Report on Currency and Finance

2022-23

TOWARDS A GREENER CLEANER INDIA

RESERVE BANK OF INDIA

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REPORT ON
CURRENCY AND FINANCE 2022-23

TOWARDS A GREENER CLEANER INDIA

RESERVE BANK OF INDIA

"The findings, views and conclusions expressed in this Report are entirely those of the contributors from the Department of Economic and Policy Research (DEPR) and do not represent the views of the Reserve Bank of India".

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FOREWORD

Climate change has always been an integral part of human existence. With rapid industrialisation and urbanisation since the 19th century, climate change has acquired a new dimension, threatening the sustainability of life, livelihood and the surrounding ecosystem. The rising incidence of extreme climate events in recent decades has raised greater public awareness about its adverse effects. Growing scientific evidence that climate change is also caused by human activities – a result of excessive burning of fossil fuels; deforestation; inappropriate agricultural practices, *etc.* – has led to a global consensus on the need for coordinated policy actions, encompassing both adaptation and mitigation strategies. Since the historic Paris Agreement of 2016, climate agenda has increasingly become target-oriented.

India has embarked on an ambitious and targeted climate action plan while balancing its growth and environmental objectives. In line with the target of Net Zero emissions by 2070, India has updated its nationally determined contributions (NDCs), which aim at raising the share of renewable energy and reducing the carbon emissions intensity of GDP by 2030. India presented its Long-Term Low Emission Development Strategy at the COP27, covering plans for expansion of green hydrogen production, electrolyser manufacturing capacity and increased use of biofuels. To strengthen solutions-based international cooperation, India has also launched and nurtured the International Solar Alliance, the Coalition for Disaster Resilient Infrastructure, and the Mission LiFE (Lifestyle for Environment).

India ranked high (seventh) in the list of most affected countries in terms of exposure and vulnerability to climate risk events as per the Global Climate Risk Index 2021, but it is also the highest ranked G-20 country in its climate protection performance as per the Climate Change Performance Index 2023. This reflects the progress made on four parameters – greenhouse gas (GHG) emissions; renewable energy; energy use; and climate policy. India will soon become the most populous country in the world. Preserving food and energy security amidst extreme climatic events while obtaining access to technology and critical raw materials required for successful green transition will, therefore, remain a key policy challenge for India.

Climate change induced risks to macro-financial prospects of the country and the range of policy options available to mitigate climate risks require dedicated research. Such research becomes even more critical in the context of the complexity and non-linearity of the ways in which climate, economy, financial systems and related policies operate. Hence, this year's Report on Currency and Finance has "Towards a Greener Cleaner India" as its theme. Structured in four chapters, this Report highlights the importance of climate goals as a policy priority and examines the macro-financial implications of climate change for India in the medium to long term. The focus is on growth, inflation and financial stability. It explores the range of available policy options – fiscal policy; technology; trade policy; regulatory policy; and monetary policy – for mitigating climate risks. I commend the team from the Department of Economic and Policy Research (DEPR) of the Reserve Bank for examining some of the key aspects of the climate change challenge for India in this Report, with a forward looking perspective. I hope this Report will enrich public policy discourse on the subject.

Shaktikanta Das
Governor
May 3, 2023

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LIST OF ABBREVIATIONS

ACC	Automotive Cell Company
ACES	Automated, Connected, Electric and Shared
ACPR	Autorité de contrôle prudentiel et de resolution [French Prudential Supervision and Resolution Authority]
AEs	Advanced Economies
AI	Artificial Intelligence
APS	Announced Policies Scenario
ASI	Annual Survey of Industries
AUM	Assets Under Management
BAU	Business As Usual
BB	Bank of Bangladesh
BC	Benefit-Cost
BCAs	Border Carbon Adjustments
BCBS	Basel Committee on Banking Supervision
BEE	Bureau of Energy Efficiency
BF/BOF	Basic Oxygen Furnace
BIS	Bureau of Indian Standards
BIS	Bank for International Settlements
BoE	Bank of England
BoJ	Bank of Japan
BRICS	Brazil, Russia, India, China, South Africa
BRRs	Business Responsibility Reports
BRSR	Business Responsibility and Sustainability Report
BSE	Bombay Stock Exchange
CAGR	Compound Annual Growth Rate
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CAPEX	Capital Expenditure
CAT	Climate Action Tracker
CaT	Cap-and-Trade
CBA	Cost-Benefit Analysis
CBAM	Carbon Border Adjustment Mechanism
CBDC	Central Bank Digital Currency
CBG	Compressed Biogas
CBT	Carbon Border Tax
CCA	Climate Commitment Act
CCM	Climate Change Mitigation
CCPI	Climate Change Performance Index
CCPT	Climate Change Principle-based Taxonomy
CCUS	Carbon Capture, Utilisation and Storage
CCUS	Carbon Capture, Usage and Storage
CDM	Clean Development Mechanism
CDRI	Coalition for Disaster Resilient Infrastructure
CEA	Central Electricity Authority
CERF	Climate Equity Reference Framework
CFBL	Carbon Footprint of Bank Loans
CFCs	Chlorofluorocarbons

CFGs	Climate Friendly Goods
CH4	Methane
CI	Carbon Intensity
CMEMS	Copernicus Marine Environment Monitoring Service
CMIE	Centre for Monitoring Indian Economy
Cms	centimetres
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of the Parties
CPHS	Consumer Pyramids Household Surveys
CRISK	Capital Shortfall Risk
CRP	Climate Risk Portfolio
CSA	Climate Smart Agriculture
CSE	Centre for Science and Environment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	Corporate Social Responsibility
DFM	Dynamic Factor Model
DICE	Dynamic Integrated model of Climate and the Economy
D-i-D	Difference in difference
DISCOMs	Distribution Companies
DNSH	Do No Significant Harm
DP	Detailed Process
DSGE	Dynamic Stochastic General Equilibrium
EAF	Electric Arc Furnace
EBF	European Banking Federation
ECB	European Central Bank
eCoC	Electronic Certificate of Compliance
E-DSGE	Environment-DSGE
EI	Energy Intensity
EIBs	European Investment Bonds
EIE	Emission Intensity of Value-added on Exports
EIM	Emission Intensity of Value-Added on Imports
EKC	Environmental Kuznets Curve
ELIS	Environmental Labelling and Information Schemes
EM-DAT	Emergency Events – Database
EMEs	Emerging Market Economies
EMS	Emission Trading Systems
EPPA	Economic Projection and Policy Analysis
ERPs	ESG Rating Providers
ESCS	Extremely Severe Cyclonic Storms
ESG	Environment, Social and Governance
ESRB	European Systemic Risk Board
ETR	Environmental Tax Reform
ETS	Emissions Trading System
EU	European Union
EVs	Electric Vehicles
FAME	Faster Adoption and Manufacturing of Hybrid Electric Vehicles

FAO	Food and Agriculture Organisation
FDI	Foreign Direct Investment
FIT	Feed-in-Tariffs
FSB	Financial Stability Board
FTA	Free Trade Agreements
GAR	Green Asset Ratio
GCCI	Global Climate Change Index
GDP	Gross Domestic Product
GDP_{PC}	GDP Per Capita
GFSG	Green Finance Study Group
GGEF	Green Growth Equity Fund
GHG	Green House Gases
GIS	Geographic Information System
GMSL	Global Mean Sea Level
GNPA	Gross Non-Performing Assets
GOBARdhan	Galvanising Organic Bio-Agro Resources Dhan
GoI	Government of India
GPCB	Gujarat Pollution Control Board
GSDP	Gross State Domestic Product
GSF	Green Supporting Factor
GST	Goods and Services Tax
Gt	Gigatonnes
$GtCO_2eq$	Gigatonnes of CO_2 equivalent
GVA	Gross Value Added
GVCs	Global Value Chains
IAM	Integrated Assessment Model
IBFI	Index Based Flood Insurance
ICAAP	Internal Capital Adequacy Assessment Process
ICE	Internal Combustion Engine
ICSU	International Council of Scientific Unions
ICT	Information and Communications Technology
IEA	International Energy Association
IFRC	International Federation of Red Cross and Red Crescent Societies
IMD	India Meteorological Department
IMF	International Monetary Fund
INCCA	Indian Network for Climate Change Assessment
INFORM	Index for Risk Management
IOSCO	International Organization of Securities Commissions
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPSF	International Platform for Sustainable Finance
IRA	Inflation Reduction Act
IRDA	Insurance and Regulatory Development Authority
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
ISTS	Inter-state Transmission Systems
KLEMS	Capital, Labour, Energy, Material, and Services
Km^2	Kilometer Square
KPIs	Key Performance Indicators

kWh	Kilowatt-hour
LCOE	Levelised Cost of Electricity
LiDCs	Low-Income Developing Countries
LED	Light Emitting Diode
LiFE	Lifestyle for Environment
LIMITS	Low climate Impact scenarios and the Implications of required Tight emission control Strategies
LMDI	Logarithmic Mean Divisia Index
LPA	Long Period Average
LST	Land Surface Temperature
LT-LEDS	Long-term Low Greenhouse Gas Emission Development Strategies
LULC	Land Use and Land Cover
MaaS	Mobility as a Service
MARS	Multivariate Adaptive Regression Splines
MFs	Mutual Funds
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MIGA	Multilateral Investment Guarantee Agency
MIT	Massachusetts Institute of Technology
ML	Machine Learning
Mm	Millimetre
MMT	Million Metric Tonnes
MT	Million Tonnes
MW	Megawatt
MNRE	Metric tonnes per year
MoEFCC	Ministry of Environment, Forest and Climate Change
MoES	Ministry of Earth Sciences
MoPNG	Ministry of Petroleum and Natural Gas
MoSPI	Ministry of Statistics and Program Implementation
MoU	Memorandum of Understanding
MRTS	Mass Rapid Transit Systems
MRV	Monitoring, Reporting, And Verification
MRV	Measurement, Reporting, and Verification
MSCI	Morgan Stanley Capital International
MSMEs	Micro, Small and Medium Enterprises
N_2O	Nitrous Oxide
NBFCs	Non-Banking Finance Companies
NCEF	National Clean Energy Fund
NCR	National Capital Region
NDC	Nationally Determined Contribution
NDTL	Net Demand and Time Liabilities
NECR	Net Effective Carbon Rate
NeML	National Commodities and Derivatives Exchange e-Market Limited
NFCI	National Financial Conditions Index
NGBRC	National Guidelines on Responsible Business Conduct

NGFS	Network for Greening the Financial System
NGO	Non-governmental organization
NHPC	National Hydroelectric Power Corporation
NIFTY	National Stock Exchange Fifty
NIGEM	National Institute Global Econometric Model
NIO	North Indian Ocean
NMEEE	National Mission for Enhanced Energy Efficiency
NMSA	National Mission for Sustainable Agriculture
NOAA	National Oceanic and Atmospheric Administration
NPAs	Non-Performing Assets
NRDC	Natural Resources Defence Council
NSDP	Net State Domestic Product
NSO	National Statistical Office
NSSO	National Sample Survey Organisation
NVA	Net Value Added
O3	Ozone
OHC	Ocean Heat Content
OECD	Organisation for Economic Cooperation and Development
OWID	Our World in Data
PAT	Perform, Achieve, Trade
PBoC	People's Bank of China
PE	Private Equity
PIB	Press Information Bureau
PLI	Production Linked Incentive
PM-PRANAM	PM Programme for Restoration, Awareness, Nourishment and Amelioration of Mother Earth
PPP	Public-Private Partnerships
PRA	Prudential Regulation Authority
PRI	Principles of Responsible Investment
PSBs	Public Sector Banks
PSL	Priority Sector Lending
PTAs	Preferential Trade Agreements
PV	Photovoltaic
PVBs	Private Banks
QE	Quantitative Easing
R&D	Research and development
RBI	Reserve Bank of India
RCPs	Representative Concentration Pathways
RPO	Renewable Purchase Obligations
RTAs	Regional Trade Agreements
SAARC	South Asian Association for Regional Cooperation
SCBs	Scheduled Commercial Banks
SCS	Severe Cyclonic Storms
SDG	Sustainable Development Goals
SEBI	Securities and Exchanges Board of India
SECI	State Energy and Climate Index
SGBs	Sovereign Green Bonds
SGS	State Government Securities
SME	Small to Medium Enterprise

