors to facilitate circular economy and sector coupling approaches (BEE, 2022).

Box 2.4: Perform Achieve Trade (PAT) Scheme for Industries

The PAT scheme is the flagship programme of the National Mission for Enhanced Energy Efficiency. This scheme identifies designated consumers across select energy-intensive industries who have to meet mandated energy efficiency targets in a given time period. The cement industry has been part of PAT cycles since their inception in 2012, and in every cycle the industry has been able to overachieve its reduction targets. In PAT cycle I, it was able to overachieve the target by 82% and in PAT cycles II and III, it was able to overachieve by 49% and 75% respectively. In the iron and steel sector, a total of 5.013 Mtoe of energy savings were achieved between 2012 and 2020 under the PAT scheme, amounting to total GHG emission reductions of 18.64 million tonne CO_2eq. Similarly, 12 designated consumers from the aluminum industry have successfully achieved an emissions reduction of 5.24 $MtCO_2$ between 2016 and 2019. The fertilizer industry, which plays a key role in ensuring India's food security, is also included under the PAT scheme, with 36 designated consumers. It has achieved energy savings of 0.447 Mtoe between 2016 and 2019 and an emissions reduction of 0.71 $MtCO_2$ in this period. Refining Sector has been included in PAT scheme from cycle-2, commencing 1.4.2016. Against the energy reduction target for refining sector in PAT cycle-2 of 5.49% equivalent to 1.01 Million TOE, the actual energy reduction of 8.05%, equivalent to 1.48 Million TOE was achieved and for current PAT cycle (2018-19 to 2022-23), the target of 5.49% has been retained which is equal to energy saving target of 1.17 Million TOE. The PAT scheme has been similarly successful in reducing energy consumption and avoiding CO_2 emissions across other sectors, including petrochemicals, textiles, paper and pulp, power, among others.

2.4.2.2 Process and fuel switching, and electrification

Given rising energy consumption in industry, natural gas is envisaged to have a prominent role in the energy mix in the near to medium term, and establishing a reliable, effective natural gas network offering access to major industrial zones will be an important aspect of India's strategy for the industrial sector.

The electrification of industrial operations through power generated by renewables will also be prioritised in this element, with attention to the rationalisation of electricity tariffs for industries. Biomass-based energy, including biofuels, could also play a role in avoiding higher coal use in low-heat thermal applications. Finally, hydrogen as a fuel source will be developed to play a key role in driving industrial production in the long term.

2.4.2.3 Enhance material efficiency and recycling

The Steel Scrap Recycling Policy will be a good reference point to address sector-specific issues (MoS, 2019). With the expected expansion of the natural gas network and establishment of a hydrogen network, India will encourage the adoption of circular economy principles and material efficiency in the planning stage of infrastructure development.

2.4.2.4 Promoting green hydrogen technology and infrastructure

Through the National Hydrogen Mission, India envisages being a global leader in the hydrogen market. Pursuing R&D, infrastructure and technology development will be critical in success of this goal. Reducing electrolyser costs and exploring pathways to ensure round the clock RE supply would be crucial for making green hydrogen commercially viable. Demand creation, interventions to strengthen supply side for hydrogen production, setting up of domestic manufacturing of critical equipment, incentives to accelerate

initial deployment for domestic and export markets, enabling ecosystem of policies, regulations and standard, development of green hydrogen hubs and infrastructure, and encouragement to innovation through R&D and pilot projects will be elements of the strategy for the promotion of green hydrogen in India. By 2030, India aspires to achieve 5 million tonne of annual production of green hydrogen, increase the electrolyser manufacturing capacity several-fold and put in place mechanisms to enable India to become one of the world's major exporters of green hydrogen.

2.4.2.5 Exploring options for low-carbon growth of hard-to-abate (steel and cement) sectors

For the steel sector adoption of best available technology to increase energy efficiency and increase utilization of scrap are important strategies for reducing emissions. Hydrogen has a key role to play in the long term, but capex requirements are high and would need to reduce substantially to enable increased scale of hydrogen use for steel production. Electrification of the secondary steel industry (SSI) sector through renewable energy could have significant impact on overall emissions from the steel sector and the potential for this will be explored. Green procurement policies could help to establish a pull for green steel thus enhancing efforts for achieving sustainability in this sector. The cement sector in India is already a global leader in terms of sustainable practices and has one of the lowest values of emissions intensity in the world. In India, increasing Alternate Fuels and Raw Materials (AFR) and Refuse-derived fuel (RDF) use would be an important element of continued sustainable development in this sector.

2.4.2.6 Sustainable Development of Micro Small and Medium Enterprises (MSMEs)

MSMEs are essential to the Indian economy. MSMEs constitute about 6.1% of the manufacturing GDP and 24.63% of the GDP from service activities (CII, n.d.). About 45% of the overall exports from India are from the MSME sector which provide employment to around 120 million persons. About 20% of the MSMEs are based out of rural areas, which indicates the deployment of significant rural workforce in the MSME sector. These enterprises promote sustainable and inclusive development as well as generate large scale employment, especially in the rural areas. Sustainable development in this sector is important but also challenging due to smaller scales of production and limited financial flexibility available to the units to invest in energy efficiency and low carbon measures.

A key near term strategy for the MSME sector would be to provide support for knowledge sharing activities and building capacities and awareness of the MSMEs about low carbon technologies. Implementing technology upgradation programmes, providing incentives for RE adoption where possible and relevant, improving electricity connectivity and reliability of supply are key steps that India will take to ensure overall development and sustainability of the MSME sector.

2.4.3 Potential Benefits and Challenges

Enabling the development of an efficient, innovative, and environmentally sustainable industrial system will lead to potential benefits, but will also carry many challenges.

1. Lower industrial reliance on fossil fuels could reduce the costs of purchasing coal and gas in spot markets.
2. Additionally, promoting green hydrogen, and industrial fuel switching and electrification could help create demand for clean electricity powered by renewable energy, indirectly reducing the challenge of renewable energy penetration in the electricity sector. However, the costs of enabling these measures in industry will be substantial.

3. An increase in demand for electric vehicles could drive growth in associated sectors such as semiconductors, information technology (IT), IT-enabled services, or Internet of Things. However, there will be a simultaneous negative impact on the supply chains and related infrastructure of ICE vehicles impacting labour absorption as well as revenues from this sector.
4. The growing dependence of industries on captive renewable energy-based energy technologies would only yield employment benefits if manufacturing of related equipment is domestic. In the absence of the same, higher dependence on renewable energy can lead to higher import dependence which consequently can threaten energy security.
5. A reduction in the use of raw materials and natural resources, and new business models and opportunities to reuse industry wastes as inputs in other sector processes can be a potential benefit. However, actualising this benefit would require improved freight transportation systems to connect regions and industries spread across different geographies in the country to ensure the circular flow of materials.
6. New business opportunities for MSMEs are possible as new sectors and technologies are developed. Skill development of the workforce on new energy efficiency, sustainable mobility, and green hydrogen technologies will be needed.
7. The costs of waste management related to RE development and EV production will be a major factor that must be considered as low-carbon growth plans are developed. The costs can be prohibitive in the near term.
8. The costs of R&D and implementation in improving energy efficiency, sustainable mobility, and green hydrogen technologies will be high. While there are benefits for the world in terms of climate change mitigation if India undertakes these activities, the realisation of the full potential of these policies will be contingent on the availability of, and access to, low-cost finance.
9. With an increased load on the electricity grid, the financial health of DISCOMs may be affected as industrial energy requirements change and reduce. DISCOMs play a crucial role in ensuring access to electricity for multiple purposes. Industrial sales are crucial for the DISCOMs to continue playing this role. Moves to promote grid-independence of industries must take into account this potential trade-off.
10. The near to medium term reliance on the use of natural gas in industries would require significant investments in expanding the natural gas network.
11. Onboarding and integrating MSMEs in a formal financing framework and assessing their credit worthiness may be a challenge. The availability of commercially viable technologies for MSMEs is a critical issue.

2.5 CO_2 Removal and Related Engineering Solutions

The urgency to mitigate climate change and the perception that the adoption of CCUS is inevitable in the long term for certain sectors are driving nations toward the adoption of CCUS technologies, with announcements and investments from several countries, especially developed ones. If successful, and if economic, technological, and political barriers are overcome, the global CCUS industry could possibly become a source of growth in the new low emissions economy. However, few countries have mentioned CCUS in their NDC thus far.

In the long-term pilot projects may be taken up for coal-based methane, carbon capture, utilisation and storage (CCUS), and promotion of technology development for coal-to-gas and coal-to-liquid, with international finance, technology transfer and collaboration. A detailed analysis of costs and probable expenditures for scaling up CCUS will need to be conducted.

The economic and political feasibility of CCUS is highly uncertain. The emphasis in this field is on R&D and building human and infrastructure capacity to evolve technologies and methodologies that address issues related to high capital costs, safety, logistics and high auxiliary power consumption. The CCUS technology at present is not matured and India can take up only demonstration projects at this stage to assess the viability of the proposed solutions. Retrofitting of existing thermal power generating units for CCUS implementation is not a viable option, until the technology is cost effective and less energy intensive. India requires considerable climate finance and technology transfer with effective international collaboration to enter this arena.

2.6 Enhancing Forest and Vegetation Cover

In India, about 24.62% of the total geographical area is under Forest and Tree Cover (i.e., 80.95 million hectares). India has the tenth largest forest area in the world, constituting approximately 2% of the world's forest cover (FSI, 2021). Forest canopy density is classified into four major types: Very Dense Forests (9.978 million hectares), Moderately Dense Forests (30.689 million hectares), Open Forests (30.712 million hectares), Scrub Forests (4.654 million hectares) for a total forest area of 71.378 million hectares, with the remaining area under Tree Cover (FSI, 2021)[2]. Since 1987, Scrub Forests (<10% canopy cover) have declined at an average rate of 0.1721 million hectares every two years, while Open Forests (10-40% cover) increased at an average rate of 0.3495 million hectares every two years since 1987 and Dense Forests (>40% cover), including both moderate and very dense forests, increased at an average rate of 0.2155 million hectares every two years since 1987. Figure 2.3 is a map of the forest cover in India. India's forests and other natural habitats such as grasslands, wetlands and mangroves harbour a rich and fairly intact diversity of plant and animal species, as well as provide the biomass needs of a majority of its human population.

Occupying nearly 10% of the geographical area of the country, Trees Outside Forests (TOF) are also significant natural, renewable resource that make a vital contribution to the agroecology and socio-economic circumstances of rural areas, and environmental amelioration in the urban areas. They also feed wood-based industries with raw materials and thus generate significant employment. In India, mangroves are found in 12 States and Union Territories, covering approximately 4,992 sq. km (FSI, 2021). Mangroves play a crucial role in carbon sequestration, coastal biodiversity, and adaptation to natural hazards such as storm surges.

The country has seen significant growth in the network of protected conservation areas (protected areas, conservation reserves, community reserves, reserve forests and biosphere reserves etc). With well over 20% of its geographical area under biodiversity conservation, India has exceeded the terrestrial component of 17% of Aichi target 11 and 20% of corresponding National Biodiversity Targets relating to areas under biodiversity management (NBA, 2018).