SST	Sea Surface Temperature
STEPS	Stated Policies Scenario
SuCS	Super cyclonic storms
SWM	South-west Monsoon
TBC	To be Continued
tCO_2e	Tonne of Carbon Equivalent
$TECO_2$	Trade in embodied CO_2 database
TiVA	Trade in Value Added
TOP	Tomato, Onion, Potato
TPA	Tonnes per annum
TSC	Technical Screening Criteria
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	UN Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNISDR	United Nations International Strategy for Disaster Reduction
US	United States
USA	United States of America
USD	US Dollar
UTs	Union Territories
VAT	Value Added Tax
VC	Venture Capital
VRE	Variable Renewable Energy
VSCS	Very Severe Cyclonic Storms
VSIC	Vietnam Standard Industrial Classification
WCP	World Climate Programme
WEO	World Economic Outlook
WGMS	World Glacier Monitoring Service
WMO	World Meteorological Organisation
ZJ	Zeta Joules

I THE CLIMATE STRIKES BACK*

Climate change is manifesting itself at an alarming scale and pace globally. Emerging and developing economies are the most vulnerable in terms of technological capabilities and access to finance for adaptation and mitigation. There has been a significant increase in climate action, both multilaterally and in individual countries. Alongside fiscal policies, recent years have seen a growing experimentation with regulatory instruments and hence, the role of central banks in combating climate change is coming to the fore. The Reserve Bank of India is actively involved in fortifying India's climate defence through various policy and research initiatives.

1. Introduction

I.1 Climate change is upon us. According to the World Meteorological Organisation (WMO), the period 2015-22 is the warmest on record. Despite the cooling effects of *La Nina* into its third year, 2022 was the eighth consecutive year in which annual global temperature reached at least 1 degree Celsius above pre-Industrial Revolution levels, fuelled by ever-rising greenhouse gas (GHG) concentrations and accumulated heat.

I.2 In the European Alps, glacier melt records were broken in 2022. Switzerland lost about 6 per cent of its glacier ice volume between 2021 and 2022. For the first time in history, there was no accumulation of fresh ice even at the very highest measurement sites (WMO, 2023). Sea levels increased by about 5 millimetres during January 2021 – August 2022 due to increasing ice melt. In 2021, the upper 2000 metres of the ocean continued to warm to record levels. Furthermore, 58 per cent of the ocean surface experienced at least one marine heat wave during 2022 (*ibid*). There was a drop in the Antarctic sea ice extent to 1.92 million km^2, which was the lowest level on record and was almost 1 million km^2 below the long-term average. In East Africa, rainfall was below-average in four wet seasons consecutively, the longest in 40 years (WMO, 2023). The persistent drought resulted in the worst levels of food crisis for an estimated 18.4-19.3 million people (WMO, 2022).

I.3 Pakistan witnessed record breaking rains in July and August 2022 leading to extensive flooding, taking at least 1,700 lives and affecting 33 million people. The flooding occurred on the heels of an extreme heat wave in March and April in both Pakistan and India. China experienced the most extensive and long-lasting heatwave since national records began. Large parts of Europe sweltered in repeated episodes of extreme heat. More than 15,000 excess deaths associated with extreme heat were reported across Europe (WMO, 2023). European rivers, including the Rhine, Loire and Danube, fell to critically low levels. In the United Kingdom (UK), temperatures rose above 40 degrees Celsius in July 2022 for the first time. Southern Africa was battered by a series of cyclones over two months at the start of 2022. Hurricanes swept across Cuba and Florida, causing extensive damage and loss of life in 2022. During 1970-2019, weather, climate and water hazards claimed 45 per cent of total

* This chapter has been prepared by a team comprising Michael Debabrata Patra, Pallavi Chavan, Harendra Behera, Soumasree Tewari, Kovuri Akash Yadav, Ranjeeta Mishra, Paritosh Jha, Amarendra Acharya and Jessica Maria Anthony.

reported deaths and 74 per cent of total reported economic losses (WMO, 2021). These hazards have undermined livelihoods and infrastructure as well as health, food, energy and water security. Human well-being is endangered and so is the future of the planet.

I.4 India has faced its hottest February in 2023 since record-keeping began in 1901 (IMD, 2023). In March, large parts of the country experienced hailstorms and torrents of unseasonal rain, leading to apprehensions of extensive damage to standing crops. According to India's Centre for Science and Environment (CSE), the country experienced extreme weather events on 314 of 365 days of 2022, which claimed 3,026 lives, affected 1.96 million hectares of crop area and 4,23,249 houses, and killed over 69,899 animals[1]. Central India witnessed the highest intensity of extreme weather events. Among the states, Madhya Pradesh had the highest number of days with extreme weather, but Himachal Pradesh from the north-west region reported the highest number of deaths. In the eastern and north-eastern regions, Assam suffered from the highest number of damaged houses and animal deaths. In the southern peninsula region, Karnataka experienced extreme weather events on 91 days during the year and accounted for 53 per cent of the total crop area affected across the country.

I.5 In 2022, India recorded its seventh wettest January since 1901[2]. March was the third driest and warmest ever in 121 years. Eastern and north-eastern India saw their warmest and driest July in 121 years. These regions also recorded their second warmest August and the fourth warmest September in 2022. India seems to be at the watermark of climate change – rather than single events, it is the increased frequency of extreme weather occurrences that is breaking the back of our capability to cope with natural disasters. There is a definite rising trend; but more than the events themselves, India is grappling with severe losses and damages – the human toll of the impact of climate change.

I.6 Awareness of the impact of greenhouse gases on earth's temperature is not new. Joseph Fourier, a French physicist, had identified the "greenhouse effect" in 1824, which was quantified in 1896 by Svante Arrhenius, a Swedish scientist (Steiner and Fortuna, 2020). Since the 18th century, the impact of climate and environment on the course of human development has drawn attention (Livingstone, 2011)[3]. While natural factors can contribute to climate change, it is now widely recognised that the current scale and pace of climate change is primarily attributable to the anthropogenic factors (NRC, 2001). In fact, the period from the mid-20th century has been defined as the "Anthropocene" epoch, marking a significant impact of human activity on earth's climate due to an increased use of oil, coal and other fossil fuels to support economic growth (Subramanian, 2019).

I.7 It is only from the late 20th century that there has been an increased interest in the

1 India's Atlas on Weather Disasters, https://www.downtoearth.org.in/weather_disasters_india/india.html, Accessed on April 28, 2023.

2 *India-2022: An Assessment of Extreme Weather Events*, Down To Earth, New Delhi; see https://cdn.downtoearth.org.in/pdf/extreme-weather-report-20221102.pdf?utm_source=Mailer&utm_medium=Email&utm_campaign=Down%20To%20Earth-extreme-weather-report-20221102

3 Baron de Montesquieu argued that "there are countries where the excess of heat enervates the body, and renders men so slothful and dispirited that nothing but the fear of chastisement can oblige them to perform any laborious duty…" (1748, p. 354). Alfred Marshall regarded climate as being a determinant of racial characteristics. He argued that in warm countries we find early marriages and high birth rates, "and in consequence, a low respect for human life: this has probably been the cause of a great part of the high mortality that is generally attributed to the insalubrity of the climate…Vigour depends partly on race qualities: but these, so far as they can be explained at all, seem to be chiefly due to climate" (Marshall, 1895, p. 276).

"economics of climate change", relating to (a) assessing the economic impact of climate change on growth and development; and (b) economic assessment of climate change policies. Seminal work attempting to understand the economics of climate change has been undertaken through the Integrated Assessment Models (IAMs) such as the Dynamic Integrated model of Climate and the Economy (DICE) (Nordhaus, 1992; Stern, 2007).

I.8 Affirmative action in pursuit of the climate as a global policy good is of even more recent vintage. The Paris Agreement of 2016 has been a landmark in achieving the first legally binding international treaty on climate change for all signatories, a successor to the Kyoto Protocol of 2005. This Agreement has introduced long-term goals regarding the reduction of GHG emissions, and provision of finance to developing countries by developed countries to adapt to and mitigate climate change. Despite the slow pace of implementation, unfulfilled commitments towards collectively financing climate action and vulnerability/discord/knowledge gaps, the Agreement has offered a glimmer of hope about the transition towards a greener cleaner world.

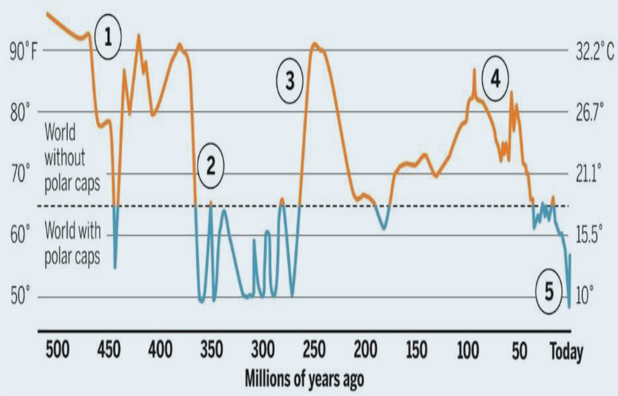
I.9 India's development strategy since independence has left certain environmental imprints[4]. This recognition is belatedly spurring investments in environment-friendly alternative sources of energy and in climate science and technology. Today, India is striving to consolidate its position in the ongoing global climate policy discourse with an urgency not seen before as the world races to head off the debilitating effects of climate change.

I.10 Against this backdrop, the Report on Currency and Finance for the year 2022-23 adopts "Towards a Greener Cleaner India" as its theme. The following section underscores the need for speed and resolute commitment by analysing the manifestations of climate change through key physical indicators at the global level. The third section reviews the state of play that is leading up to global climate policies. India's position in global negotiations is set out in the fourth section. Central banks, including the Reserve Bank of India (RBI), have emerged as stakeholders in the global climate change discussions and this forms the subject matter of the fifth section, which is followed by the lay-out of the rest of the Report to conclude this chapter.

2. Global Manifestation of Climate Change

I.11 The global mean surface temperature today is about 14.8 degrees Celsius (Chart I.1)[5].

Chart I.1: Estimated Global Temperature Over Past 500 Million Years



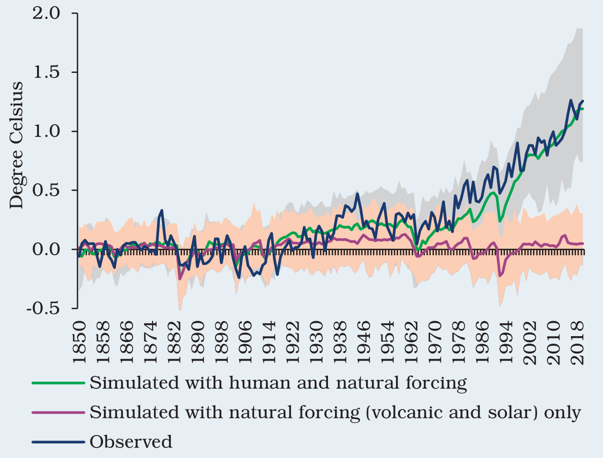
Notes: a. (1): Marine life diversified in extreme heat; (2): Land-based plant absorbed CO_2 and polar ice caps formed; (3): Volcanoes and erosion increased CO_2 levels; (4): Mammals evolved in a warm period; (5): Humans are rapidly warming the climate.
b. Based on preliminary results from a Smithsonian Institute project led by Scott Wing and Brian Huber.

Source: Scott and Lindsay (2020).

[4] For instance, see Pingali (2012) for an illustration of the environmental impact of green revolution in developing countries, including India.

[5] Global temperature is worked out based on data from National Centers for Environmental Information. Accessed on April 28, 2023 from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202113.

Chart I.2: Causes of Recent Global Warming



Note: Changes in global surface temperature for the past 170 years, by simulating the data for 1850-1900, highlight the dominance of anthropogenic factors in the recent global warming.
Source: IPCC Sixth Assessment Report - Summary for Policymakers (2021).

Although temperature increases have been recorded during the course of earth's history, the current episode of anthropogenic climate change is qualitatively different from the historical experience in four major ways. First, changes in the earth's climate that are underway are largely human-induced, as noted earlier, while the earlier incidences were primarily the result of various natural factors (Chart I.2).

I.12 Second, the pace of climate change during the current phase is remarkably rapid – it is unfolding over decades whereas earlier occurrences of climate change happened over centuries and millennia (Krishnan *et al*., 2020). Third, costs involved in the policy responses for adaptation to and mitigation of climate change-related challenges are unprecedented. Fourth, the current experience with climate change is truly global in nature with accentuated regional implications.

I.13 Climate scientists recognise three anthropogenic drivers of climate change: GHG emissions; aerosols; and land use and land cover (LULC) (*ibid*). While GHGs help to keep the earth warm and habitable, it is the imbalance in GHGs in earth's atmosphere that leads to global and regional warming. The amount of GHGs in the atmosphere prior to the Industrial Revolution was relatively constant, but their concentration has increased significantly and consistently since then (IPCC, 1990). Among the GHGs, the concentration of carbon dioxide (CO_2) has shown the highest increase since pre-industrial times (Chart I.3a). Atmospheric CO_2 gets stored transiently in land or oceans as mineral deposits before it gets removed over centuries or even more, making the mitigation of climate change a daunting task (*ibid*)[6].

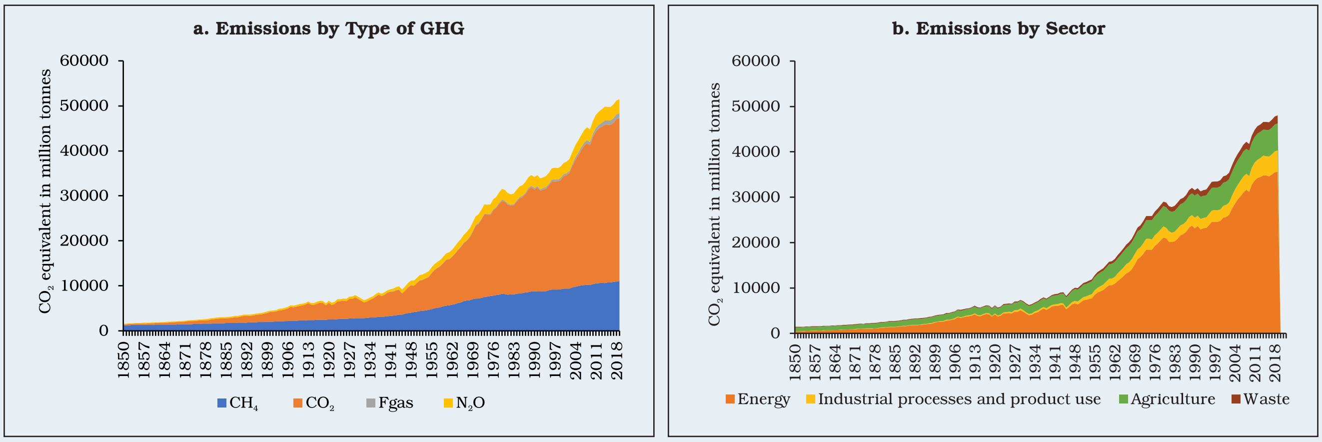
I.14 Methane (CH_4), the second highest GHG in occurrence, has been growing primarily due to agricultural activities[7]. The concentration of nitrogen oxides and carbon monoxide (CO) is also on the rise, leading to an increase in tropospheric ozone (O_3), another GHG (*ibid*). Chlorofluorocarbons (CFCs), which damage the O_3 layer in the stratosphere that is responsible for filtering the sun's ultraviolet radiation also contribute to global warming[8]. Among various economic sectors, energy has contributed the

[6] As observed by Natural Resources Defence Council (NRDC), "accounting for about 76 per cent of global human-caused emissions, carbon dioxide (CO_2) sticks around for quite a while. Once it is emitted into the atmosphere, 40 per cent still remains after 100 years, 20 per cent after 1,000 years, and 10 per cent as long as 10,000 years later".

[7] Paddy fields emit significant amounts of CH_4 as they are flooded with (often warm) water for better yields (Krishnan *et al*., 2020). This cuts off the oxygen supply to the soil from the atmosphere, leading to anaerobic fermentation of soil organic matter, and CH_4 is a result of this fermentation (Neue, 1993). Similarly, belching of cattle also leads to the release of CH_4.

[8] Chlorofluorocarbons (CFCs) such as freon used in refrigerators are halogenated hydrocarbons that contain carbon, hydrogen, chlorine and fluorine and contribute to ozone depletion in the upper atmosphere.

Chart I.3: Historical GHG Emissions



Note: Fgas refers to Fluorinated gas.
Sources: Gutschow *et al.* (2016); and Potsdam Institute for Climate Impact Research.

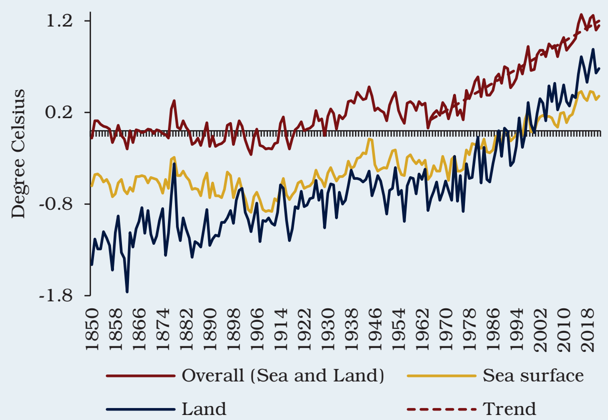
most to GHG emissions, followed by agriculture and industry (Chart I.3b).

I.15 Aerosols are small, suspended particles or droplets that either scatter solar energy or absorb it or do both. By scattering solar energy, they can offset the warming caused by GHGs but by absorbing it, they contribute to global warming (*ibid*)[9]. The common sources of anthropogenic aerosols are urban/industrial emissions and smoke emanating from biomass burning (*ibid*). The changes in LULC caused by deforestation owing primarily to agricultural and pastoral activities reduce the ability of the earth's surface to sequestrate (absorb) CO_2, thus contributing to climate change (*ibid*).

I.16 Climate scientists use many physical indicators, including atmospheric, oceanic and cryospheric, to assess climate change:

- Global mean surface temperature (the average of land surface temperature (LST) and sea surface temperature (SST)): from 2012 onwards, the earth has turned warmer by more than 1 degree Celsius as compared with the 1850-1900 average, with each decade being warmer than the previous one by around 0.2 degree Celsius since the 1980s (Chart I.4).

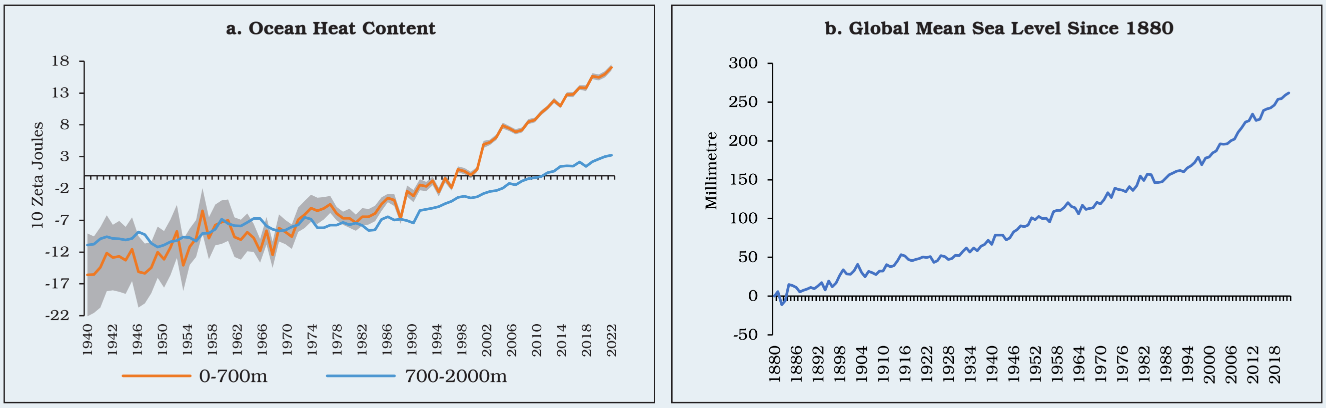
Chart I.4: Global Mean Surface Temperature Anomaly



Notes: Anomalies are calculated relative to a 1981 to 2010 baseline and offset by 0.69 degree Celsius which is the best estimate difference for that period from the 1850-1900 average reported by IPCC. Overall global temperature refers to *HadCRUT5*, sea surface temperature is *HadSST4* and land surface air temperature denotes *Berkeley Earth Land*.
Source: Met Office, UK.

[9] The IPCC has acknowledged that aerosols so far have had a net cooling effect on earth's climate, partially counterbalancing the heating effect of GHGs (*ibid*).

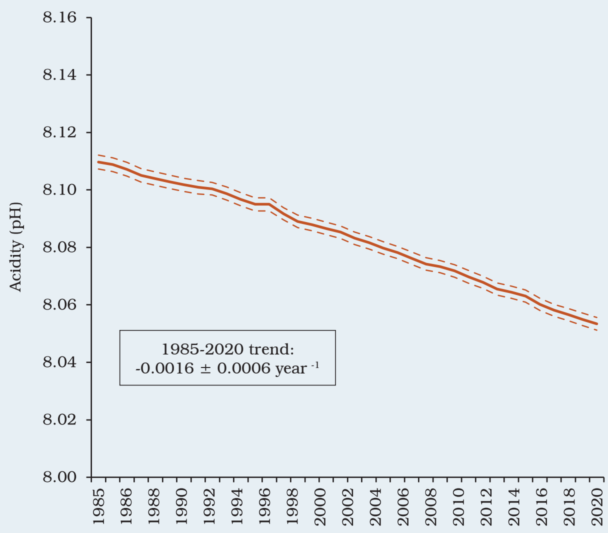
Chart I.5: Ocean Heat Content and Sea Level Rise



Notes: Global sea level data are from Church and White (2011) and updated with Commonwealth Scientific and Industrial Research Organisation (CSIRO) latest information. The shaded area indicates 95 per cent confidence intervals.
Sources: Met Office, UK; Cheng *et al*. (2017); Church and White (2011); and CSIRO.

- Long-term warming and acidification of oceans: more than 90 per cent of the net energy or heat increase in the climate system is stored in oceans and over 60 per cent in the upper ocean (0-700 metres). The heat absorbed in the upper layer of the ocean has increased at an annual average level of 1.9 zeta joules (ZJ)[10] during 1940-1970 to 5.2 ZJ during 1971-2022 (Chart I.5)[11], causing thermal expansion, melting of glaciers and ice caps, rise in sea level and ocean acidification (Chart I.6)[12].
- Changing mass of cryosphere (all regions on and beneath the surface of the earth where water is in solid form): this has resulted in high reflectivity of solar radiation and depletion of fresh water supply, including snow and ice (Sejas *et al*., 2014) (Chart I.7)[13].