2. VDF – canopy >70%; MDF – Canopy >40 % and <70%; OF- >10% and <40%; and Scrub - <10%

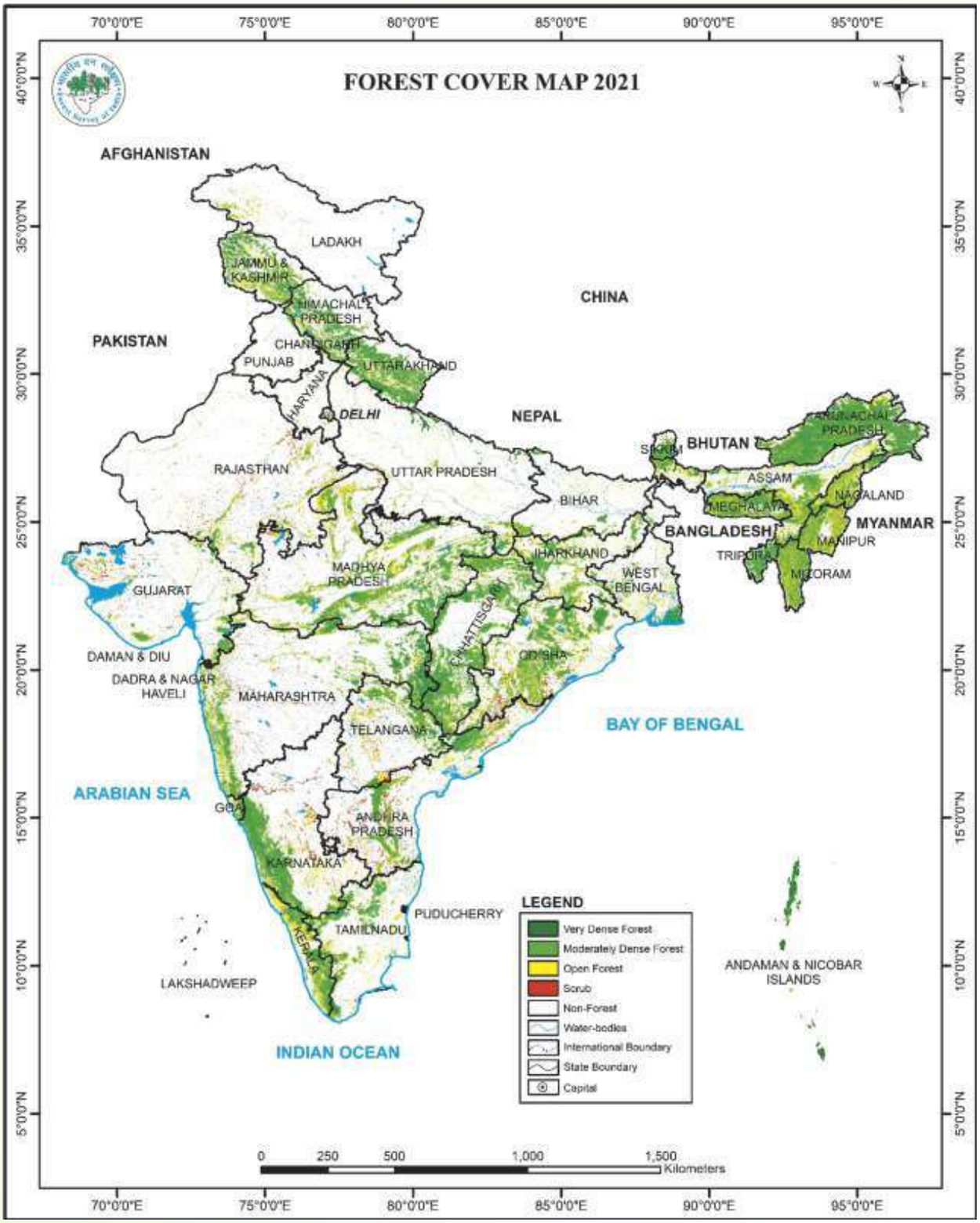


Figure 2.3 Forest Cover Map in India, 2021 *(FSI, 2021)*

India has among the lowest rates of gross deforestation, in absolute terms, in per capita terms, and in annual rates (MoEFCC, 2021). Annual rates of deforestation have also been consistently coming down in the country in recent decades (Reddy et. al., 2018). The carbon stock in forests has been estimated to be 7,204 million tonnes (FSI, 2021). The annual increase of carbon stock during 2019-21 is estimated to be 39.7 million tonnes or 145.6 million tonnes of CO_2 equivalent. This translates into carbon sequestration of 0.44 tonnes carbon per hectare per year which is comparable to or higher than reported for tropical forests globally in recent times (FSI, 2021).

In contrast to the huge emissions from the forest fires in regions such as Western USA and Canada, the Siberian Arctic, the Amazonian basin, Indonesian rainforests, and south-eastern Australia, the emissions from forest fires in India contribute a mere 1-1.5% of all global emissions from wildfires (MoEFCC, 2021). India's forests are teeming with wildlife. They support ~70% of the global tiger population, >60% of Asian elephants, ~80% of the one- horned rhinoceros, 100% of the Asiatic lion population and thousands of endemic species, making India one of the 17 mega biodiverse countries in the world.

While forests formally contribute only 1.7% to India's GDP, yet they employ 6.23 million people, the highest in Asia (FAO, 2020). The intangible benefits provided by forests are often unaccounted. The demands of a growing human population for food, medicine, fibre, fodder, shelter, and fuel, along with the need for economic development, are increasing the pressure on biodiversity and ecosystems throughout the country.

The impacts of climate change on the forestry sector can be attributed to a series of cumulative factors such as loss of habitat due to global temperature increase and changing rainfall patterns which may lead to prolonged droughts. Such conditions enable only drought resistant trees to survive while eliminating tree species with lower resilience which may have been endemic to the region. Hence forest cover, density and biodiversity are affected, which in turn also affects the ecosystem services accessed by the local people and the industries based on forest products. At the national level, 23%, 37%, 24% and 16% of forest grid points show low, medium, high, and very high inherent vulnerability to climate respectively as seen in Figure 2.4 (MoEFCC, 2021).

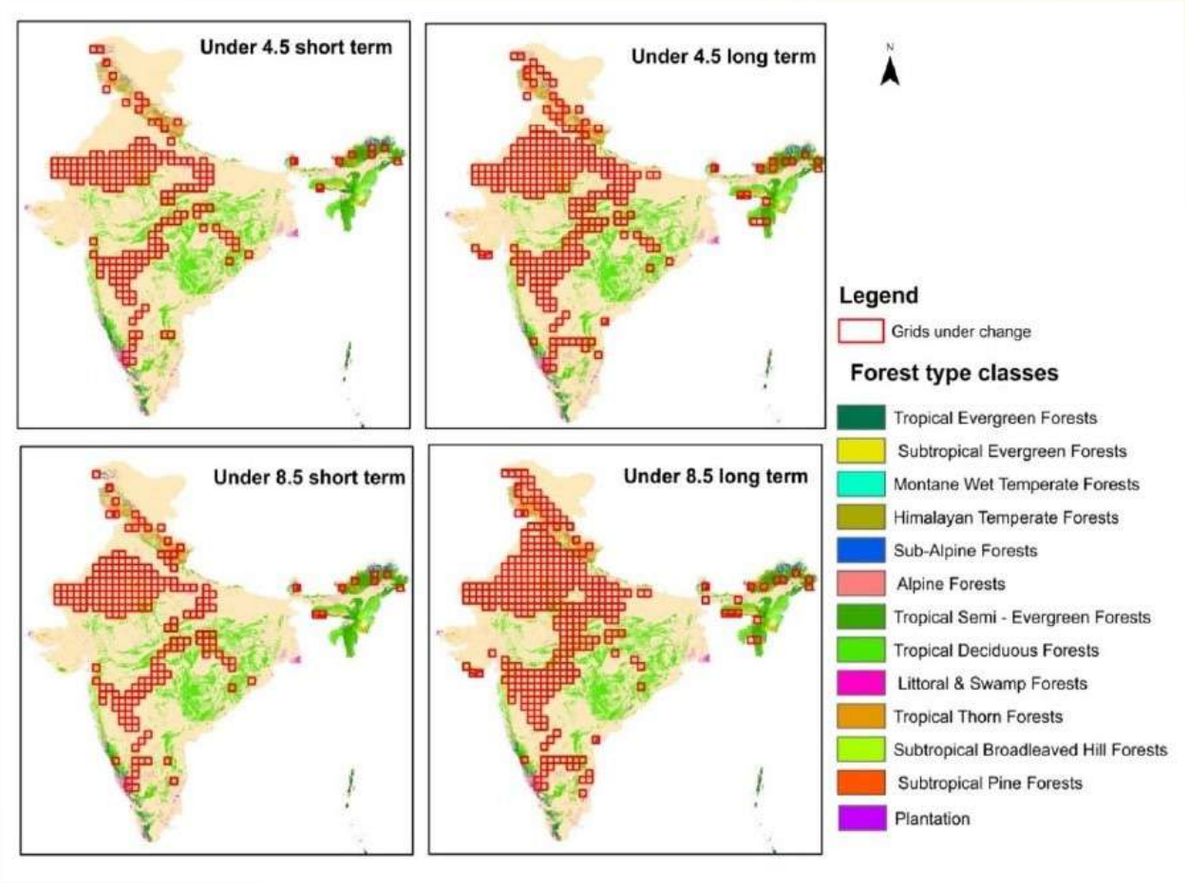


Figure 2.4 Projected impacts of climate change on different forest types and regions of India. Grids in red indicate change in vegetation type in the near term (2030s) and the long term (2080s).

Source: *(Ravindranath & Bala, 2019).*

Forest governance is underpinned by a robust legal framework including the Indian Forest Act, 1927, the Forest (Conservation) Act, 1980, the Forest Rights Act, 2006, the Biological Diversity Act, 2002, Wildlife Protection Act 1972, Panchayats (Extension to Scheduled Areas) Act, 1996 and other Central/State laws as applicable.

2.6.1 Current Policies and Programmes

1. Major policies and programmes: India is undertaking several significant actions in the forest sector, in the light of its firm commitment to preserving its natural resources, heritage and biodiversity.

    a. The National Forest Policy (1988): The policy aims at bringing 33% of the country's geographical area under forest and tree cover. To achieve this goal, India has been actively pursuing a number of strategies and programmes from the National to local levels.

    b. National Afforestation Programme (NAP): The objective of the programme is to "develop the forest resources with people's participation, with focus on improvement in livelihoods of the forest-fringe communities, especially the poor". NAP is being implemented for afforestation of degraded forest lands. NAP has streamlined flow of funds from Centre to States, Districts and Villages.

    c. National Mission for a Green India (GIM): It is one of the National Missions under the NAPCC that was implemented to protect, restore and enhance the decreasing forest cover of India. The

mission goals include: improve forest/tree cover by 5 million ha; improve quality of forest/tree cover by another 5 million ha; enhance ecosystem services including carbon sequestration and other services such as hydrological, provisioning and biodiversity; increase livelihood of 3 million households based on forests.

d. Tree cover in urban and peri-urban areas: NAP has been merged with GIM under which there is a specific sub-mission for enhancing tree cover in urban and peri-urban areas. An area over 2 million ha was sanctioned for taking up afforestation in the States/Union Territories (UTs) with an investment of about INR 39,364.1 million till 2020-21 under NAP since its launching year 2000. Under GIM, an amount of about INR 4,550 million has been released to States/UTs from 2015-16 to 2020-21.

e. National REDD+ Strategy 2018: REDD+ aims to achieve climate change mitigation by incentivizing forest conservation. The strategy seeks to address drivers of deforestation and forest degradation and develop a roadmap for enhancement of forest carbon stocks and achieving sustainable management of forests through REDD+ actions.

f. Compensatory Afforestation Fund Management and Planning Authority (CAMPA): This is one of the programmes to ensure that social dimensions of forestry are prioritized. Funds under CAMPA are collected from public and private sector infrastructure developers as compensation for the forest land converted into non-forest land by infrastructure projects. The fund is used to promote afforestation, forest regeneration and ensure maintenance of ecosystem services (MoEFCC, 2022).

g. Forest Fire Prevention and Management Scheme (FFPMS): Ministry of Environment, Forest and Climate Change provides financial support to the States/Union Territories under FFPMS for protection against forest fire.

h. Nagar Van Yojana (NVY): This urban forest scheme intended to create 400 'Nagar Vans' and 200 Nagar Vatikas in the vicinity of urban areas under the National Fund of CAMPA.

i. School Nursery Yojana (SNY): The scheme aims at creating awareness and inculcating a habit of caring for nature, and is to be implemented for a period of five years from 2020-21 to 2024-25.

j. Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS): MGNREGS is a livelihood and employment scheme that guarantees minimum wage and days of employment for needy households. A guideline for convergence of MGNREGS with GIM has been released by the central Government in 2015. This shall lead to guaranteed availability of manpower for forestry related activities.

k. Aajeevika - National Rural Livelihoods Mission (NRLM): One of the strategies under NRLM is to conserve Non-Timber Forest Products (NTFP) species, promote sustainable harvesting practices of NTFP and promote development of NTFP market value chains.

l. Atal Mission for Rejuvenation and Urban Transformation (AMRUT): Creating and upgrading green spaces, parks and recreation centres in Mission cities.

m. Tree plantation, being a multi-departmental, multi-agency activity, is also being taken up cross-sectoral under various programmes/funding sources of other Ministries and also through State Plan budgets. Some such programmes relevant to the long-term transition of forests include the Finance Commission outlays, National Agroforestry Policy and Integrated Watershed Management Programme (IWMP). Further, policies and programmes in the areas of invasive

species management, river rejuvenation, water conservation and environment friendly lifestyles also contribute to increasing the quality and quantity of green cover.

2. NDC and other contributions

   a. Forests also form a key element in India's NDC. India has proposed creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030 (UNFCCC, 2022). India is also the signatory of various international conventions and intergovernmental fora that guide its forestry sector approach. India targets to restore 26 million ha of deforested and degraded land by 2030 under the Bonn Challenge (IUCN, n.d.). India has also prepared a National Biodiversity Action Plan (NBAP) in 2008, and an Addendum to NBAP was prepared in 2014 with 12 National Biodiversity Targets, developed in line with the 20 global Aichi biodiversity targets.

2.6.2 Elements of a Long-Term Low-Carbon Development Strategy

To achieve the goal of promoting the quality and coverage of forests consistent with their social use and ecological attributes, the following long-term directions are being considered. The "Core Principles" for implementation are discussed in Box 2.5 below.

Box 2.5: Core Principles for implementation

Enhanced implementation of landscape-based approach and improvement of the forest/ecosystem goods and services (carbon stocks, water, and meeting biodiversity conservation and livelihood security needs) with local communities, as mandated in the National Forest Policy (NFP) of 1988. Public forest lands that serve as the life sustaining resource base for the rural communities shall remain in the public domain so that the benefits accrue to all sections of society.

- Empowerment of communities (youth and women) and strengthening of social use through decentralized local governance of forests.
- Integrating traditional ecological knowledge of communities with forestry science and state-of-the-art technology.
- Restoration of native biodiverse species mix at the landscape level.
- Massive afforestation/reforestation at all spatial scales of urban and rural areas, public and institutional lands, river catchments, watershed areas promoting the water-food-energy-forest nexus.
- Promotion of innovative technologies, finance instruments and private sector engagement with focus on youth entrepreneurship.