Chart I.6: Global Ocean Acidification



Note: Lower pH value means higher acidity.
Source: Copernicus Marine Environment Monitoring Service (CMEMS).

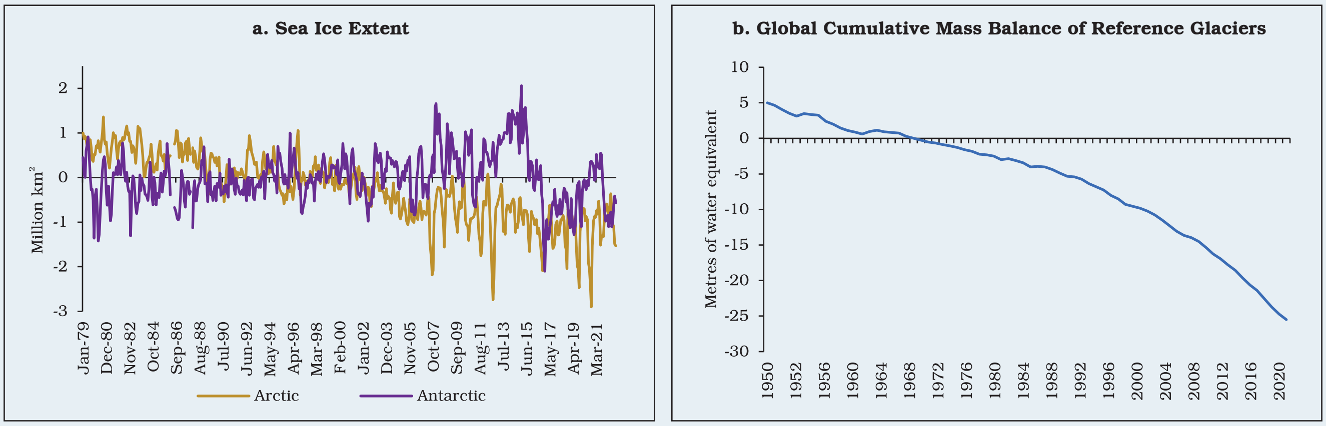
10 Ocean heat content (OHC) is measured in joules with 1 zeta joule = 10^{21} joules. According to the United States Environmental Protection Agency estimates for 2018, a one unit (1 x 10^{22} joules) increase in OHC is equal to approximately 17 times the total amount of energy used by all the people on earth in a year.

11 Cheng *et al*., 2019.

12 The global mean sea level (GMSL) has swelled by over 26 centimetres (cms) from 1880 to 2022 at an average rate of 1.8 mm per year. The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate concluded that sea level rise has accelerated (extremely likely) due to the combined loss from Greenland and Antarctic ice sheets (very high confidence).

13 Decadal means for Arctic sea ice area have decreased significantly, although the relative changes in the Antarctic sea ice area have been small.

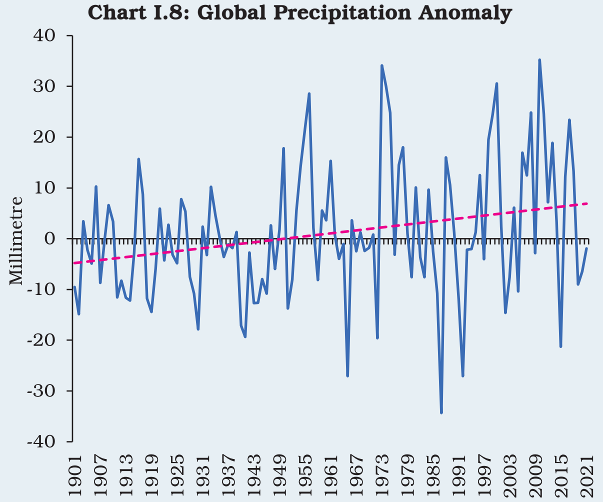
Chart I.7: Ice and Glacier Balance



Note: The sea ice extent is calculated in relation to 1981-2010 average. The cumulative mass change of reference glaciers is relative to 1976.
Sources: Met Office, UK; and World Glacier Monitoring Service (WGMS).

- Global average precipitation: wet areas are getting wetter while dry land is becoming drier as global average precipitation has increased since the 1950s, marked by years of extremely heavy rainfall and severe droughts (Chart I.8).

Chart I.8: Global Precipitation Anomaly



Notes: 1. Global anomalies are calculated from the average precipitation during 1901-2000.
2. Dotted line indicates the trend.
Source: National Oceanic & Atmospheric Administration (NOAA) *via* the US EPA.

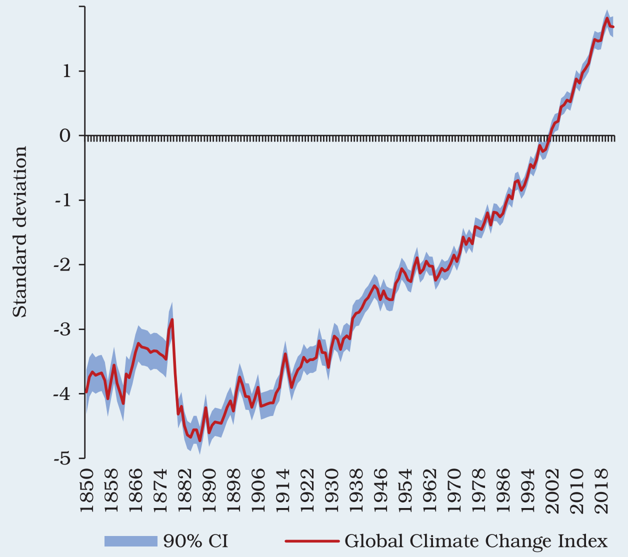
I.17 Using select key physical indicators[14] of climate change, a dynamic factor model (DFM) capable of extracting unobserved underlying factors has been developed to create a composite measure of global climate change, namely, the Global Climate Change Index (GCCI). Constructed by taking data from 1850 to 2022, the GCCI shows an upward trend since the late 19th century following the Industrial Revolution (Chart I.9).

I.18 The correlation between the GCCI and the total number of extreme weather events is estimated at 0.9. Evidently, the frequency of disaster events has gone up with climate change (Chart I.10).

I.19 The Bai-Perron structural break test shows five major statistically significant breaks (1880; 1913; 1938; 1973; and 1998) in the GCCI (Table I.1). As the year 1880 marked the beginning of modern record-keeping for global temperatures, the availability of robust data

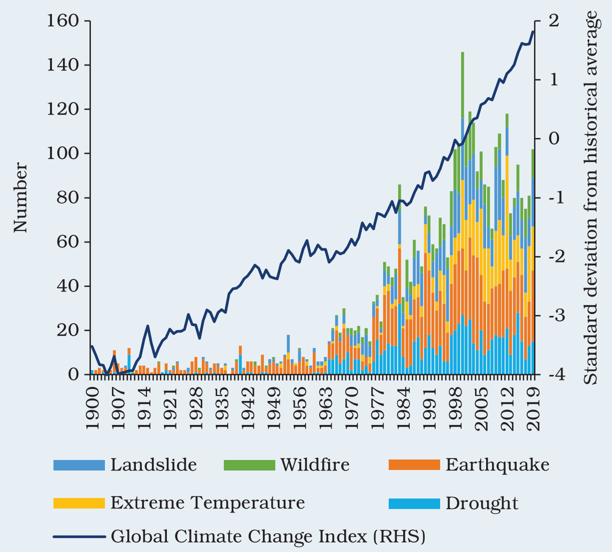
[14] The selected 11 key indicators of climate change are the global mean surface temperature; land surface temperature; sea surface temperature; ocean heat content; sea level rise; Arctic sea ice extent; Antarctic sea ice extent; snow cover; glacier mass balance; global precipitation; and global CO_2 emissions.

Chart I.9: Evolution of Climate Change



Source: Authors' calculations.

Chart I.10: Global Climate Change and Disaster Events



Sources: Our World in Data (OWID); and Authors' calculations.

on global temperatures could explain the first structural break in the GCCI[15]. The period from 1880 to 1912 is considered as the period of the Second Industrial Revolution involving several technological advances majorly benefitting the advanced countries outside Europe. The period from 1913 to 1937 included the outbreaks of the two World Wars, possibly reflecting increased emissions. The last break in 1998 was marked by a well-known *El Nino* effect in the tropical Pacific, which resulted in significant climate disruptions in the form of floods in Latin America and Africa, and droughts in south-east Asia.

Table I.1: Bai-Perron Structural Breaks in GCCI

Variable	Coefficient	Std. Error	t-Statistic	Prob.
1850 - 1879 -- 30 obs				
C	-3.57	0.07	-52.62	0.00
1880 - 1912 -- 33 obs				
C	-4.27	0.06	-66.09	0.00
1913 - 1937 -- 25 obs				
C	-3.41	0.07	-46.00	0.00
1938 - 1972 -- 35 obs				
C	-2.24	0.06	-35.75	0.00
1973 - 1997 -- 25 obs				
C	-1.10	0.07	-14.86	0.00
1998 - 2022 -- 25 obs				
C	0.80	0.07	10.75	0.00
Adj. R^2	0.95			
Prob(F-stat)	0.00			

Source: Authors' calculations.

I.20 In sum, climate change is manifesting itself through multiple indicators. Given that most environmental and natural processes are "silent" and "invisible", they may not be discernible immediately or experienced as intensely (Dasgupta, 2021). Silence and invisibility can no longer be associated with climate change, however, as increasingly frequent and intense extreme weather events take a rising toll on human life and the environment.

[15] Three of the world's comprehensive global temperature records began in 1880; see https://climate.nasa.gov/faq/21/why-does-the-temperature-record-shown-on-your-vital-signs-page-begin-at-1880/, Accessed on April 28, 2023.

3. Climate Policy Action

I.21 The global consensus around climate policies has been spearheaded by the United Nations (UN), although originally, its focus was more on the utilisation of the environmental or natural resources for greater economic development (Jackson, 2007). Among the international organisations, it was the WMO which has been instrumental in generating international cooperation on climate matters and strengthening post-second World War advances in climate research (Zillman, 2009).

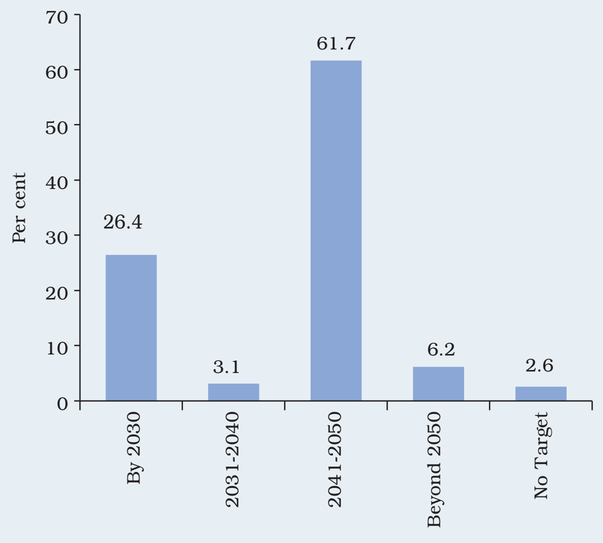
I.22 Environmental conservation engaged the attention of the UN for the first time in the first Earth Summit held in Stockholm in 1972, which led to the creation of the UN Environment Programme (UNEP), the first landmark in global cooperation and consensus on climate change. The second landmark occurred 16 years later in the form of creation of the Inter-Governmental Panel on Climate Change (IPCC) in 1988 by the UNEP and the WMO for regular scientific assessments on climate change and their implications for informed policy making (Annex I.1). Till now, there have been six assessment cycles by the IPCC.