2.6.2.1 Restoration, Conservation and Management of Forest Cover (including mangrove forests)

The preservation and sustainable management of forests have the potential to offer advantages for both adaptation and mitigation (by lowering emissions from deterioration). Potential strategies and lines of action include:

1. Improving/enhancing density and quality of forests
2. Improved protection and restoration of forest and green cover in critical and biodiversity hotspots (including, but not limited to, Himalayan Ecosystems, North-Eastern Region, Western Ghats)

3. Improved health of forest and forest hygiene
4. Improved climate smart monitoring and forest protection against forest fires

2.6.2.2 Restoration, Conservation and Management of Trees Outside Forests (TOF), Green Cover

Trees Outside Forests (TOF) are essential to rural India's social and economic well-being and provide important ecosystem services both in urban and rural areas. As the primary substitute for timber from forests, TOF-derived wood and panel products have greatly reduced strain on forests. They also act as an important source for timber and fuelwood, contribute in carbon sequestration and conservation of biodiversity, provide habitat for wildlife, and help in micro-climate stabilization. Potential strategies and lines of action include:

1. Restoration and increasing area under trees outside forests and green cover.
2. Large scale enhancement of tree/green cover in urban and peri-urban areas.
3. Rural greening with a focus on One Forest–One Village and promoting agroforestry as a major programme for increasing farming income and meeting demand of wood products.

2.6.3 Potentials and Challenges

Apart from direct benefits such as carbon sequestration, various co-benefits are associated with conservation, protection, restoration and management of forest and tree cover in India. Elements and underlying lines of action may yield specific benefits, although significant challenges exist that will shape the relevant actions and their outcome. Some common features include:

1. Conservation of biodiversity, provision of ecosystem services and associated benefits.
2. Enhanced adaptation capacity, coastal protection and microclimatic regulation.
3. Reduced soil erosion and land degradation, as well as enhanced water retention.
4. Potential for enhanced employment, incomes, and livelihoods.
5. Assisting in improving air quality and reducing pollution, with positive impacts on population health.
6. Better regulation of the hydrological cycle.
7. Land use competition may arise with farming (food security), urbanization, infrastructure, and other land-based mitigation measures.
8. Restriction in the rights and access of local people to forest resources, threatening livelihoods/ subsistence agriculture and local land access.
9. High initial costs especially in case of wetland restoration.

2.7 Economic and Financial Aspects of Low-Carbon Development and Long-Term Transition to Net-Zero by 2070

A transition to a low-carbon development pathway will entail costs pertaining to the deployment of new technologies, development of new infrastructure, and other transaction costs. In the longer term, such a systemic transition will also have broader economic impacts, necessitating consideration of the economic and financial aspects of low-carbon development pathways.

This section discusses recent assessments of financial needs to enable this transition, the potential sources for meeting these needs, how climate change is being mainstreamed through the financial sector more broadly, and how finance flows can interact with international trade considerations. It is noted that these projections have a clearly tentative character, and are likely to be modified or changed over time. They are also likely to be under estimates in several instances as the slow pace of the transition at the global scale suggests. A look backward in history to the transitions that have occurred over periods of a half century or three-quarters of a century, also suggest that these estimates are to be treated with caution and may be far more optimistic than warranted, though this cannot be determined at this stage.

2.7.1 Assessments of Financial Requirements

An important factor in determining transition pathways and their pace of implementation is the level of financial resources available. Various studies focus specifically on estimating India's financial needs; with investment requirements provided at different levels of detail. Estimates vary across studies due to differences in approaches as well as assumptions of growth, technology options, and systemic transitions across different sectors, as well as differential coverage of subsectors and technologies. One of the key requirements for a developing country like India is to assess the additionality in terms of financial resources over BAU (Business as Usual) trajectories of development. This additionality, in relative terms, may be more pertinent, as the overall scale of development may, as one would hope, outperform the BAU considered as the baseline. While such additionality may not be commensurate with disruptive transformations that may arise, there is currently no way of predicting such transformations or projecting their impact on the financial resource dimension.

2.7.1.1 Low-Carbon Development Needs

Vishwanathan and Garg (2020) estimate cumulative investments of up to 6–8 trillion USD (approximately) will be required during 2015–2030 to implement the actions required to transform the current energy systems in India. This contrasts with the USD 10 trillion estimated by CEEW (Singh & Sidhu, 2021) for a 2070 net-zero scenario, of which the investment deficit could be as much as USD 3.5 trillion and the cumulative USD 12.4 trillion for transition to net-zero estimated by Standard Chartered (2022).

Patterns of investment needs are driven by a few key trends. Investments in energy may vary depending on the extent and pace of RE expansion (IEA, 2021). The largest investments in industry are required in iron and steel, mainly due to a transition to green steel. The construction sector also has large investment requirements, since its unorganized nature leads to difficulties in implementing green measures at scale. Hydrogen investments are expected to pick up after 2030, once technology costs come down. Investment needs in transport are driven by public transport infrastructure and electrification. A third of the total investments in the building sector may be used for investments in smart grids, including building automation, microgrids, smart meters, and connected infrastructures, while space cooling may take another 30%. City gas transitions will also require significant investments.

Overall, although the estimates vary widely and are not directly comparable, these are in all cases substantial and of the order of tens of trillions of dollars by 2050.

2.7.1.2 Adaptation and Resilience

Adaptation finance is a critical component of climate finance and a significant priority, to respond to climate change without adversely affecting India's development objectives. Although adaptation is

discussed in more detail in Chapter 4, estimates of adaptation finance for all developing countries reach up to USD 300 billion by 2030, and USD 500 billion by 2050 (UNEP-DTU, 2018; UNEP, 2021) and may reach higher in view of the uncertainties in estimating the pervasive demands of adaptation.

2.7.2 Sources of Finance

Meeting the large investment needs for a low-carbon development transition, while balancing other national development needs, is a challenge. This needs mobilising international financial sources and considering the availability of domestic finance. In this, public finance can play an important role in stimulating private sector involvement.

2.7.2.1 International Public and Private Finance

On the basis of equity and the principle of CBDR-RC, the articles of the UNFCCC clearly make provisions regarding who the providers of financial resources would be, and where the resources are to be directed, including inter alia Article 4.3, 4.4, 4.5, and 4.7 of the UNFCCC. Under Article 9 of the Paris Agreement, it is also stated that "Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations under the Convention… developed country Parties should continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels."

As of 2020, the OECD report claims that developed countries have mobilised and provided 83.3 billion USD in climate finance to developing countries towards meeting developed countries' commitment to jointly mobilise USD 100 billion in climate finance by 2020 (OECD, 2022) . However, only 68.3 billion USD out of 83.3 billion USD was in the form of public finance (OECD, 2022). The OECD figure has been challenged by other independent agencies like OXFAM. The OXFAM report claims that the actual value of public climate assistance provided to developing countries by OECD is only one-third of the claimed amount, that is around 21–24.5 billion USD (OXFAM, 2022). Financially enabling the transition will therefore require a significant scaling up of international cooperation (DEA, 2015; MoF, 2018). It must be emphasised that even grant or concessional finance to developing countries often requires considerable co-financing by the recipient Government, as in the case of India in particular (MoEFCC, 2021). The financing needs are huge and so the finance flows from international sources need to have the scale, the scope and the speed to meet the low-carbon pathways.

Sources of international public finance include multilateral institutions, bilateral financial institutions, and dedicated climate funds, including the Green Climate Fund. Grant and grant-equivalent funding from these sources is expected to be significantly scaled up towards India for meeting its low-carbon development objectives (DEA, 2015; MoF, 2018).

Additional sources of international private finance can include corporates, financial institutions, and institutional investors. Their contribution towards meeting India's climate finance needs should count towards developed countries' commitments only if these are based on clear and harmonised definitions of climate finance.

International climate finance has four pillars that would integrate the needs and requirements of the developing countries, (i) qualitative, (ii) quantitative, (iii) temporal, and (iv) evolving mechanism. This would imply:

- Qualitative - improved access to grants and low-cost finance for climate actions, which conform to Article 4.3 of the Convention. The objective should be that climate action should not be onerous for the developing countries, who already face developmental challenge.
- Quantitative - The magnitude of finance has to cater to the enormity of the needs of finance. The Scope, Scale and Speed of finance need to be augmented substantially. There is a need to develop innovative financing options to improve flow of resources.
- Temporal - Like the actions in climate, the provision, mobilization and flow of finance are of essence as well. Hence a time bound action in resource provision needs to be emphasized.
- Evolving mechanism - The mechanism for estimating the finance needs by developing countries needs to be dynamic. The mechanisms for mobilising financial resources will also need to evolve and deliberation on this is vital. There should be credibility, predictability and reliability in the flow of finance.

2.7.2.2 Domestic Public Finance

Government support plays an important role in the development and maintenance of climate policies and is discussed further. Public finance has so far played a key role in supporting broader finance flows towards increasing the shares of low-carbon electricity and electrification.

Such support from public finance includes, between 2014 and 2021, support for transmission, that increased by 144%, partly due to the introduction of new schemes to strengthen the grid for RE (Aggarwal et. al., 2022). Support for renewable energy increased by 52%, due to a combination of accelerated depreciation and tax breaks on excise and customs duty; these are expected to increase further due to production-linked incentives for solar PV modules and advanced chemistry cell battery storage. This excludes other socialization of RE costs that are borne elsewhere in the system, including support like free inter-state transmission and other substantial system balancing costs. Conversely, support for coal, oil and gas has reduced by 42% and 75% respectively (Aggarwal et. al., 2022). Within limited subsidies in the oil and gas sectors, these are overwhelmingly directed towards ensuring affordable and clean access to energy, including for cooking in line with SDG 7. These have critical positive spill over effects especially for women and children in India. An increase in the LPG subsidy after 2018 is due to the PM Ujjwala scheme, which encourages transitions towards clean cooking in order to reduce indoor pollution (Garg, 2020; Vishwanathan, Panagiotis, & Garg 2021; Aggarwal et. al., 2022). EV subsidies have increased three-fold, largely due to the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, and concessional GST on EV 2-wheelers, 4-wheelers and electric buses. It is noted that the estimation of "subsidies" has several uncertainties and ambiguities due to varying definitions of the scope of the term. Further, in developing countries, financial support from public funds is a well-understood necessity.

2.7.2.3 Instruments of Domestic and International Private Finance

Private finance can be channelled through equity investments, debt including loans and bonds, FDI, risk mitigation instruments such as insurance and guarantees, and new and innovative forms of finance. Greater use of such instruments for low-carbon development can be facilitated by reducing search costs for investors and pooling risks, including through securitization of bank loans that are issued to green sectors, and mobilising resources through green bonds. Meeting India's financing needs will require strategic and scaled-up use of all these avenues, and resources need to be mobilised by developed countries from

various sources that are long term, concessional and climate specific. These finance flows are, however, no substitute for the flow of climate finance from public sources that forms the core of the commitment by developed countries in the UNFCCC and its Paris Agreement. It is also essential that there should be early resolution of the New Quantified Goal on Finance at the UNFCCC and appropriate new funds begin to flow. As India noted in its National Statement at COP26, new and ambitious climate action over the long-term requires equal ambition in the provision of climate finance (MEA, 2021e).

2.7.3 Mainstreaming Resources for Climate Actions

The mainstreaming of climate finance implies a shift in financial practices, to make climate change – in terms of opportunities and risks – a key consideration in financing decisions, while paying due attention to prioritising development.

2.7.3.1 Monetary Policy and the Financial Sector

Climate change, and policies to address it, can affect the dynamics of the economy and the financial system, thereby impacting inflation targets, affecting financial stability, and limiting the room available for conventional monetary policy. This suggests the need for caution in climate policy making, paying attention to the implications for monetary, fiscal, and economic policies. Climate change may also weaken the transmission of monetary policy through its effects on financial markets, including for instance via losses generated through the stranding of assets.

BOX 2.6 – Initiatives of the Reserve Bank of India (RBI)

Since April 2021, the RBI has been a member of the Network for Greening the Financial System (NGFS), a group of central banks that contributes to the development of climate risk management in the financial sector, and to mobilize mainstream finance to support the transition toward a sustainable economy (NGFS, n.d.). Subsequently, the RBI also established a Sustainable Finance Group to lead regulatory initiatives in the area of investments linked to climate risk and sustainable finance (Rani & Handoo, 2022).

In parallel, the RBI has been incentivising bank lending towards greener industries and projects. For example, renewable energy projects have been included under Priority Sector Lending (PSL), including off-grid renewable energy solutions for households, solar power generators, wind mills, micro-hydel plants, and non-conventional energy-based public utilities (RBI, 2021).

Box 2.6 shows current initiatives by the Reserve Bank of India. Options to further integrate climate considerations into the financial system and monetary policy include green lending policies, deepening the corporate green bond market, mandating green bonds as a requirement for the Statutory Liquidity Ratio (SLR), allocating Green Asset Ratios, and strategically expanding the PSL scheme towards sustainable sunrise sectors, as well as promoting innovative financial instruments to support nascent low-carbon technologies (D'Souza & Rana, 2020).