I.23 The third landmark was the Paris Agreement in 2016, about three decades later. This agreement bound *all* signatories to undertake targeted efforts to combat climate change. It was aimed at ensuring that GHG emissions from human activity are maintained at the same levels as can be absorbed by the environment - known as net zero - between 2050 and 2100. This would limit global warming to 1.5 degrees Celsius as compared with pre-Industrial Revolution levels.

I.24 The implementation of the Paris Agreement is based on Nationally Determined Contributions (NDCs), which are plans of action for climate change submitted by each signatory, followed by a five-year cycle of increasingly ambitious climate actions[16]. Countries also have to frame long-term low emission development strategies (LT-LEDS). Unlike NDCs, LT-LEDS are not mandatory. Developed countries have been assigned the added responsibility of providing support to developing countries for adaptation and transition to clean energy through climate finance. There have been numerous global dialogues and interventions leading up to and following the Paris Agreement (Annex I.1).

I.25 The achievements of climate policy action can be ascertained using several parameters. First, almost all countries have committed to timelines for the transition to net zero emissions, with the majority committing to achieve this target by 2050 (Chart I.11). 23 per cent of the

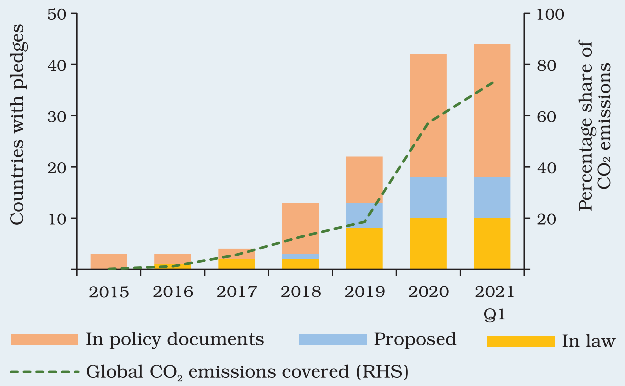
Chart I.11: Target Year of Commitment for Countries



Source: Net zero tracker, https://zerotracker.net

[16] See https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Chart I.12: Number of Net Zero Pledges and Share of Global CO_2 Emissions Covered



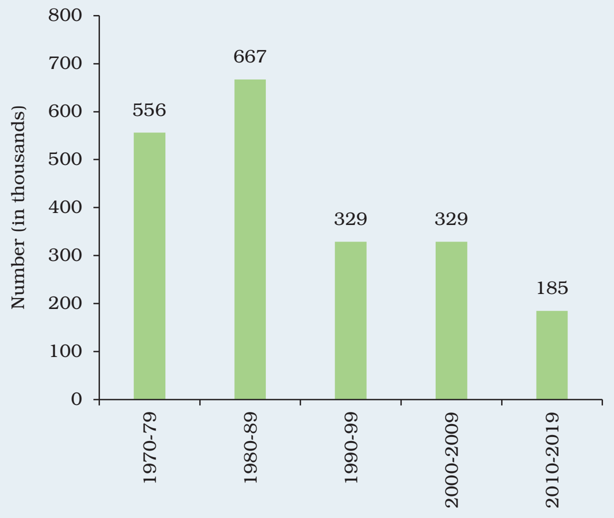
Notes: In law = a net zero pledge has been approved by respective parliament and is legally binding;
Proposed = a net zero pledge has been proposed to the parliament to be voted into law;
In policy document = a net zero pledge has been proposed but does not have a legally binding status.
Source: International Energy Agency (2021).

countries have made the target a legal obligation, 18 per cent have proposed to make it into a legal obligation and remaining 59 per cent have made their pledges in official policy documents. All these countries together account for around 73 per cent of global CO_2 emissions (Chart I.12).

I.26 Second, the financial commitments made towards providing climate finance for adaptation and mitigation have also grown over time. In COP15[17] in Copenhagen in 2009, developed countries committed to US$ 100 billion per year by 2020 for climate action in developing countries. In COP27 in Sharm-El-Sheikh in 2022, the Parties acknowledged that the initial pledge was not sufficient and adapting to climate crisis would require US$ 160-340 billion annually by 2030, accelerating to US$ 565 billion annually by 2050 if climate conditions deteriorated further. Parties have also reached a consensus to establish funding arrangements, including a dedicated fund for loss and damage. The G20 and G7 have jointly launched the Global Shield against Climate Risks to provide vulnerable countries more means to protect themselves from increasingly extreme weather, with Germany providing €170 million in grants. Many of the advanced economies have made financial commitments addressing loss and damage, with the UK also announcing that it will suspend vulnerable nations' debt repayments for up to two years following a climate disaster. The UN has unveiled a US$ 3.1 billion plan to ensure that everyone is covered by early warning systems in the next five years to bolster countries' ability to prepare for hazardous weather.

I.27 Third, weather-related mortality has declined over the decades as advances in technology and early warning systems across countries have reduced the incidence of death significantly (Chart I.13).

Chart I.13: Number of Reported Deaths Due to Weather-Related Calamities



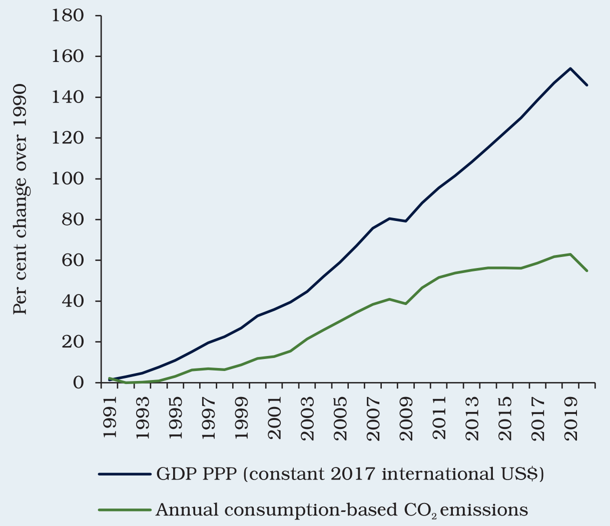
Source: WMO.

[17] COP or Conference of the Parties is the supreme decision-making body of the UN Framework Convention on Climate Change (UNFCCC). All countries that are parties to the UNFCCC are represented at the COP which meets every year to review the Conventions' implementation; see https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop

I.28 Fourth, NDCs have increased the momentum of emission reduction, resulting in a glide path towards net zero. While relative decoupling of economic growth and emissions is currently underway at the global level, the trends vary significantly across high-income and middle-income countries (Chart I.14; Box I.1).

I.29 Notwithstanding the progress, the pace of implementation of climate policy remains far from adequate. There are still considerable gaps in scientific knowledge on informed climate-resilient pathways, strategies, choices and actions that can reduce climate change and its impact (Denton *et al.,* 2014). Delays in current policy action can limit the scope for setting future climate-compatible

Chart I.14: Change in Global CO_2 Emissions and GDP



Source: Our World in Data (OWID).

Box I.1
Decoupling of Global Growth and GHG Emissions

The carbon-growth nexus is based on the argument that as economies grow, energy usage requirement increases, leading to higher emissions (Torun *et al.*, 2022). The environmental Kuznets curve (EKC) hypothesis argues that this relation is non-linear, with emissions increasing faster at lower stages of economic development and falling at higher stages with the use of energy-efficient resources, *ceteris paribus* (Stern, 2004). Under relative decoupling, the carbon intensity of GDP declines even though it may still be on a rise in absolute terms.

With the various policy interventions for addressing climate change in the last few decades, the decoupling elasticity, defined as the response of emissions to a one per cent change in GDP, has weakened. The changes in the decoupling elasticity can be seen from the response curve of the time varying estimate (β_t) in equation (1), controlling for energy intensity of GDP during 1965-2021:

$$\Delta CO_2 = \alpha + \beta_t \Delta\, GDP_{PC} + \gamma_t \Delta EI + \mathcal{E}_t \text{..........(1)}$$

CO_2: Per capita emissions; GDP_{PC}: Per capita GDP; and EI: Energy intensity of GDP.

The results show a non-linear relationship between per capita GDP and emissions over time. After 2000, however, the decoupling elasticity has increased, though moderately (Chart 1).

Decomposition of the contributing factors, based on the Logarithmic Mean Divisia Index (LMDI)[18] (an extension of the Kaya identity[19]), brings out the role of declining energy intensity of output which has helped in containing global emissions growth, despite higher per capita economic

(Contd...)

[18] LMDI is defined as the decomposition of the weighted contribution of each factor in the change in emission level (Kar, 2022) in period *t* over base period 0 as:

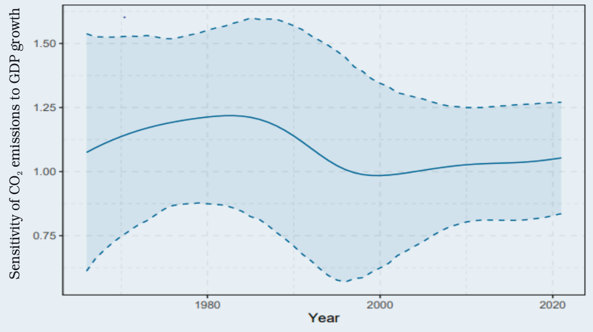
$$\Delta CO_2 = \Delta\, GDP_{PC} + \Delta EI + \Delta CI \text{............ (1)}$$

where each component C_{it} *viz.,* GDP per capita (GDP_{PC}), energy intensity of GDP (EI) and carbon intensity of energy use (CI) is defined as:

$$\Delta C_{it} = Ln\left(\frac{C_{it}}{C_{i0}}\right) * \left(\frac{\Delta CO_2}{Ln(CO_{2t}) - Ln(CO_{20})}\right)$$

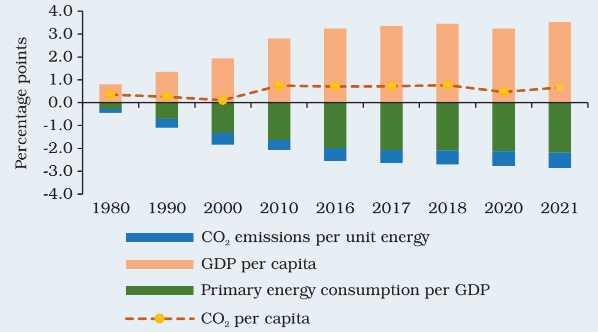
[19] Kaya identity is a simple mathematical framework to assess the main factors governing global CO_2 emissions (Kaya, 1989). The identity relates GHG emissions to population growth, economic growth and energy use, and quantifies the emissions generated from human sources in terms of population, economic activity, energy intensity of output and carbon intensity of energy consumption.

Chart 1: Global Growth Sensitivity of CO_2 Emissions



Source: Authors' calculations.

Chart 2: Contribution to Global CO_2 Emissions (LMDI)



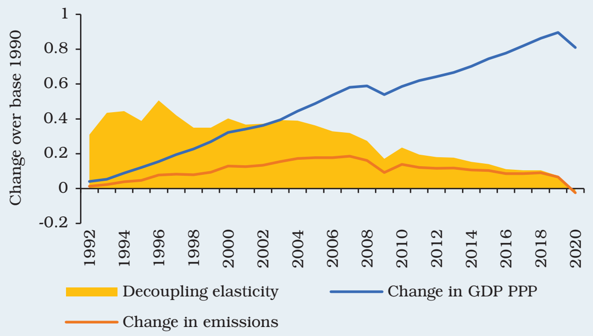
Sources: OWID; and Authors' calculations.

growth. This is weakening the carbon-growth nexus (Chart 2). The pace of emissions, however, has increased since 2000 and has remained elevated, as the moderation in energy intensity of output has been outweighed by carbon intensity of energy use associated with economic growth, which has shown only a moderate decline.

The carbon-growth nexus path has been quite diverse among countries at different income levels. While both relative and absolute decoupling is evident in the high-income countries, the middle-income countries have not been successful in reaching carbon-efficient economic growth in their high growth phase (Charts 3 and 4). Policy interventions, however, have significantly moderated the absolute change in emissions since 2015 for the middle-income countries.

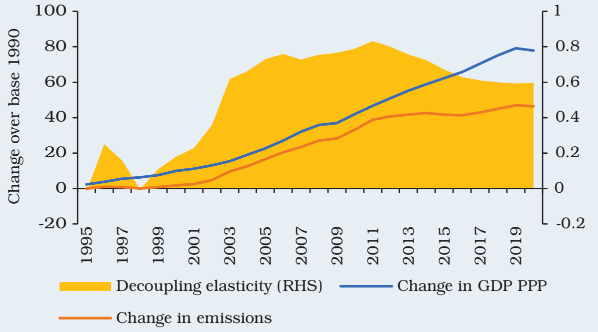
In sum, while the growing recognition of and actions concerning climate change have weakened the correlation between carbon emissions and GDP growth globally, an absolute decoupling is yet to happen. Reduction in energy intensity of GDP and carbon intensity of energy consumption are two important channels for ensuring an absolute decoupling, going forward.

Chart 3: Decoupling in High-Income Countries



Sources: OWID; and Authors' calculations.

Chart 4: Decoupling in Middle-Income Countries



Sources: OWID; and Authors' calculations.

References:

Kar, A. K. (2022). Environmental Kuznets Curve for CO_2 Emissions in Baltic Countries: An Empirical Investigation. *Environmental Science and Pollution Research*, 29(31), 47189-47208.

Kaya, Y. (1989). Impact of Carbon Dioxide Emission Control on GNP growth: Interpretation of Proposed Scenarios. *Intergovernmental Panel on Climate Change/Response Strategies Working Group*, May.

Stern, D. I. (2004). The Rise and Fall of The Environmental Kuznets Curve. *World Development*, 32(8), 1419-1439.

Torun, E., Akdeniz, A. D. A., Demireli, E., and Grima, S. (2022). Long-Term US Economic Growth and the Carbon Dioxide Emissions Nexus: A Wavelet-Based Approach. *Sustainability 2022*, 14, 10566.

trajectories. There are also potential trade-offs between adaptation and mitigation policies, resulting in implementation challenges. Cross-country differentials in historical emissions and development priorities make the issue of "equity" central to adaptation and mitigation policies. While climate change is a global phenomenon, it is the emerging and less-developed economies that are most vulnerable in terms of (i) climate science and technological capabilities; and (ii) finance for adaptation and mitigation. Climate change can push them several places down the development ladder as the potential costs of transitioning to a greener path for them could be higher relative to their advanced economy peers. Their contribution to GHG emissions has been relatively limited and they demand a larger slice of the future carbon space as well as compensation for climate change (Box I.2).

I.30 In the current state of climate policy action that incorporates all pledges and targets announced so far, the global rise in temperature can reach a minimum of 1.9 degrees Celsius above pre-Industrial Revolution levels under the most optimistic path of global emission reduction

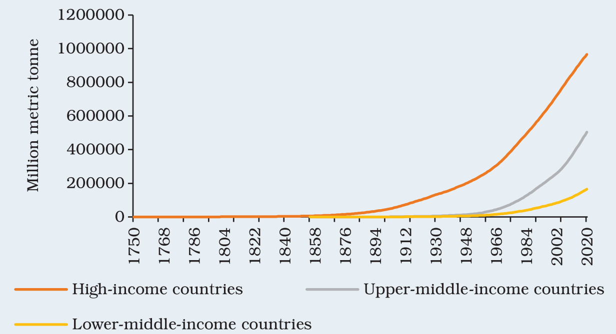
Box I.2
International Climate Equity and Justice: Some Analytical Insights

Any sustainable solution to climate change needs to factor in the unequal contributions to past emissions and the unequal future ramifications for development across countries. This has been emphasised in the principle of "Common but Differentiated Responsibilities and Respective Capabilities" of the UNFCCC (UN, 1992). 58 per cent of the historical cumulative net emissions occurred between 1850 and 1989 and about 42 per cent between 1990 and 2019. High-income countries have cumulatively contributed about 57 per cent of total CO_2 emissions during the period of 1750-2020 (Charts 1 and 2).

In comparison with the earlier Contraction and Convergence approach, the Climate Equity Reference Framework (CERF) includes elements of responsibility and capability to arrive at country-specific mitigation and adaptation plans (Kanitkar and Jayaraman, 2019).

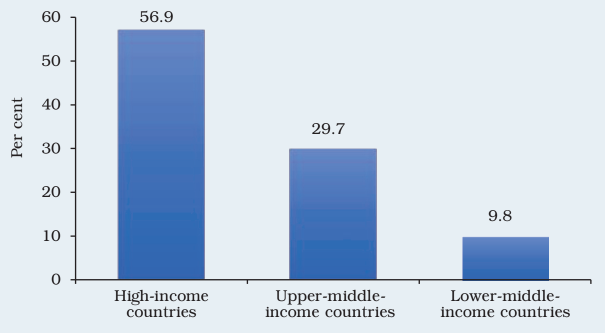
The major role played by high-income countries in global CO_2 emissions is borne out when we consider the per capita emissions instead of absolute emissions (Chart 3). Taking consumption-based emissions instead of production-based emissions also underlines the greater contribution of high-income countries to global CO_2 emissions. This is because even if the domestic production in these countries may entail lower emissions, they are net importers of emissions (Chart 4).

Chart 1: Cumulative Emissions of CO_2



Sources: OWID; and Authors' calculations.

Chart 2: Contribution to Cumulative CO_2 Emissions, 1750-2020



Sources: OWID; and Authors' calculations.

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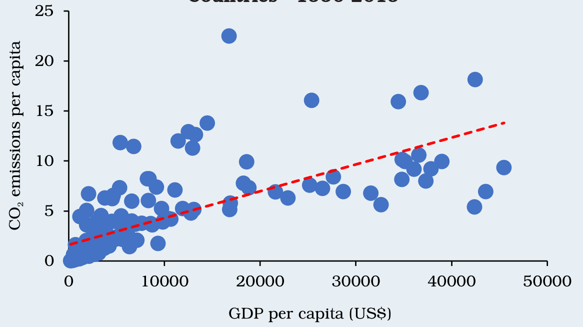
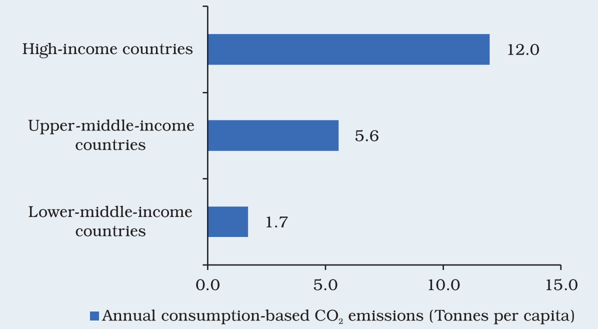
Chart 3: Average Per Capita CO_2 Emissions and Income of Countries - 1990-2019



Sources: WDI; World Bank; OWID; and Authors' calculations.

Chart 4: Consumption-based CO_2 Emissions, 2019 (Per capita)



Sources: WDI; World Bank; OWID; and Authors' calculations.

The current central estimate of the carbon budget from 2020 onwards for limiting warming to 1.5 degrees Celsius (with a probability of 50 per cent) has been assessed at 500 CO_2 gigatonnes ($GtCO_2$), and 1150 $GtCO_2$ for limiting warming to 2 degrees Celsius (with a probability of 67 per cent) (IPCC, 2022). In apportioning this remaining carbon space, the cumulative carbon space used by countries since their industrialisation needs to be an important consideration for ensuring global equity and justice.

References:

IPCC (2022). Summary for Policymakers. Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press, Cambridge,* UK and New York. Doi: 10.1017/9781009157926.001.

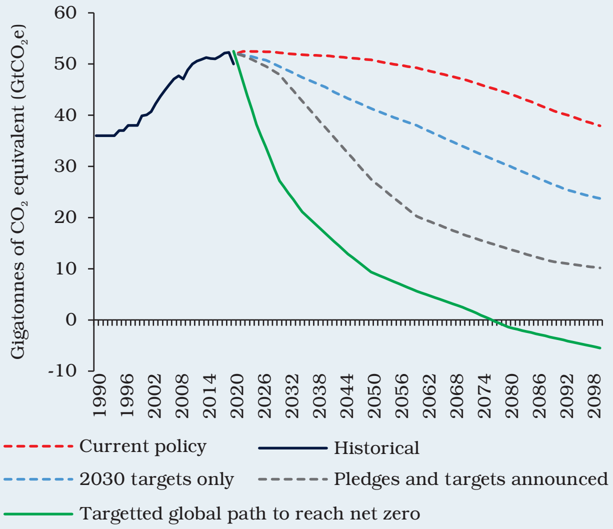
Kanitkar, T. and T. Jayaraman (2019). Equity in long-term mitigation. In Dubash. N. K. (*ed.*). *India in a Warming World: Integrating Climate Change and Development. Oxford University Press*, pp. 92-113. ISBN 9780199498734.

United Nations (UN) (1992). Report on United Nations Conference on Environment and Development. https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf

– above the current target of 1.5 degrees Celsius (Charts I.15 and I.16).

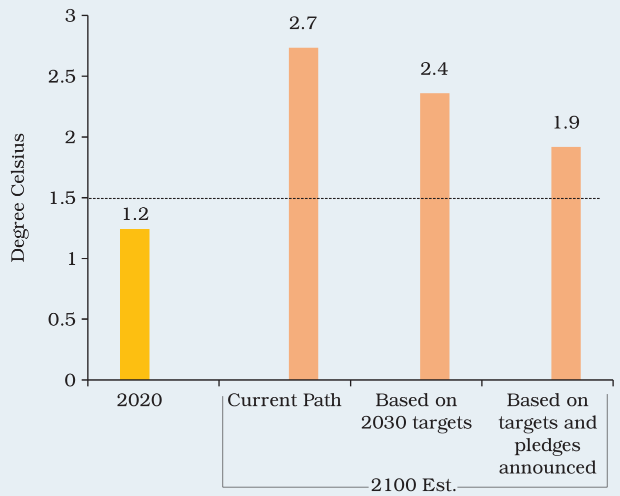
I.31 Implementation of various climate finance commitments from advanced economies has been far from satisfactory. The extent of green financing for climate change adaptation has been about 5-10 times lower than required, and the gap between the required and actual has only grown (UNEP, 2022). As against the amount of US$ 100 billion pledged by advanced economies, only US$ 83.3 billion has been provided in 2020, marking an increase of just 4 per cent from 2019 (Chart I.17). While the Paris Agreement has emphasised on maintaining a balance between adaptation and mitigation finance, financial

Chart I.15: Global Carbon Emission Paths



Source: Climate Action Tracker, Climate Analytics and New Climate Institute.

Chart I.16: Global Temperature Rise over Pre-Industrial Average

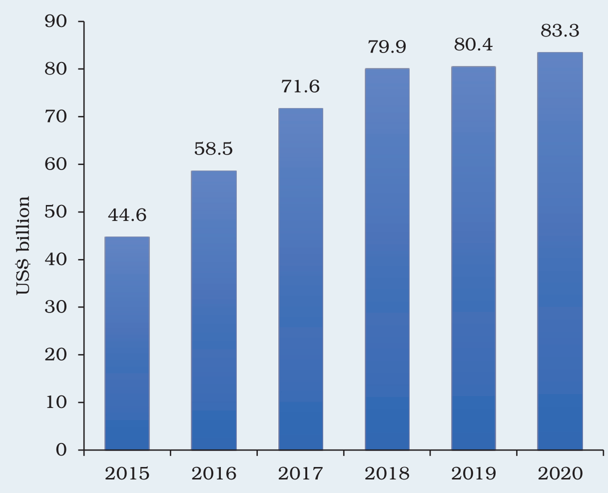


Source: Climate Action Tracker, Climate Analytics and New Climate Institute.

support for mitigation has remained higher than for adaptation (Chart I.18).