Box 2.7: Initiatives of Securities and Exchange Board of India (SEBI)

With a view to bring in greater transparency and enabling identification and assessment of sustainability-related risks and opportunities by investors, SEBI has adopted sustainability reporting for listed entities. In May 2021, SEBI issued new mandatory sustainability reporting requirements on Environmental, Social and Governance (ESG) parameters for the top 1000 listed entities called the Business Responsibility and Sustainability Report (BRSR). The reporting requirements are intended towards having quantitative and standardized disclosures on ESG parameters to enable comparability across companies. It shall enable companies to better demonstrate their sustainability objectives, position and performance resulting in long-term value creation. At the same time, access to relevant and comparable information will enable investors to make better investment decisions. Overall, higher standards of ESG disclosures and transparency will help in attracting more capital and investments.

2.7.3.2 Domestic Public Finance and Fiscal Policy

Integration of climate considerations into fiscal policies can play an important role in climate mitigation and adaptation, and can also boost economic growth (Dilip & Kundu, 2020; Krogstrup & Oman, 2019). A wide range of policy tools exist at both the sector and economy-wide levels for integrating climate considerations into public finance (Dilip & Kundu 2020; Krogstrup & Oman 2019), with however serious knowledge gaps on how climate related policies, especially mitigation, interact with other policy objectives. India is already attempting to use fiscal policy in support of the low-carbon transition. For instance, in 2010 India had introduced a coal cess, the proceeds of which were used to finance clean energy. It is also providing support to the deployment of electric vehicles through its FAME scheme (MHI, n.d.). Other fiscal tools have included support for the development of low-carbon technologies such as solar PV and batteries through production-linked incentives (PLIs) or capital guarantees (PIB, 2021a).

At the economy-wide level, fiscal instruments typically include carbon taxes, carbon trading, feebates, regulations, and public credit guarantees (Calice, 2021; Krogstrup & Oman 2019). Exemplifying the use of such instruments, Gujarat is the first Indian State to be launching a carbon market (Nandi, 2022), while instruments such as the PAT scheme utilise market mechanisms to enhance energy savings for energy intensive industries (Asia Pacific Energy, n.d.). A further expansion of such policies, building upon growing discussions domestically, will however require studying their implications for India's macro-fiscal framework (Box 2.8) and broader developmental needs. For instance, policies that increase the costs of fossil fuels would imply a higher cost of living, which may require either subsidies or recycling of public revenues back into the economy through various support schemes.

BOX 2.8 – Fiscal Losses and Increased Costs from a Low-Carbon Transition

India heavily taxes all fossil fuels at various stages from extraction to final consumption. This amounts to an effective carbon tax, higher than many developed countries, totaling approximately INR 5.5 trillion in FY 2019-20. At a more operational level, the "must-run" status of renewables has led to significant increased costs for State-level distribution companies (Kanitkar et. al., 2021), and the system overall socializes the costs of transmission, which are kept free for many RE technologies. Since public sector distribution companies bear the brunt of affordable electricity supply for weaker sections, the supplementary duty of undertaking Renewable Purchase Obligations (RPO) also adds to costs. Such additional costs constitute further investment by India in climate mitigation.

Further mainstreaming climate into the fiscal architecture can include using policy to promote green investments (including public infrastructure), thereby generating green jobs. This requires coordination among relevant line ministries and adoption of an appropriate budgeting framework.

2.7.4 Linkages to International Trade

Financial aspects of the low-carbon transition can affect, and in turn get affected, by the international trade regime. The Government will seek to ensure that obligation in international trade agreements will not curtail the existing policy space to nurture domestic producers of environmental goods and services.

The domestic and foreign policies of other countries, especially developed ones, to address emissions – through carbon border adjustment mechanisms – can also affect developing economies like India adversely, without achieving their stated objectives. There is a need to strike the right balance between the requirements of development, trade, and low-carbon pathways.

Chapter 3 RESEARCH AND INNOVATION

Innovation is an important part of development and sustainable growth in all sectors of the economy. It is also necessary for sustainability through recycling, reuse, and disposal of materials, waste and residues.

Innovation needs to be backed by institutions and human capital. There is a need to further improve the R&D base for green technologies and climate change mitigation and adaptation, both globally and nationally. India needs to equip institutions involved in R&D with the latest scientific equipment, physical infrastructure and needed skilled resources. R&D institutions need to engage with academia and industry, not only in India but also in other countries, keeping in view India's needs as a developing country facing the double challenge of growth and development and climate resilience.

The achievement of the Paris Agreement temperature targets will require significant new technologies, as noted by the IPCC Working Group III contributions to the Sixth Assessment Report. The process of developing, adapting, and deploying innovative technologies requires large up-front capital investment, but the returns to that investment are influenced by the presence of complementary infrastructure and the conduciveness of the policy framework. Limiting global temperature increase to 1.5°C requires the deployment of new technologies on a massive scale in developing countries. The cost of low-carbon technology is falling amidst large scale deployment and rising investment. "But the benefits have been unevenly distributed across the world, especially due to the lack of enabling conditions in developing countries." (IPCC, 2022)[3].

India's effort in innovation for climate action and sustainable development will be closely linked to its developmental vision for mid-century, and India's vision of *Aatmanirbhar Bharat* and Make in India in the industrial, especially manufacturing, sector. The pursuit of climate action and sustainability needs to be linked to self-reliance, reduced dependence on imports, and development of the innovative capacities of India's economy and society and cannot be driven largely by imports and uncritical adoption of processes and technology developed elsewhere.

India has initiated steps for establishing a National Research Foundation (NRF). The NRF aims to catalyze, facilitate, coordinate, seed, grow, and mentor research in academic institutions around the country, particularly at universities and colleges where research capacity is currently in a nascent stage. This will be the first of its kind foundation to promote research and development across the country. For creation of the National Research Foundation, a total expenditure of Indian Rupees 50,000 crore over a period of 5 years beginning from 2021-22 has been approved (PIB, 2021b).

In general, it is difficult to project future technology requirements in the face of its rapid and continuous development. Access to relevant, affordable, and scalable technologies, along with technical skills, can prove to be a game-changer, provided adequate financial support is received. The study of energy and industry transitions for the future indicates which low carbon technologies may dominate globally.

3. IPCC further says: "Adoption of low-emission technologies lags in most developing countries, particularly least developed ones, due in part to weaker enabling conditions, including limited finance, technology development and transfer, and capacity. In many countries, especially those with limited institutional capacities, several adverse side-effects have been observed as a result of diffusion of low-emission technology, e.g., low-value employment, and dependency on foreign knowledge and suppliers."

Coupled with a roadmap for R&D and investment to scale, such technologies can be developed and commercialized if adequate additional financial support is available. A large section of the population is vulnerable to climate change impacts, and thus adaptation is as relevant to India as mitigation. Most technologies for climate adaptation in sectors like agriculture, forestry, water, and health are available in India only on a very limited scale. These technologies need to be locally adapted and scaled up to ensure climate resilience according to the country's ecosystems and local population needs, an effort that also requires substantial financial support. The issue of technology, finance, and capacity-building needs to be addressed simultaneously and holistically following a comprehensive integrative approach.

Innovative technologies are particularly needed in the following sectors (not exhaustive): Carbon capture and storage (CCS), energy-intensive industries, aviation, biofuel supply, energy storage, and negative emission technologies. Thus by 2070, when emissions will need to be net-zero, India will be heavily reliant on CCS and negative emissions technologies to achieve this goal, and, in particular, to offset emissions from challenging and hard-to-abate sectors. In the following, the innovation requirements in specific sectors are discussed.

Under the UNFCCC, developed countries are committed to provide technology transfer on concessional terms to developing countries. Developing countries make known their specific requirements through several forums and discussions under the UNFCCC, including through their Biennial Update Reports (BURs). A non-exhaustive list of needed technologies has been provided by India to the UNFCCC in its First and Second Biennial Update Reports. Provision of these lists of necessary technologies, however, have not received any response from the developed countries. The details are given below (Table 3.1), as listed in India's Third Biennial Update Report. A majority of these are short- and medium-term requirements, while a further discussion is presented in section 3.1 focusing more on long-term innovation requirements.

Table 3.1 List of additional technology needs

S. No.	Area of Implementation	Technology/Remarks
1	Solar Photovoltaics	• Currently, crystalline Silicon (c-Si) technology contributes 95% of global solar PV installations, and thin films contribute to the remainder. Thus, c-Si is likely to contribute 400 GW by 2050 and is essential for India's future clean energy trajectory. • India lacks technology and manufacturing for the upstream segment of the supply chain, i.e., polysilicon/ingot/wafer. Indian cell manufacturers import wafers, and similarly, cells are imported for module manufacturing. • c-Si technology has made vast advancements, and the Indian manufacturers have not been able to keep pace with technology changes. • Existing module manufacturing plants lack economies of scale, which prevents cost reduction. • India lacks the crucial technologies needed to process/manufacture the raw materials for cell and module manufacturing.

S. No.	Area of Implementation	Technology/Remarks
		• Equipment (assembly line) used for cell, module, and BoM (Bill of Materials) component manufacturing is not available in India and is imported. • India needs next-generation PV technologies, including Perovskites, Multi-Junction Solar Cells, Dye induction photovoltaics and organic/inorganic composites. • China, UK, USA are some of the key countries for technology sourcing.
2	Offshore Wind	• Technology limitation exists in the survey space (oceanographic and geotechnical). • Heavily dependent on imports for rare earth metals. • Potential to increase the capacity factor of domestic manufacturing units. • Need for modelling and simulation tools, including HPC to improve. generation forecasting and performance analysis. • Denmark, the UK, and Germany are the major technology providers.
3	Advanced Ultra Supercritical Coal Technology (AUSC)	• Materials having characteristics of high creep rupture strength and corrosion resistance at elevated temperature and pressures are not available. • Japan and South Korea are potential collaborators for technology transfer (welding technologies).
4	Light Emitting Diode bulb	• LED chip (Wafer Fabrication) is imported.
5	Room Air Conditioners	• Rotary compressors – a key component in room air conditioners is largely imported. • The local availability of propane and isobutane-based refrigerants that have low Global Warming Potential footprints is a constraint.
6	Iron & Steel Manufacturing	Current technology mix dominated by the Blast Furnace-Basic Oxygen Furnace route, which uses coke, coal, and oxygen to produce steel. Through adoption of several energy efficiency measures and low carbon processes, an integrated steel plant can save emissions substantially. These, however, are being acquired through international commercial collaboration or require further technology transfer. Further, the following technologies can be adopted as and when these technologies are available for adoption on commercial scale. • H_2 based iron & steel making technologies. • HISARNA Technology which is being developed under ULCOS (Ultra Low Carbon Dioxide Steel Plant) Programme. • Pilot projects for CCUS in this and other relevant sectors.

S. No.	Area of Implementation	Technology/Remarks
7	Biofuels	• Scaling up issues exist for large scale enzyme production. • Feedstock sourcing has been a perennial problem. • Commercial production of Bio-methanol is cost-prohibitive. • Higher Ethanol compatible Vehicles and Flex Fuel Vehicle to be introduced. • CBG based vehicles is needed. • Technology development for SAF Production in the country.
8	Hydrogen	• Technologies for type III and type IV cylinders, as well as hydride and carbon materials for hydrogen storage. • Catalysts, membranes, and fuel cell manufacturing assemblies. • Hydrogen supply chain infrastructure and dispensing stations. • Green hydrogen utilization in the industry, including ammonia for fertilizers and iron and steel production. • Petroleum sector is planning for utilisation of green hydrogen in the refineries as well as for blending with CNG/CBG in gas pipelines.
9	Lithium-Ion Battery (LiB) & Flow Battery	• Raw materials and technology are barriers to large scale manufacturing of Lithium-Ion Batteries in India. • Advances in battery storage technologies.

Table 3.2 Technologies which need investment

S. No.	Area of Implementation	Technology/Remarks
1	Cement	• Proliferation of technology for waste heat recovery from preheater exhaust and cooler vent for co-generation of power. • Wider adoption of grate cooler technology. • Wider adoption of low-Nox multi-channel burners for combustion.
2	Iron & Steel	• Injection of plastic waste in the blast furnace.
3.	Energy	• Storage system and offshore wind.

In the following, we list some of the key innovative technologies required in particular sectors over the longer term, with a focus on some of the key innovative technologies that are already being developed in India and are available at various levels and stages of development.

3.1 Innovative Technologies in Energy Sector

3.1.1 Smart Grid Developments

The use of smart grid technologies to create both a nimbler and more resilient grid as well as one that is flexible and able to better incorporate clean energy is an essential requirement. India has a roadmap for installing hundreds of millions of smart meters in a few years, and this can then enhance not just utility

operations but also greater rooftop solar integration. Complementary to efforts at the consumer or retail level, India is building out more flexible markets for wholesale electricity, with a range of business and regulatory innovations to support greener supply.

3.1.2 Developing Bio-Based Clean Energy Innovations and Carbon Dioxide Removal Technologies

On the mitigation side, biotechnology must play a lead role in the restoration, and conversion of domestic carbon sources (such as those found in agricultural and forest residues, municipal wastes, and sewage, gases feedstock from industries) into bio-based fuels and chemicals to replace fossil-derived fuels and chemicals, specifically for hard-to abate sectors like a long-distance truck, aviation, marine, and polymer industry. India, through the Department of Biotechnology, will be working to develop the technologies in the above areas with the potential to make available sustainable cost-effective biotechnology-based fuels and chemicals.