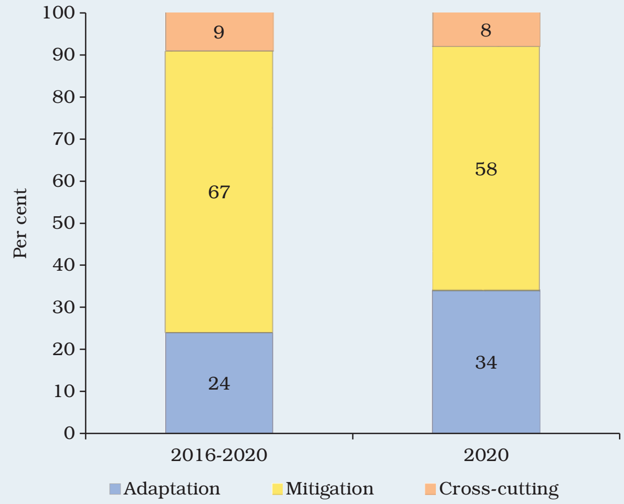
I.32 While the number of deaths associated with extreme weather events has been on the wane, reflecting better adaptation, the economic costs associated with such events have been on a rapid rise (Chart I.19).

Chart I.17: Mobilisation of Climate Finance from Developed to Developing Countries



Source: OECD.

Chart I.18: Use of Climate Finance

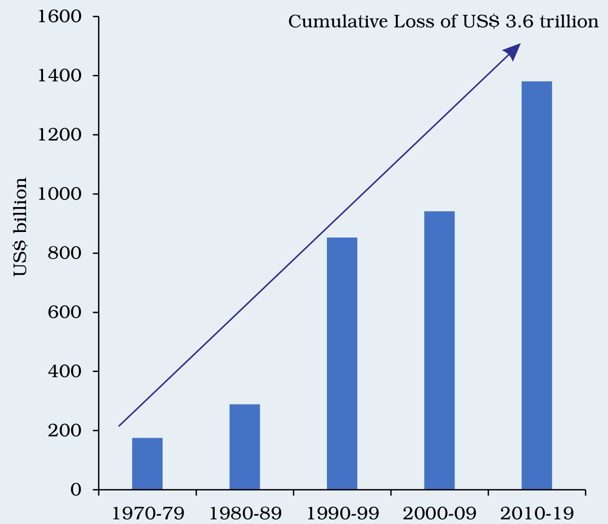


Note: Cross cutting projects include a combination of adaptation and mitigation financing.
Source: OECD.

3.1 Instruments of Climate Policy

I.33 Most economies have adopted fiscal policy as the primary instrument to achieve climate change commitments and targets (Annex I.2), as it is widely regarded as the most effective means for internalising the externalities of climate change and curbing emissions (Barker and Ekins, 2001;

Chart I.19: Reported Economic Losses from Weather, Climate and Water Hazards

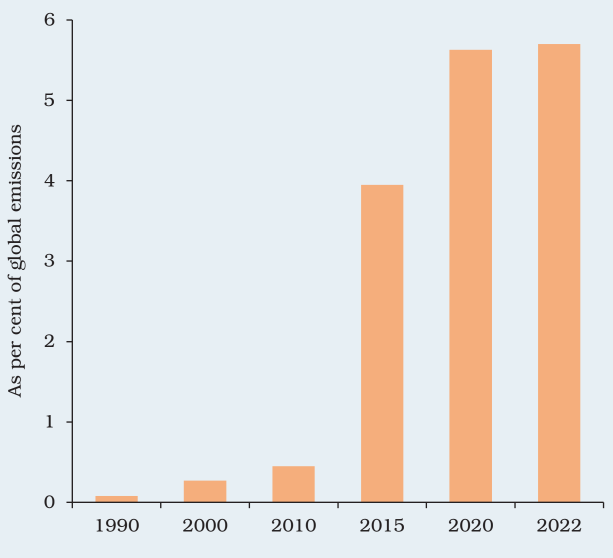


Source: WMO.

Nordhaus, 2007; Weitzman, 2014). The commonly used fiscal policy instruments include (a) price-based instruments – carbon taxes; feed-in tariffs; renewable subsidies; and (b) quantity-based instruments – emissions trading system (ETS) and renewable quotas.

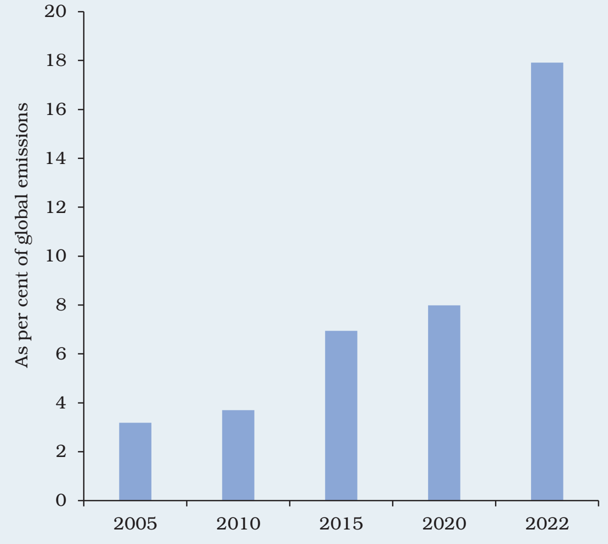
I.34 Carbon taxes are expected to shift power generation from coal towards renewables while supporting public revenue mobilisation and bringing down the distortionary effects of other taxes[20]. Emissions trading systems (ETS), being market-based, are easier to implement; however, they have limited coverage, as they are used primarily by large emitters (Parry *et al.*, 2022). Unlike carbon taxes which can help in the price discovery of carbon emissions, emission trading targets the quantum of emissions while keeping the carbon price uncertain (Weitzman, 2014). Globally, there has been a rapid increase in the use of carbon taxes and ETS (Charts I.20 and I.21), but they still account for a small share of total global emissions.

Chart I.20: Global Carbon Tax Coverage



Source: Carbon Price Dashboard, World Bank.

Chart I.21: Global ETS Coverage



Source: Carbon Price Dashboard, World Bank.

I.35 Traditionally, monetary and regulatory policies have been considered neither necessary nor effective in addressing climate change. In recent years, however, there has been a growing role of regulatory policies in the climate policy toolkit (Annex I.2). This reflects the recognition of their role in encouraging green or Environmental, Social and Governance (ESG) finance and incentivising investors towards low-carbon instruments. Making further headway in climate action requires not just meeting the earlier commitments but also entering into swifter and stronger policy commitments for the future.

4. India's Involvement in Global Climate Change and Action

I.36 India will surpass China in 2023 to become the most populous country in the world. Alongside

[20] This is known as the "double dividend" hypothesis and has been illustrated taking country-specific cases, see Mckitrick (1997).

its aspiration to transform into the manufacturing hub of the world, India's energy needs will rise and hence, a large and more intense involvement in global climate action is crucial. This also assumes urgency in view of India's vulnerability to climate change.

4.1 India's Vulnerability to Climate Change

I.37 The natural impact of climate change on India is evident in more than one way. First, the average air surface temperature for India has risen by around 0.7 degree Celsius during 1901-2018 (Krishnan *et al.*, 2020). When compared globally, however, the rise in India's temperature across all decades seems limited (Chart I.22).

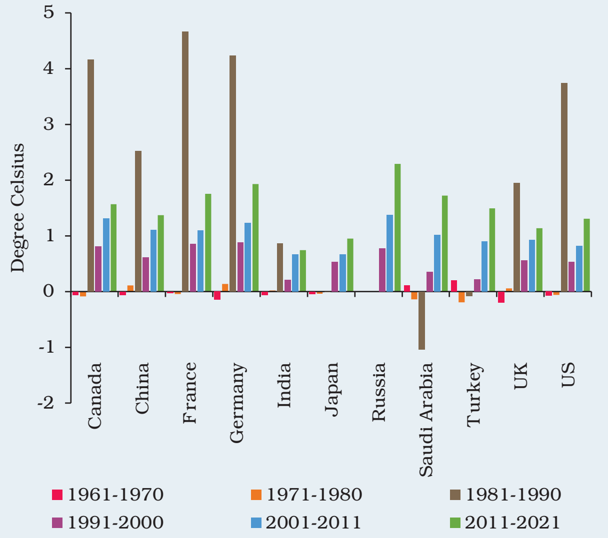
I.38 The average temperature in India by the end of the 21st century is projected to increase by about 4.4 degrees Celsius relative to the average during 1976-2005 (*ibid*) (Chart I.23).

I.39 Second, the rise in the sea level in the north-Indian Ocean was at a rate of 1.06-1.75 mm per year during 1874-2004, which accelerated to 3.3 mm per year during 1993-2017 that is comparable to the current rise in the global mean sea level (*ibid*). India remains vulnerable to sea level increase, which threatens its low-lying small islands as well as major coastal cities[21]. Third, the precipitation for June to September in India declined by around 6 per cent during 1951-2015, particularly over the Indo-Gangetic plains and the Western Ghats. This is attributed to aerosol cooling over the northern hemisphere, which has offset the warming from GHGs (*ibid*). Fourth, there has been a distinct increase in the occurrence of natural disasters in India in recent decades (Chart I.24).

4.2 India's Contribution to Global Climate Change

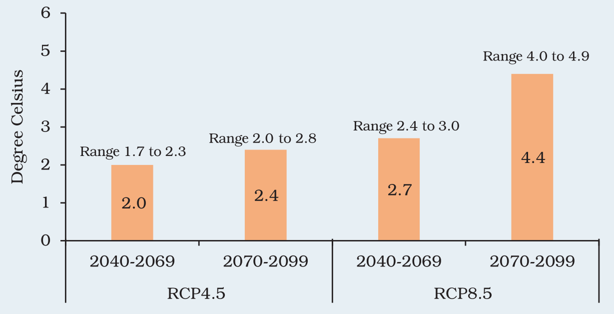
I.40 India's contribution to cumulative global emissions of GHGs has been limited, although its cumulative emissions have increased during 1950-1990 and 1991-2020. Its contribution to consumption-based emissions is, however,

Chart I.22: Annual Surface Temperature Anomaly (Compared to baseline 1950 to 1980)



Sources: International Monetary Fund; and Authors' calculations.

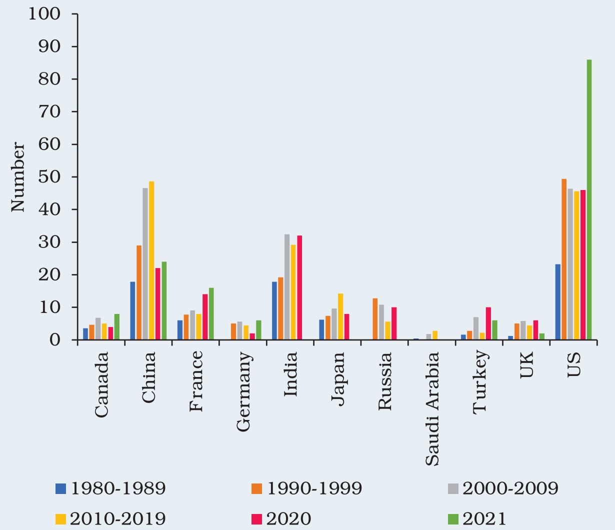
Chart I.23: Change in Surface Air Temperature over the Indian Region



Notes: Estimates are "best" estimate and range in the change in surface air temperature. Changes are relative to their climatological average from 1976 to 2005. Projected changes are reported under the RCP4.5 and RCP8.5 scenarios of IPCC. RCPs (Representative Concentration Pathways) are standardised forcing scenarios with each scenario being a time series of emissions and concentrations of GHGs, aerosols and LULC changes through the 21st century predicting a Radiative Forcing for 2100.
Source: Krishnan *et al.* (2020).