India being a member country of the Mission Innovation will be supporting the Carbon Dioxide Removal Mission, aimed to enable Carbon Dioxide Removal Technologies. India will be taking initiatives to develop and demonstrate the Intensified CO_2 capture.

3.1.3 Energy Storage Systems

Electricity storage is a key enabling technology, which will be necessary to accommodate the high level of intermittent renewable generation technologies (i.e., wind and solar) required for the development of low-carbon electricity systems. Apart from pumped hydro storage, which is currently the world's most dominant form of energy storage, lithium batteries are also considered significant. The research priorities for electrical batteries include new cell chemistries emerging from the lithium-ion family such as lithium-air, lithium-sulphur or other metals such as sodium and magnesium.

These could improve power and charge density, decreasing cost per unit of energy stored. Improved manufacturing techniques and efficient management of battery packs can provide evolutionary cost and performance improvements. However, as lithium is not available in India, research, and innovation for exploring other battery technologies is a strategic requirement.

Keeping in view the large-scale integration of RE into the grid, the need for Energy Storage Systems (ESS) to cater to the variability and intermittency of RE is highly significant.

3.1.4 Hydrogen Economy

Hydrogen is considered one of the key future energy carriers, having a variety of potential applications. Its applications are foreseen in process industries, fuel cells for power generation, grid balancing functions, steel industry and transportation. There is a need to further develop technologies to produce green hydrogen and its end-use applications. Green hydrogen / green ammonia could be used in co-firing the thermal power plants and later become the sole source of energy.

Box 3.1: Green Hydrogen

India announced the National Hydrogen Mission in 2021 with the objective of meeting mitigation goals as well as making India an export hub for green hydrogen and green ammonia. India aims to achieve production of 5 million tonne of green hydrogen by 2030 and the related development of renewable energy capacity is required (PIB, 2021b). In India, green hydrogen can serve the dual purpose of enhancing energy security as well as contributing to the development of a low-carbon economy. The Government is currently introducing various incentives to promote and scale the production of green hydrogen/ammonia, including the introduction of a PLI scheme for the manufacture of electrolysers, mandating a 'green hydrogen purchase obligation' for industry, allowing green hydrogen /ammonia manufacturers to purchase renewable energy from the power exchange or set up renewable energy capacity themselves or through any other developer, waiver of inter-state transmission charges for a period of 25 years for projects commissioned before 30th June 2025, and priority connection to the grid for green hydrogen projects.

3.1.5 Nuclear Energy

Nuclear energy is a key substitute for delivering base load power free of intermittency in place of energy from fossil fuels. India considers nuclear energy as a significant component of its non-fossil fuel power generation capacity and will continue to pursue research and innovation in this sector.

As India has a declared 'closed fuel cycle' policy, reprocessing of spent fuel is at the center of India's nuclear programme, not only from the perspective of the waste management but also for recovery of fissile material to use it in next stage reactors. With India now having safeguarded reactors using natural as well as enriched uranium as fuel, reprocessing of both types of fuels and development of associated technologies is an ongoing research and innovation area.

Demonstration of advanced reactor technology (sodium-cooled fast breeder reactor) is under progress. India is pursuing research and innovation in this area for over three decades and at present, a test reactor based on the same technology is under operation, while another technology demonstrator is under commissioning. Research and development of reactor fuel cycle technologies is underway.

India's Department of Atomic Energy (DAE) is developing sea water desalination technology using nuclear power. It is also developing technologies for Hydrogen production.

3.1.6 Development of Biomass-to-Liquids Fuel Production from Thermo-Chemical processes

India is an agricultural economy, with agriculture contributing nearly 20% to GDP and providing employment to approximately 50% of the population. The quantum of crop residues for 11 major crops in the country was estimated to be around 683 million tonnes in 2018 (Jain et. al., 2018) . In most places, part of these residues is used as fodder or for energy purposes. These residues are a rich source of renewable organic carbon that can be used to produce fuel, chemicals, or petrochemical feedstocks. Biotechnological or thermochemical routes are being developed for efficient and sustainable use of these biomasses.

The Council of Scientific and Industrial Research (CSIR) - Indian Institute of Petroleum (IIP) has developed a palletization process, whose outputs can be used in a pellet burner, for domestic cooking applications or heating applications in small scale industries. These pellets when produced in larger quantities can also be supplied to heavy duty industries or even to thermal power plants to produce electricity by co-generation. A mobile pyrolysis unit has also been developed by CSR-IIP. Bio-oils can be used for supplementing furnace oil requirement and the testing of these oils for repellent properties is under progress. Once more avenues for utilization of different fractions of bio-oil are identified, it will increase the economic viability of the process. The modified oils have found application as bio-binder for flexible pavement construction.

Overall, this will reduce the burden to import fossil fuels as it will be supplemented by the domestic carbon resources available within our borders and lead the country on to a path of self-reliance and low-carbon development.

3.1.7 Commercialization and Initiatives of Cellulosic Ethanol

India's Council of Scientific and Industrial Research (CSIR) has been working on 1G (first generation), 2G, and 1.5G bioethanol programmes for the last 10 years. Under the PANCSIR2GE program, CSIR is working on developing an integrated process for 1G, 2G, as well as 1.5G bioethanol, starting from sugary, starchy, as well as vegetal/lignocellulosic biomass feedstocks.

3.1.8 Integrated Gasification Combined Cycle (IGCC) Technology

IGCC technology has shown capability of power generation at higher efficiency and lower emission levels as compared to pulverized coal combustion technologies as demonstrated in some developed countries. Research in IGCC technology may be focused to open up new product areas along with electricity generation like liquid fuel generation, hydrogen production, pre-combustion CO_2 capture and integration of fuel cell which may provide future options of zero emission coal technologies with higher efficiency.

3.1.9 Waste Heat Recovery Systems for Utilizing the Flue Gas

Many industries make use of waste heat recovery system for capturing the high temperature flue gases in many industries and reusing it for producing power is equally important for environmental protection since lower quantity of fossil fuels shall be burnt for same quantum of useful energy. Further, research and innovation in Indian context may be made in developing technologies where waste heat can be efficiently and economically recovered and applied to produce refrigeration/air-conditioning using vapour absorption/adsorption machines (VAM) based on Li–Br, Ammonia absorption system.

3.2 Innovative Technologies in Industrial Systems

3.2.1 Low-carbon development of the industrial sector

Low carbon development of the industrial sector is particularly challenging now owing to competitiveness issues, and its inherent heterogeneity, especially in view of the large presence of the MSME sector. Except for biomass usage in certain applications, currently all of these options are still in the concept phase and there is an urgent need for the development of breakthrough processes (e.g., steel production based on hydrogen or electrolysis), which can result in a step-change in emissions reductions.

3.2.2 Aviation Industry

According to India's Third BUR civil aviation constituted 6% of the total transport emissions in India in 2016. Globally emissions from the aviation sector in 2018 was 903 $MtCO_2$ which was 2.48% of the total global emissions (Graver, et. al., 2020) .

Currently, the options for low (or zero) carbon airplanes are extremely limited. These include, inter alia:

1. Radical new aircraft designs (e.g., the 'blended wing' concept) that could improve fuel efficiency by 25% compared to the most efficient planes today.
2. Biofuel-powered planes have been proven to be technically feasible and blending of up to 50% is now allowed for commercial use.
3. New engine designs that can cope with the low aromatics' composition of biofuels
4. Hydrogen powered aircraft, which however face significant technical challenges for commercial scale use to become a reality.

Technology Information Forecasting and Assessment Council (TIFAC) has taken up assessment of Indian industries for identifying potential technologies and imparting requisite capacity building towards low carbon development. The sectors taken up include steel, cement, transport, MSMEs. TIFAC has also initiated a major study for designing of an innovative cooperative based model for enhancing utilization of biogas and demonstration of biogas grid in Punjab.

3.2.3 Steel and Cement Industry

In the Indian steel industry low carbon development is a big challenge as opposed to developed economies. It needs R&D intervention for seamless transition to non-coal-based technologies with alternate fuels like hydrogen. This transition needs to be over a period considering the high capital expenditure and readiness of befitting technology. During this transition period innovative R & D technology may be there to reduce the carbon footprint of existing technologies.

Some of these technology options include:

1. Cooling tower energy consumption optimization
2. Chiller Plant energy consumption optimization
3. Coke Oven Gas (COG) Consumption reduction by installing tail gas cleaning system
4. By-product fuel gas optimization in a steel industry
5. Integrating cutting-edge technologies like additive manufacturing and Artificial Intelligence, to make products and production smarter and more sustainable

Development of alternative building materials to steel and cement is an important research priority, which can reduce emissions from both industry and the built environment. Alternative cement chemistries (i.e., not based on limestone) could provide a low-carbon solution for cement; however, extensive testing is required to provide the construction industry with the necessary confidence for wide-scale acceptance.

3.3 Sustainable Bioresource & Marine Biotechnologies to Reduce Emissions

Marine bioresources such as Micro- and Macroalgae are getting attention due to their potential to capture

the carbon(C) to mitigate the GHG emission and climate change. Exploration the role of managed ecosystems of marine bioresource in mitigating climate change by promoting carbon sequestration and storage and by buffering against uncertainty in management, environmental fluctuations, directional change, and extreme events will be considered. Marine bioresources are a viable low-tech, cost-effective adaptation strategy that would yield multiple co-benefits from local to global scales, improving the outlook for the environment and people into the future. Oceans are a major reservoir of carbon sink, either through absorption of carbon dioxide from the atmosphere or assimilation of inorganic carbon.

3.4 Gaps in Research and Innovation

Gaps in Industrial Long-Term Transitions

There are several structural issues related to industrial long-term transitions. These include the increased speed of technological and organizational change, the impact of general-purpose technologies (such as ICT and AI), the diffusion of innovation, challenges arising from the globalization of technologies and the role of technology in profound socio-economic transitions required by ambitious climate mitigation and adaptation. Some of the major gaps in technology, development and innovation related to climate mitigation and adaptation with respect to different industrial elements are listed in the table below:

Table 3.3 Gaps in Industrial Long-Term Transitions

Element	Gaps
Improving Energy Efficiency	• CAPEX requirement for energy efficiency projects (especially MSMEs) • R&D cost to innovate new technologies
Sustainable Mobility Technologies	• Lack of Infrastructure, technology standards, data standards and Guidelines
Enhance material efficiency and recycling	• Industry needs sector specific solutions to address waste – budgets need to be allocated to pursue R&D • As India transitions to a clean technology frontier, there is proliferation of new technologies and products with associated waste issues that need to be urgently addressed
Green hydrogen technology and infrastructure	• Costs of production are currently high, making all green hydrogen-based products more expensive than fossil fuel-based alternatives. • Transporting and storing hydrogen is costly, and significant build-out of infrastructure is required to bring down the costs of delivered hydrogen. • IPR clearance for the technologies (e.g., Electrolysers)
Hard-to-abate sectors	• High financial costs of implementation of new technologies and alternate fuels (NG, H_2 etc.) • Hydrogen technologies still require R&D and are economically not viable • Lack of financing for R&D, piloting and demonstration of Hydrogen based technologies

MSMEs	• Financing the MSMEs sector • Availability of commercial technologies • Unskilled workers

Several technologies to achieve energy productivity improvement are not yet commercially ready. The steel and plastics sectors face the problem of "downcycling" due to contamination of the primary material by other materials (copper for steel, additives for plastics), limiting the increase of recycling rates. Accelerating development of key technologies is therefore vital (chemical recycling of plastics, better collection and dismantling processes, design for disassembly). High upfront investment costs in infrastructure and higher costs of zero-carbon feedstock are strong impediments to the deployment of energy efficient and material-efficient environments. Many industries (e.g., cement, plastics) are so fragmented that incentives to build an end-to-end circular and efficient value chains are ineffective. Collaboration across the value chain and between the private and public sector is key to build synergies and support a comprehensive innovation and deployment agenda (Agrawal & Sonkusare, 2021).

Chapter 4 ADAPTATION AND RESILIENCE

Development and growth are the first lines of adaptation and resilience for developing countries. Strengthening basic infrastructure such as sanitation systems, irrigation networks, and disaster resilient buildings, as well as institutional infrastructure such as disaster response teams are pre-requisites for successful adaptation and resilience. These cannot be achieved in the absence of rapid growth and development and must also be facilitated by adequate international financial support for adaptation.

As a developing nation, India is facing several socio-economic challenges, which contribute to the vulnerability of its population to climate impacts. Building resilience implies addressing specific vulnerabilities as well as raising incomes to bolster the capabilities of individuals and communities to adapt to long-term changes in the climate. Similarly, raising farmer incomes is necessary to strengthen farmers' capacity and allow them the flexibility to adapt to changes in their micro-climates. The remainder of this chapter reviews climate impacts in India, adaptation strategies, and linkages between adaptation and mitigation.

4.1 Climate Change Impacts in India

India has a diverse geography with landscapes varying from snow-capped mountain ranges to deserts, plains, hills, plateaus, coastal regions and islands. The diverse geography of India manifests varied climate regimes ranging from continental to coastal, from extremes of heat to extremes of cold, from extreme aridity and negligible rainfall to excessive humidity and torrential rainfall. India's climate is significantly influenced by the presence of the Himalaya and the Thar Desert. India receives nearly 80% of its annual rainfall during the southwest monsoon season of June to September. Rainfall distribution and intensity have a significant impact over different socio-economic sectors, especially agriculture and hydrology, besides impact on other aspects of various ecosystems.

For India, 2019 was the seventh warmest year on record since 1901, and 11 out of 15 warmest years were recorded during the fifteen years from 2005 to 2019. The duration of heat waves over central and north-west India has increased by about five days over the past 50 years (MoEFCC, 2021). India's average surface air temperature has risen by around 0.7°C during 1901–2018, largely on account of GHG-induced warming, and is estimated to rise by 2.0-2.8°C under Representative Concentration Pathway (RCP) 4.5 relative to the recent past (1976-2005 average), by the end of the century (Krishnan et. al., 2020). The steric sea level rise in the North Indian Ocean by the end of the century is projected to be 300mm relative to average over 1986-2005 under the RCP 4.5 scenario (Krishnan et. al., 2020).

Alongside such physical impacts, several expected impacts are projected to affect vulnerable ecosystems and human-managed systems, an illustrative set of which are summarized in Table 4.1.

Table 4.1 Illustrative list of expected climate impacts and associated vulnerabilities

Human-managed systems and ecosystems	Illustrative expected impacts and associated vulnerabilities
Agriculture	• Rain-fed rice yields in India are projected to reduce marginally (<2.5%) in 2050 and 2080 and irrigated rice yields by 7% in 2050 and 10% in 2080 scenarios. (PIB, 2021c). • Wheat yield may reduce by 6-25% in 2100 and maize yields by 18-23%. (PIB, 2021c). • Impacts on production of wheat, mustard and chickpeas in the Indo-Gangetic plains in the rabi season. (Kumar and Viswanathan, 2019). • Increasing soil erosion, crop water requirement and land degradation. (Kumar and Viswanathan, 2019).
Water	• Substantially altered water flow in Himalayan rivers – increased short-term stream flow but long-run downstream dry-season shortages (Srinivasan, 2019). • Increase in the annual and summer monsoon mean rainfall, as well as frequency of heavy rain occurrences over most parts of India during the twenty-first century. (Krishnan et. al., 2020).
Coasts and marine systems	• High risk of coastal inundation along parts of the east coast. (Krishnan et. al., 2020) • Phytoplankton have reduced by up to 20% in the Indian Ocean as a result of ocean warming (Roxy et. al., 2016). • Vulnerability to strong storm surge activity due to sea-level rise coupled with unusually severe (albeit less frequent) cyclonic activity (Arthur, 2019).
Himalayan ecosystem	• Rise in surface air temperature over the Hindu-Kush Himalaya (HKH) region by 2.2-3.4°C by the end of the century (RCP4.5). (Krishnan et. al., 2020). • Significant decline in snowfall and glacier retreat over several regions of the HKH, except in the Karakoram Himalayas. (Krishnan et. al., 2020). • Hydrological and agricultural impacts in the HKH region. (Krishnan et. al., 2020).
Forestry and grasslands	• 18-28 % forests grids are expected to be impacted by projected climate change under different emission scenarios in the short (2030s) and long (2080s) term. (MoEFCC, 2021). • Wildfires are projected to increase, although estimates vary significantly. About 36% of country's forests are highly prone to fires. (MoEFCC, 2021). • Encroachment of woody-shrubs into grassland biomes, impacting wildlife species specialized to living on grasslands. (MoEFCC, 2021). • Loss of habitat for particular species such as the grizzled giant squirrel (Ratufa macroura), the snow leopard (Panthera uncia), the blue sheep (Pseudois nayaur), and the Nilgiri tahr (Nilgiritragus hylocrius). (Lele and Krishnaswamy, 2019).

Extreme weather events	• Increase in frequency, spatial extent and severity of droughts, while flood propensity is projected to increase over the major Himalayan river basins (Krishnan et al., 2020). • Increase in the frequency of extreme precipitation events especially over the central and southern parts. (Krishnan et. al., 2020).

4.2 India's adaptation strategies

4.2.1 Adaptation actions and priorities

India is undertaking a variety of adaptation actions across sectors and scales. A brief account of India's current adaptation actions and goals are presented in India's first NDC and its Third Biennial Update Report to the UNFCCC. A sample list of key actions (policies, missions, plans, projects) is presented in Table 4.2 below.

Table 4.2 Key existing adaptation actions.

Category	Key Institutions/Initiatives/Policies/Programmes
National Action Plan on Climate Change	National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustainable Agriculture, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a Green India, National Mission on Strategic Knowledge for Climate Change
Agriculture	Mission for Integrated Development of Horticulture, Pradhan Mantri Krishi Sinchayee Yojana, National Innovations in Climate Resilient Agriculture (NICRA), National Agroforestry Policy (NAP), National Crop Insurance Programme, National Mission for Sustainable Agriculture (NMSA)
Water	Namami Gange programme, Jal Jeevan Mission, National Water Policy
Disaster Management	National Disaster Management Plan (NDMP), National Disaster Relief Fund, National Disaster Management Authority
Health	National Action Plan on Climate Change and Health
Coastal Regions and Islands	Environmental and Social Management Framework (ESMF), Coastal Regulation Zones/Island Protection Regulations, Integrated Coastal Zone Management Programme
Ecosystems	Schemes for conservation of corals and mangroves; Wetlands (aquatic ecosystems)
Cities	Atal Mission for Rejuvenation and Urban Transformation, Smart Cities Mission, National Mission for Sustainable Habitat
Sub-national action	State Action Plans on Climate Change, Heat Action Plans in leading cities, Tripura Forest Environmental Improvement and Poverty Alleviation Project, Tamil Nadu Climate Change Mission
Cross-cutting	National Adaptation Fund for Climate Change, Mahatma Gandhi National Rural Employment Guarantee Scheme, India Cooling Action Plan, National Green Highways Mission

Source: *(MoEFCC, 2021) and (Patra, 2016)*

Alongside actions by the Indian State across scales, various stakeholders participate in delivering adaptation in practice through adaptation projects and local initiatives. The National Adaptation Fund for Climate Change (NAFCC) was established to support adaptation activities in the States and Union Territories (UTs) of India that are vulnerable to the adverse effects of climate change.

The India Cooling Action Plan (ICAP) provides an integrated vision towards cooling across sectors encompassing, inter alia, reduction of cooling demand, refrigerant transition, enhancing energy efficiency and better technology options by 2037-38 through forging synergies with on-going programmes/ schemes of the Government. The ICAP seeks to: (i) reduce cooling demand across sectors by 20% - 25% by 2037-38; (ii) reduce refrigerant demand by 25% - 30% by 2037-38; (iii) Curtail cooling energy requirements by 25%-40% by 2037-38; (iv) recognize "cooling and related areas" as a thrust area of research under National S&T Programme; (v) organise training and certification of 100,000 servicing sector technicians by 2022-23, synergizing with Skill India Mission. These actions will have significant climate benefits (PIB, 2019c).

4.2.2 Adaptation Finance

India's adaptation finance needs are substantially challenging to quantify. In its NDC in 2015, India had put forward a preliminary estimate that it would need around USD 206 billion (at 2014-15 prices) between 2015 and 2030 for implementing adaptation actions in agriculture, forestry, fisheries, infrastructure, water resources and ecosystems.

A more recent analysis by a sub-committee of India's Ministry of Finance has estimated that the cumulative total expenditure for adapting to climate change in India would amount to INR 85.6 trillion (at 2011-12 prices) by the year 2030 (DEA, 2020). 'Financial needs', as defined in this analysis, focus on the linkages between adaptation, SDGs and basic needs, and may therefore differ from the definitions typically used for adaptation finance. Climate change impacts are expected to worsen with the passage of time. Hence, India's adaptation needs will have to be intensified and so the adaptation costs will increase beyond official estimates.

While individual estimates are subject to uncertainty, the broad trend is clear that the adaptation finance required is likely to be significantly higher than current adaptation finance flows. The 2021 UN Adaptation Gap Report found that estimated adaptation costs in developing countries were 5-10 times greater than current public adaptation finance flows, and that the adaptation gap was widening. Urgently increasing adaptation finance flows to India is a crucial requirement for India to be able to meet its long-term sustainable development and low emission growth goals.

4.2.3 Loss and Damage

A wide range of estimates exist regarding the economic losses and damages caused by climate impacts to the Indian economy. Isolating the climate component of total losses due to extreme weather events continues to remain a challenge. Developed countries fulfilling their commitment in providing adaptation finance to minimise further losses, and adequate compensation for unavoidable loss and damage, is critical for developing countries.

4.2.4 Governance and Institutional Arrangements for Adaptation

India's governance approach to adaptation operates within the division of powers laid out in the Constitution of India and long-standing practices in India's fiscal federalism. Adaptation responsibilities are divided between three levels of Government – the National Government, the States, and local Governments. Long-term, sustainable reductions in climate vulnerability therefore require significant coordination between these levels.

Responsibility for several core adaptation areas rests with India's States – areas such as water, agriculture, health, and managing local Government. This has led to a diversity of adaptation-related policies across the States. Such actions are often listed in State Action Plans on Climate Change, drawn up by the States, which list local vulnerabilities and policy actions to address them. Box 4.1 illustrates the adaptation approaches taken by States in relation to managing heatwaves.

Box 4.1 Sub-national Heat Action Plans

In order to build resilience against increasing heat stress, some cities and States in India have introduced Heat Action Plans (HAPs), which are now proliferating rapidly. HAPs are comprehensive extreme heat warning systems and preparedness plans. There are now 23 State level HAPs at various stages of development (NRDC, 2022), with support from the IMD and India's National Disaster Management Authority (NDMA). HAPs are examples of sub-national innovation for adaptation.

Existing HAPs are tailored to State and city contexts. Most States' HAPs include short-term responses to extreme heat as well as building long-term capacity and awareness against heat stress. (Hess et. al., 2018).

At the same time, Indian federal practice vests the National Government with significant financial and agenda-setting powers that influence the adaptation policy landscape. Centrally-Sponsored Schemes, have emerged as an important channel through which vulnerabilities are addressed. Additionally, several of the climate-specific adaptation Missions under the NAPCC are implemented with key participation of States, including the National Water Mission, the National Mission for Sustainable Agriculture, and the National Mission for Sustainable Habitats.

The National Adaptation Fund for Climate Change is an important source of funding adaptation governance, and was set up to disburse project-specific grants to address State-determined vulnerabilities. The Finance Commission, tasked with recommending the devolution of monies to the States, has also increasingly taken environmental conditionalities into account, focusing on improving disaster-preparedness among other climate-related subjects.

Finally, the Central Government has also played an increasingly evident, and important, role in establishing national frameworks (see Table 4.2) and assessments that inform State adaptation policies. The National Disaster Management Authority (NDMA) has, for example, led the creation of guidelines for several different types of extreme events, from heatwaves to glacial lake outburst flooding, while national institutions like the Department of Science and Technology and the Indian Institute of Tropical Meteorology make disaggregated information about climate vulnerability available to sub-national actors.

4.3 Interlinkages between Mitigation, Adaptation, and Development

Both mitigation and adaptation strategies are crucial to manage climate change, but neither approach is sufficient by itself. Mitigation, at the global level, reduces the most severe of potential climate hazards first, in terms of both occurrences and magnitude. Adaptation activities, best targeted at the local level, increase the ability to cope with climate hazards of lesser magnitude at the lower end of the potential range. The crux of mitigation clearly lies in the developed world, with high per capita emissions and continuing over-use of the global carbon budget beyond their fair share. On the other hand, the burden of adaptation is significantly higher for developing countries, which have historically and in the present contributed little to global warming.

There are potential interlinkages between the climate change impacts, mitigation and adaptation activities, and the developmental outcomes, recognition of which can help identify climate-resilient development pathways.

Adaptation is already being mainstreamed in many development actions in India across sectors and scales, (Singh et al., 2014). India is pursuing both hard (e.g., disaster resilient infrastructure) and soft forms of adaptation (capacities, institutions, knowledge sharing mechanisms) within the ambit of its development projects.

While climate-resilient development is a normative aspiration, it is extremely challenging in practice for developing countries. Many trade-offs exist between adaptation, mitigation and development. The extent to which synergies can be feasibly pursued are constrained by availability of climate finance. Further, pursuing climate-resilient development pathways also depends on future climate risks, socio-economic inequalities, national and subnational circumstances (resources, vulnerability, culture, and values), adaptation responses and access to a fair share of the global carbon budget. Foregrounding the needs of vulnerable and marginalized communities, equity, and social justice through integrated planning processes are important for achieving climate-resilient development.

Chapter 5 LiFE - LIFESTYLE FOR ENVIRONMENT

LiFE, Lifestyle for Environment was announced by Prime Minister Narendra Modi, at COP26 in Glasgow on 1st November 2021 in India's National Statement. Speaking on the occasion, Prime Minister said: "This One-Word, in the context of climate, can become the basic foundation of One World. This is a word - LiFE…L, I, F, E, i.e., ***Li***festyle ***F***or ***E***nvironment. Today there is a need for all of us to come together, with collective participation, to take Lifestyle For Environment (LiFE) forward as a campaign. This can become a mass movement of Environmental Conscious Life Style. What is needed today is Mindful and Deliberate Utilization, instead of Mindless and Destructive Consumption. These movements together can set goals that can revolutionize many sectors and diverse areas such as fishing, agriculture, wellness, dietary choices, packaging, housing, hospitality, tourism, clothing, fashion, water management and energy."

The underlying philosophy of LiFE has its roots in India's ancient saying:, प्रकृतिः रक्षति रक्षिता, (Nature protects if she is protected), that has been inscribed as the motto on the seal of India's Ministry for the Environment, Forests and Climate Change. LiFE aims to promote globally the practice of a lifestyle that is synchronous with nature and does not harm it, by individuals and communities. It proposes to bring about a fundamental change in both the way we produce and the way we consume. India has updated the first of its Nationally Determined Conclusions to include LiFE as follows: "India will put forward and propagate a healthy and sustainable way of living based on its traditions and the values of conservation and moderation, including through a mass movement for LiFE, as a key to combating climate change".

Subsequently India's Prime Minister, in his address to the World Economic Forum, referring to India's commitment to combating climate change, further elaborated on this theme.

" 'Throw away' culture and consumerism have made the climate challenge more serious. It is very important to rapidly shift today's 'take-make-use-dispose', economy towards a circular economy. The same spirit is at the core of the idea of Mission LiFE that I discussed at COP26. LiFE – means Lifestyle for Environment, a vision of such a Resilient and Sustainable Lifestyle that will be useful in not only dealing with Climate Crisis but also with futuristic unpredictable challenges. Therefore, it is important to transform Mission LiFE into a global mass movement. A public participation campaign like LiFE can be made into a big base for, P-3 'Pro Planet People' ".

Mission LiFE was launched by Hon'ble Prime Minister and Mr. Antonio Guterres, Secretary General at Ekta Nagar, Gujarat, India on October 20, 2022 as a global initiative to combat climate change and make it a people's movement across the world.

5.1 Three Core Shifts in Mission LiFE

As a global programme, Mission LiFE envisions three core shifts in our collective approach towards sustainability. These are:

1. Change in Demand (Phase I): Nudging individuals across the world to practice simple yet effective environment-friendly actions in their daily lives.

2. Change in Supply (Phase II): Changes in large-scale individual demand are expected to gradually nudge industries and markets to respond and tailor supply and procurement as per the revised demands.
3. Change in Policy (Phase III): By influencing the demand and supply dynamics of India and the world, the long-term vision of Mission LiFE is to trigger shifts in large-scale industrial and Government policies that can support both sustainable consumption and production.

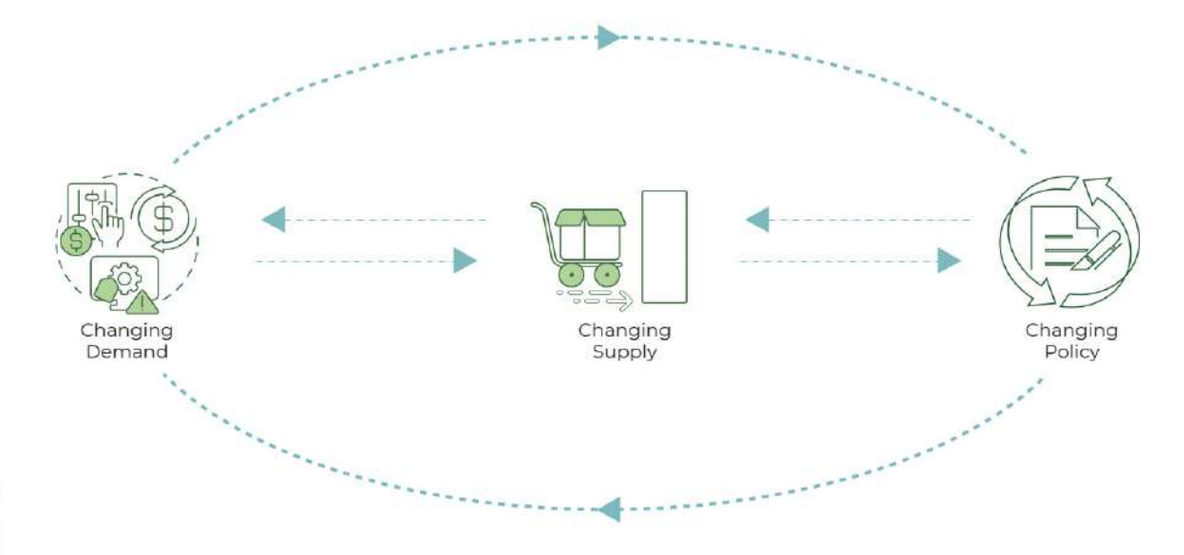


Figure 5.1 Inter-relationship between three Core Shifts in Mission LiFE

Source: *NITI Aayog, 2022a.*

In 2022-23, Mission LiFE will focus on Phase I, Change in Demand, by nudging individuals, communities and institutions to practice simple environment-friendly actions (LiFE actions) in their daily lives. In view of Mission LiFE being launched in the 75th year of India's independence, a comprehensive and non-exhaustive list of **75 individual LiFE actions** across **7 categories** is identified such that most actions are:

1. Specific and measurable
2. Easy to practice by individuals, communities and institutions, with minimal supply-side dependencies
3. Non-disruptive to ongoing economic activity, and, in fact, promoting economic activity in the foreseeable future

The identified 7 categories are:

1. Energy consumption
2. Water consumption
3. Reduced consumption of single use plastic
4. Adopting sustainable food systems
5. Reduction of wastes (Swachhata actions)
6. Adoption of healthy lifestyles
7. Reduction in e-waste

5.2 LiFE and Sustainable Development Goals (SDGs)

The SDGs, focused on sustainable cities and communities (SDG 11), responsible production and consumption (SDG 12), climate change (SDG 13), life on land (SDG 15), and life under water (SDG 14), all promote the sustainable use of natural resources. Further, bold environmental action could create large scale employment by 2030 (SDG 8: Decent Work and Economic Growth). SDG 12 entails decoupling economic growth and environmental degradation and demands more efficient and environmentally friendly management of resources, including improving energy efficiency, sustainable infrastructure, access to basic services, and providing green and decent jobs to ensure a better quality of life for all. The societal responsibility towards SDG 12 goes beyond businesses, to involve individual consumers as active participants in the process of achieving this goal. Given the global commitment to achieving the SDGs by 2030, it is important to note that Mission LiFE contributes directly and indirectly to almost all the SDGs.

5.3 Impact of Collective Action – Lifestyle for Environment

When estimated against a business-as-usual scenario the impact of LiFE actions globally can be significant. According to the United Nations Environment Programme (UNEP), if 1 out of 8 billion people worldwide adopt environment-friendly behaviours in their daily lives, global carbon emissions could drop up to 20%. The 2020 UNDP report 'The Next Frontier: Human Development and the Anthropocene' says that, "Humans wield more power over the planet than ever before. In the wake of COVID-19, record-breaking temperatures, and spiraling inequality, it is time to use that power to redefine what we mean by progress, where our carbon and consumption footprints are no longer hidden".

India has rich experience in implementing large-scale behavioural change programmes. While the world is focusing on policy and regulatory measures to address the environmental crisis, India has demonstrated success in harnessing the power of collective action to solve complex problems. LiFE builds upon India's environment-friendly culture and traditional practices, noting that India's per capita annual emissions are only a third of the world average (MoEFCC, 2021).

Taking LiFE forward as a global mission, India has, in a global call for ideas and papers, invited Ideas and research proposals from leading global scholars on how environment-friendly actions can be adopted by individuals, communities and institutions in a measurable and attributable manner. Partnering with other countries, MoEFCC and the Ministry of External Affairs, with the support of NITI Aayog, will coordinate efforts to continually identify and build capacity of countries worldwide to implement Mission LiFE for their respective populations.

Preparing a LiFE Compendium of Global Best and Traditional Practices, the NITI Aayog and MoEFCC, in partnership with United Nations India, will create a comprehensive repository of traditional and contemporary best practices from around the world that facilitate the adoption of environment-friendly lifestyles by individuals and communities.

Chapter 6 INTERNATIONAL COOPERATION

6.1 Strengthening global climate action

India has demonstrated a longstanding commitment to multilateral cooperation, which is critical to addressing the global climate challenge (MEA, 2018a). While India's historical responsibility for climate change – both in terms of its cumulative emissions contribution and its per capita emissions contribution – is low compared to that of developed nations and in absolute terms (See Section 1), it has nonetheless contributed substantially to global climate action. As the Indian economy continues to grow rapidly, meeting India's developmental needs will require scaling up infrastructure development and energy use. However, as a responsible global actor, India will ensure efficient and low-carbon growth that will allow for achievement of its development goals and contribute to mitigating greenhouse gas emissions, in accordance with its Nationally Determined Contribution (NDC) under the Paris Agreement.

As a developing country representing ~17% of the world's population, India has taken significant steps to implement climate mitigation measures to further global climate action (MEA, 2021e). Despite its development challenges, India is one of the few large economies on track to achieve its climate mitigation commitments under the Paris Agreement (MEA, 2021c). In addition, at COP26, Prime Minister Modi announced the *Panchamrit* ('five nectar elements') pledges, a series of new and forward-looking climate pledges to enable progress on India's energy transition and laying the groundwork for net-zero emissions by 2070 (MEA, 2021e). India is working with other countries to strengthen multilateral initiatives and foster strategic bilateral partnerships to meet these climate goals. It is also supporting other developing countries to do the same by advocating for a fair international climate regime that acknowledges the principle of equity and CBDR-RC under the UNFCCC and provides vulnerable populations with access to financial and technical assistance to meet their climate obligations without sacrificing their development and poverty alleviation goals.

6.2 International Leadership and Collaboration

6.2.1 Developing multilateral climate initiatives and platforms

Climate change is a global collective action problem that can only be tackled through multilateralism and international cooperation (MEA, 2021c). As a responsible international actor, India has recently developed several forward-looking and participatory global initiatives, partnerships, and coalitions to combat climate change and foster greater collaboration. These multilateral initiatives have focused largely on the experiences of vulnerable developing countries such as India, where climate impacts pose developmental and infrastructural risks to populations and livelihoods (MEA, 2021b).

1. Through the creation of the International Solar Alliance (ISA), a dedicated platform for cooperation between Governments, multilateral organizations, and industry, India together with France helped strengthen global cooperation on solar energy. The ISA aims to increase the use and quality of solar energy to meet energy needs in an affordable manner (MEA, 2018a). The ISA, to which India is providing financial, capacity-building and organizational assistance, is among the fastest-growing international organisations, with 107 signatory countries and 87 countries that have ratified the Framework Agreement (MEA, 2021b; ISA, 2022). In 2018, the Indian government announced

nearly USD 1.4 billion worth of lines of credit (LoCs) covering 27 solar projects in 15 countries, which are under various stages of implementation (MoEFCC, 2021). At COP26 in Glasgow, India and the United Kingdom also announced the first international network of interconnected transnational solar grids, called the Green Grids Initiative-One Sun One World One Grid (GGI-OSOWOG) (ISA, 2021). The ISA will continue to mobilize member countries to address technical, financial and capacity-building barriers to the deployment of solar energy (MEA, 2021a).

2. India launched the Coalition for Disaster Resilient Infrastructure (CDRI) at the 2019 Climate Summit. More than 25 countries – many from the G20 – and eight international organizations have joined the CDRI (CDRI, 2022). This international partnership of National Governments, UN agencies, Multilateral Development Banks, the private sector, and knowledge institutions will promote the resilience of new and existing infrastructure systems to growing climate risks and disasters. The Government of India has allocated US$70 million to support the work of the CDRI (MEA, 2021b). At COP26, India co-launched the Infrastructure for Resilient Island States (IRIS) Initiative, which aims to improve the resilience of infrastructure to climate change and disaster risk in Small Island Developing States (SIDS), strengthen knowledge and partnerships to integrate resilience, and promote gender equality and disability inclusion through resilient infrastructure (CDRI, 2021).
3. In the spirit of south-south cooperation, the India-UN Development Partnership Fund aims to contribute to developing countries' efforts to realise the 2030 Agenda for Sustainable Development Goals, including on Climate Action. Established in 2017, the fund continues to support countries in the Pacific Islands, Africa, and the Caribbean with climate early warning systems, solar home systems, solar pumps, and projects to repair damage due to climate-induced weather events. The fund has supported projects in 48 countries for various SDGs through a US$150 million multi-year pledge by the Government of India (MEA, 2021b).
4. At the 2019 Climate Summit, India and Sweden launched the Leadership Group on Industry Transition (LeadIT), supported by the World Economic Forum and the Stockholm Environment Institute. This initiative provides a platform for Governments and the private sector to identify low-carbon business opportunities, cooperate on net-zero technology innovation and exchange knowledge on sectoral roadmaps for hard-to-abate sectors (MEA, 2019). Currently, the LeadIT initiative includes 19 industry leaders and 18 member countries (MEA, 2021b; LeadIT, 2022).
5. These collaborations reflect the continuation of India's longstanding commitment to global climate cooperation under the UNFCCC. Reflecting this commitment, India is also a signatory to numerous international agreements, conventions, protocols, and treaties on climate and environmental issues (UNEP, 2005).

6.3 Towards an Equitable Global Climate Response

The United Nations Framework Convention on Climate Change establishes that "the largest share of historical and current global emissions of greenhouse gases has originated in developed countries"; that "per capita emissions in developing countries are still relatively low" and that the "share of global emissions originating in developing countries will grow to meet their social and development needs" (United Nations, 1992). The principles and commitments of the Convention also establish that climate action should be determined on the basis of equity and in accordance with common but differentiated responsibilities and respective capabilities, with adequate consideration of socioeconomic conditions,

development priorities, and national objectives and circumstances (UN, 1992). Based on climate science, the operationalization of equity and climate justice requires that all countries have access to an equitable and fair share of the global carbon budget.

BOX 6.1: India's International Climate Actions

India has taken leadership in launching Coalition for Disaster Resilient Infrastructure (CDRI) to promote resilience of new and existing infrastructure systems to climate and disaster risk. This currently has membership of 31 countries including India and US, and 8 international organisations.

The International Solar Alliance (ISA) is also a prime example of how positive and constructive global climate action can be taken forward through partnership. The ISA currently has 108 countries as signatory, the latest being the United States, Norway, Hungary and Panama that joined the Alliance.

India and Sweden are leading the industry (LeadIT) transition track to promote voluntary action for low carbon transition in hard to abate industry sectors, following the original invitation by the United Nations Secretary General.

As a climate-vulnerable country with a limited historical contribution to causing climate change, and low historical and current per-capita emissions, India has made significant progress towards global climate action by reducing the emissions intensity of its economic activities and enabling a clean energy transition. India's stated climate goals can be fully realized only if financial assistance, low-carbon technology transfer and capacity-building needs are met under the provisions of the UNFCCC and its Paris Agreement. Developed nations must take the lead not only in emissions reductions, but in developing international climate finance and technology arrangements that respond to gaps in available resources in the developing world.

India can neither afford to defer the unmet energy and human development requirements of its population, nor remain unresponsive to the threat that climate change poses to its development goals. Predictable, sustained and adequate climate finance would accelerate progress towards India's climate and development goals (MEA, 2018b; 2021d).

6.3.1 Improving Access to Climate Finance

In this context, there remain serious shortcomings in the scope, scale, and speed of the climate finance made available to developing countries from developed countries, multilateral development banks, and

multilateral climate funds, including UNFCCC funds (MoEFCC, 2021). There are also shortcomings in defining, tracking, and reporting international climate finance flows in standardized ways (MoEFCC, 2021). In addition, the climate finance available to the developing world is inadequate to meet either mitigation or adaptation needs as set out in NDC, and existing financial resources tend to be skewed towards mitigation rather than adaptation, with adverse implications for developing countries facing climate-induced disasters (MoEFCC, 2021). In the past, India has repeatedly drawn attention to these issues (DEA, 2015; (MoEFCC, 2021)).

Raising India's climate ambitions will require new, additional, and climate-specific financial resources and support. Furthermore, India is committed to global cooperation on developing transparent climate finance processes and equitable market mechanisms to fill financing gaps. Initiatives aimed at scaling up sustainable investments, particularly in climate adaptation, will play an important role in financing long-term low-carbon development pathways. India will urge the global community to disseminate information on best practices related to climate finance, closely track international climate finance flows though standardized processes, and identify barriers and opportunities to scale up international climate finance in multilateral discussions with other countries. In the absence of a roadmap for climate finance, India and other developing countries will face serious constraints in achieving the climate goals in subsequent updates to NDC (MEA, 2018a). Therefore, it is India's view that the global climate regime should track progress not just on climate mitigation efforts, but on the delivery of international climate finance to developing countries (MEA, 2021e).

6.3.2 Facilitating Technology Transfer, and Support for Losses and Damages

India cannot deploy low-carbon climate technologies at a significant scale unless a facilitative global technology transfer regime is in place, and the incremental and associated costs of these technologies are met from international climate funds. A collaborative international mechanism needs to ensure that barriers such as intellectual property rights are lowered to facilitate technology transfer from developed to developing countries. Through engagement with multilateral platforms, India will seek to increase access to low-carbon technologies, including solar photovoltaics, offshore wind equipment, LED bulbs, efficient air conditioners, low-carbon iron and steel manufacturing technologies, biofuels and hydrogen technology (MoEFCC, 2021). India will aim to stimulate markets for clean energy technologies emerging in India, with investment pathways developed in accordance with international best practices for research, innovation, and manufacturing in this field. India also aims to support multilateral initiatives to create networks of research institutions working on clean energy technologies and their deployment-related best practices in India and in other countries (MoEFCC, 2021). Enabling low-carbon technologies and emerging scientific fields may require institutions to create global technological standards to encourage production and use. India will also contribute to, and support, such efforts (MEA, 2022).

As climate-induced heat waves, floods, cyclones, and irregular rainfall patterns increase in frequency and intensity over South Asia, India will experience infrastructural losses and damages due to climate change. India looks forward to furthering a productive global dialogue on a potential framework with which to address developing countries' responses to losses and damages, within the scope of the provisions and principles established under the UNFCCC (PIB, 2019a).

6.3.3 Building Cooperative rather than Exclusionary Global Processes

India is committed to advancing common sustainable development goals. It also believes that international cooperation is necessary to support developing economies through finance and technology and win-win strategies. Coordinated actions that advance technologies while expanding market access for goods from developing countries are important for a smooth transition, whereas exclusionary and discriminatory regulations such as border carbon taxes may raise barriers to the transition in developing countries (MEE, 2021). India is committed to the principles for cooperation under the United Nations Framework Convention on Climate Change, and the Paris Agreement negotiated under the Framework, and reiterates the importance of meeting the nationally determined contributions under the Agreement rather than building parallel tracks for pursuing climate progress (PIB, 2021d).

Apart from cooperation over climate finance, joint projects, inter-ministerial dialogues, channels for sharing knowledge and experience, joint development of global technology standards, building networks of research institutions, and strategic technology partnerships are some of the potential avenues for strengthening international cooperation that India believes can enable an equitable and sustainable transition (PIB, 2021e). Both non-market and market mechanisms such as agreed under Article 6 of the Paris Agreement will play an important role in India's engagement with the global community on climate change going forward (PIB, 2019b).

List of Abbreviations

AFR	Alternate Fuels and Raw Materials
AIPA	Apex Committee for the Implementation of the Paris Agreement
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AUSC	Advanced Ultra Supercritical Coal Technology
BAU	Business as Usual
BEE	Bureau of Energy Efficiency
Bio-PNG	Bio Piped Natural Gas
BoM	Bill of Materials
BRSR	Business Responsibility and Sustainability Report
BURs	Biennial Update Reports
CAGR	Compound Annual Growth Rate
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CAPEX	Capital Expenditure
CBDR-RC	Common But Differentiated Responsibilities and Respective Capabilities
CBG	compressed biogas
CCS	Carbon capture and storage
CCUS	Carbon Capture Utilisation and Storage
CDRI	Coalition for Disaster Resilient Infrastructure
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CEM	Climate Equity Monitor
CERC	Central Electricity Regulatory Commission
CII	Confederation of Indian Industry
COG	Coke Oven Gas
CORE	Central Organization for Railway Electrification
CPHEEO	Central Public Health & Environmental Engineering Organization
CSCAF	Climate Smart Cities Assessment Framework
c-Si	crystalline Silicon
CSIR	Council of Scientific and Industrial Research
DAE	Department of Atomic Energy
DCR	Development Control Regulations
DEA	Department of Economic Affairs
DISCOM	Distribution Company
DME	Dimethyl ether
DST	Department of Science & Technology
ECBC	Energy Conservation Building Code
ECCC	Executive Committee on Climate Change
EMU	Electric Multiple Unit

ESG	Environmental, Social and Governance
ESMF	Environmental and Social Management Framework
ESO	Energy Storage Obligations
EVs	Electric Vehicles
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FAO	Food and Agricultural Organisation
FDI	Foreign Direct Investment
FFPMS	Forest Fire Prevention and Management Scheme
FICCI	Federation of Indian Chambers of Commerce and Industry
FSI	Forest Survey of India
GA	Green Ammonia
GCF	Green Climate Fund
GDP	Gross domestic product
GGI-OSOWOG	Green Grids Initiative One Sun One World One Grid
GH	Green Hydrogen
GHG	Greenhouse Gas
GIM	Green India Mission
GIS	Geographic Information System
GRIHA	Green Rating for Integrated Habitat Assessment
GVA	Gross value added
HAPs	Heat Action Plans
HDI	Human Development Index
HFFA	Hydro Processed Esters and Fatty Acids
HKH	Hindu Kush Himalaya
HPC	High Performance Computing
ICAP	India Cooling Action Plan
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IDSC	Inter Departmental Steering Committee
IEA	International Energy Agency
IGBC	Indian Green Building Council
IGCC	Integrated Gasification Combined Cycle
IIP	Indian Institute of Petroleum
ILO	International Labour Organization
INR	Indian Rupee
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IRIS	Infrastructure for Resilient Island States

ISA	International Solar Alliance
IT	Information Technology
IUCN	International Union for Conservation of Nature
IWMP	Integrated Watershed Management Programme
JI-VAN	Jaiv Indhan Vatavaran Anukool fasal awashesh Nivaran
LAPs	Local Area Plans
LeadIT	Leadership Group on Industry Transition
LED	Light emitting diode
LEED	Leadership in Energy and Environmental Design
Li -Br	Lithium bromide
LiFE	Lifestyle for Environment
LMV	Light Motor Vehicle
LNG	Liquified natural gas
LoCs	Lines of credit
LPG	Liquefied petroleum gas
LT-LEDS	Low-Term Low greenhouse gas Emission Development Strategies
LULUCF	Land Use and Land Use Change and Forestry
MEA	Ministry of External Affairs
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MNRE	Ministry of New and Renewable Energy
MoC	Ministry of Coal
MoEFCC	Ministry of Environment, Forest and Climate Change
MoF	Ministry of Finance
MoHUA	Ministry of Housing and Urban Affairs
MoP	Ministry of Power
MoR	Ministry of Railways
MoRTH	Ministry of Road Transport & Highways
MoS	Ministry of Steel
MSME	Micro Small and Medium Enterprises
MSW	Municipal Solid Waste
NAFCC	National Adaptation Fund for Climate Change
NAP	National Afforestation Programme
NAP	National Agroforestry Policy
NAPCC	National Action Plan on Climate Change
NBA	National Biodiversity Authority
NBAP	National Biodiversity Action Plan
NDC	Nationally Determined Contribution
NDMA	National Disaster Management Authority
NFP	National Forest Policy

NG	Natural Gas
NHAI	National Highways Authority of India
NICRA	National Innovations in Climate Resilient Agriculture
NITI Aayog	National Institution for Transforming India
NMSA	National Mission for Sustainable Agriculture
NRDC	National Research Development Corporation
NRF	National Research Foundation
NRLM	National Rural Livelihoods Mission
NTFP	Non Timber Forest Products
NUPF	National Urban Policy Framework
NVY	Nagar Van Yojana
OECD	Organisation for Economic Cooperation and Development
OMCs	Oil Marketing Companies
PA	Paris Agreement
PAT	Perform, Achieve and Trade
PIB	Press Information Bureau
PLI	Production Linked Incentive
PLI ACC	Production Linked Incentive Advanced Chemistry Cell
PMAY	Pradhan Mantri Awaas Yojana
PMUY	Pradhan Mantri Ujjwala Yojana
PV	Photovoltaic
R&D	Research & Development
RBI	Reserve Bank of India
RCP	Representative Concentration Pathway
RDF	Refuse derived fuel
RE	Renewable Energy
REDD+	Reducing Emissions from Deforestation and forest Degradation
ROSHANEE	Roadmap of a sustainable and holistic approach to National Energy Efficiency
RPO	Renewable Purchase Obligations
SAF	Sustainable Aviation Fuel
SATAT	Sustainable Alternative Towards Affordable Transportation
SBM	Swachh Bharat Mission
SCADA	Supervisory Control and Data Acquisition
SCM	Smart Cities Mission
SDGs	Sustainable Development Goals
SEBI	Securities and Exchange Board of India
SIDS	Small Island Developing States
SNY	School Nursery Yojana

SPM	Summary for Policy Makers
TACE	Technical Advisory Committee of Experts
TIFAC	Technology Information Forecasting and Assessment Council
TOF	Trees Outside Forests
TPPs	Thermal Power Plants
UJALA	Unnat Jyoti by Affordable LEDs for All
ULBs	Urban Local Bodies
UN	United Nations
UNEP	United Nations Environment Programme
UNEP-DTU	United Nations Environment Programme Danish Technical University
UNFCCC	United Nations Framework Convention on Climate Change
URDPFI	Urban and Regional Development Plans Formulation and Implementation
USD	United States Dollar
UTs	Union Territories
VAM	Vapour absorption/adsorption machines
VGF	Viability Gap Finance

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