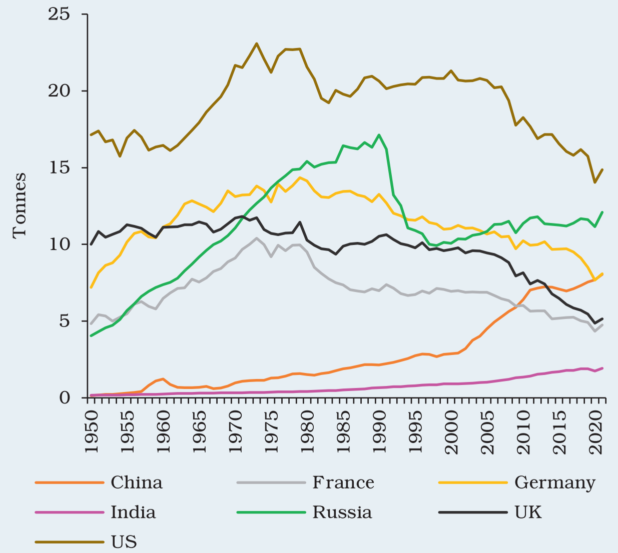
[21] Global Sea-Level Rise and Implications: Key Facts and Figures, WMO, February 2023.

Chart I.24: Climate Change-Related Disaster Frequency (Number of Events)



Sources: International Monetary Fund; and Authors' calculations.

Chart I.25: Per Capita CO_2 Emissions



Source: OWID.

significantly lower than production-based emissions *vis-à-vis* major developed countries (Table I.2).

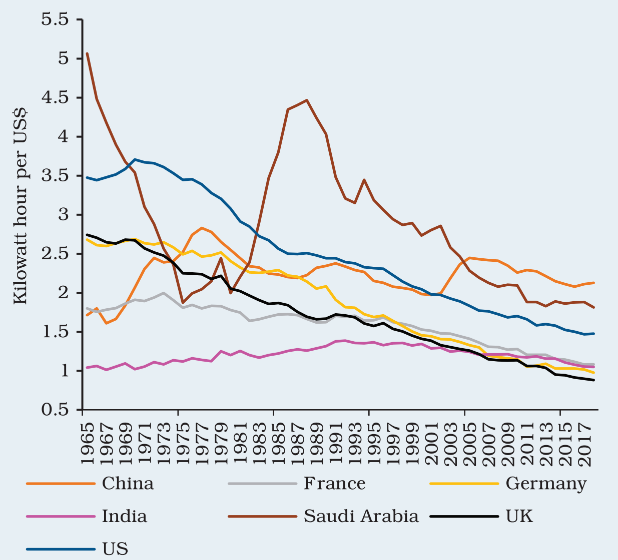
Table I.2: Cumulative CO_2 Emissions: India *vis-à-vis* World

Country	Cumulative Emissions of CO_2 (Billion tonnes)		Difference between Consumption and Production-based Emissions (Percentage points)
	1950-1990	1991-2020	
Developed world			
US	157.21	167.53	4.3
EU+UK	144.50	118.98	18.6
Three others (1)	40.46	68.44	12.2
Developing world			
China	41.13	192.56	-13.5
India	9.02	43.40	-7.1
Three others (2)	12.70	32.77	6.9
Oil and coal exporters			
Russia	59.72	48.96	-21.6
Saudi Arabia	3.06	12.75	-3.9
Three others (3)	17.08	37.84	-14.8
World	**577.29**	**888.92**	

Note: (1) Japan, Canada and South Korea, (2) Brazil, Mexico and Turkey, (3) Australia, Iran and South Africa.
Source: Desai (2022).

I.41 In India, per capita CO_2 emissions have been on a rise in recent decades, as in China and Russia (Chart I.25); however, the energy intensity of GDP (use of primary energy per unit of GDP) has been on a steady decline since the 1990s across almost all countries, including India (Chart I.26).

Chart I.26: Energy Intensity of GDP



Source: OWID.

I.42 In the deliberations and actions associated with climate change, India's position is defined less by its contribution to past global emissions of GHGs and more by (a) its higher vulnerability to the ongoing and future disruptions caused by climate change; (b) its developmental priorities that may increase its contribution of future GHGs; and (c) its role in designing both supply-side policies and demand-side innovations to manage future GHGs. The reduction in emissions can have differential effects on various sectors of the Indian economy, including agriculture (Box I.3).

Box I.3
Implications of Climate Risk Factors for Indian Agriculture

Climate change encompasses a host of factors, such as variations in temperature, precipitation, CO_2 emissions, humidity, wind, and extreme weather events. These factors individually or in interaction with other factors can influence agricultural production/productivity. They could either intensify the negative impact on production/productivity or improve it. From the emerging world, India offers an important case study for understanding the implications of climate change for agriculture, given (a) the critical role played by agriculture in providing an anchor to India's gross value-added and livelihoods through employment generation and food security; and (b) the vulnerability of Indian agriculture to climate risk factors owing to a relatively weak weatherproofing of the sector. Simulated scenarios till 2050 suggest high sensitivity of Indian agricultural production to climatic factors (Dasgupta, 2018).

Taking the recorded warmest decade of 2011-2020 (NOAA, 2021), a non-parametric multivariate adaptive regression spline model (MARS) has been used to examine the non-linear impact of climate change (x) on agriculture ($\hat{y}$):

$$\hat{y} = \sum_{i=1}^{n} b_i(x) c_i$$

where $b_i(x)$ is a weighted sum of basis functions and c_i is a constant function used in a sequential model to uncover the interactions of climate change and agriculture,

$$\hat{y}_1 = \sum_{i=1}^{n} b_i(x) c_i, \ldots., \hat{y}_N = \sum_{i=1}^{n} b_i(x) c_i$$

where $\hat{y}_1, \ldots\ldots, \hat{Y}_N$ are N sequential MARS models.

The results indicate that Indian agriculture is sensitive to climate change (Jha *et al.,* 2022). Climate risk factors, both independently and when interacted with other climate variables can negatively affect various attributes of agricultural production (Table 1).

Table 1: Salient Results from Sequential MARS Model

Independent Variables/ Interactions	Dependent Variables	Degrees of Interaction	Coefficients	R^2
Temperature	Area under foodgrains	2	0.35	0.62
CO_2 emissions	Foodgrain production	2	0.16	0.81
CO_2 emissions	Foodgrain yield	2	0.11	0.75
Precipitation	Area under oilseeds	2	-0.5	0.92
Precipitation	Oilseed production	2	-0.4	0.94
Precipitation, Irrigation	Oilseed yield	3	0.02, -0.05	0.89
CO_2 emissions	Foodgrain production (*kharif*)	2	0.72	0.78
CO_2 emissions	Foodgrain yield (*kharif*)	2	0.91	0.56
Rainfall	Oilseed production (*kharif*)	2	-0.25	0.77
Rainfall, Irrigation	Oilseed yield (*kharif*)	3	-0.18, 0.04	0.84

Note: The sequential MARS model parameters presented here reflect the impacts of climate variables taken either independently or along with their interactions with other variables.
Source: Jha *et al*. (2022).

References:

Dasgupta, P. (2018). Climatic Change Impacts on Foodgrain Production in India. In Vikram D. Anantha D. and Nandan N. (*eds.*). *Ecology, Economy and Society: Essays in Honour of Kanchan Chopra*, 63-82.

Jha, P, Chinngaihlian S, Upreti P, and Handa A. (2022). A Machine Learning Approach to Assess Implications of Climate Risk Factors on Agriculture: The Indian Case. A mimeo.

NOAA. (2021). National Oceanic and Atmospheric Administration. National Centers for Environmental Information. Monthly Global Climate Report for Annual 2020. Published online January 2021, retrieved on May 2, 2023 from https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202013.

4.3 India's Stake in Global Climate Action

I.43 India's involvement in climate change negotiations can be broadly divided into three phases (Youdon and Bajaj, 2022). In the first phase (1992-1997), India's priorities were about preserving the interests of developing and least-developed countries by advocating the principles of equity, and common but differentiated responsibilities in meeting targets for emission reductions. In the second phase (2000-2009), India focused on climate finance, technology sharing and the creation of an adaptation fund for climate action by developing countries. During the third phase covering COP15 in Copenhagen in 2009 to the Paris Agreement in 2016, India supported green transition through a more flexible, cooperative, and holistic approach for formulating its National Action Plans on climate change.

I.44 A strong commitment to climate action is reflected in various national development policies and programmes adopted by India in recent decades (Table I.3).

I.45 Before COP21 in 2015, India submitted its intended NDCs to the UNFCCC with targets upto 2030, pledging to: (i) reduce its emissions intensity of GDP by 33-35 per cent from 2005 levels; (ii) increase the share of non-fossil-fuels-based electricity to 40 per cent with the help of transfer of technology and low-cost international finance mechanisms such as the Green Climate Fund[22]; and (iii) create an additional carbon sink[23] of 2.5 to 3 billion tonnes of CO_2 equivalent through extra forest and tree cover.

Table I.3: India's Action Related to Climate Change

Area	Salient Initiatives
Science & Research	1. Indian Network for Climate Change Assessment (INCCA) 2. Himalayan Glaciers Monitoring Programme 3. Launch of Indian Satellite to Monitor Greenhouse Gases 4. India's Forest and Tree Cover as a Carbon Sink 5. India GHG Emissions Profile
Policy Development	6. Expert Group on Low Carbon Economy 7. State Action Plan on Climate Change 8. National Policy on Biofuels
Policy Implementation	9. National Missions under National Action Plan on Climate Change 10. National Conference on Green Building Materials and Technologies 11. In-Principle Approval to 30 Solar Cities 12. Energy Efficiency Standards for Appliances 13. Fuel Efficiency Norms 14. Clean Development Mechanism (CDM) Programme
International Cooperation	15. UN Climate Technology Conference 16. SAARC Environment Ministers' Conference 17. India's Submissions to UNFCCC
Forestry	18. State of Forest Report 19. Green India Mission 20. Capacity Building of Forestry, Intensification of Forestry Management and Inclusion of Forestry within MGNREGA

Source: Ministry of Environment, Forest and Climate Change, Government of India.

I.46 At COP26[24], India updated its NDCs, which represent the framework for its transition to cleaner energy for the period 2021-2030. It has committed to accommodate the *panchamrit,* which includes raising the non-fossil-fuels-based energy capacity of the country to 500 Gigawatt

[22] The Green Climate Fund has been designated as an operating entity of the financial mechanism of the UNFCCC in providing support to developing countries to limit or reduce their GHG emissions and to adapt to the impact of climate change.

[23] Carbon sinks are natural or artificial reservoirs that absorb and store the atmosphere's CO_2 through physical and biological mechanisms.

[24] The 26th UN Climate Change Conference was held at Glasgow, UK in 2021.

by 2030; 50 per cent of energy requirements from renewable sources; and 45 per cent reduction of carbon intensity by 2030. The updated NDCs reaffirm India's commitment to work towards a low-carbon emission pathway, while simultaneously endeavouring to achieve sustainable development goals. Moreover, the Mission LiFE, *i.e.*, Lifestyle for the Environment, launched by the Prime Minister in 2022, is now a global movement to connect the powers of the people for the protection of the earth. Mission LiFE makes the fight against climate change democratic, because everyone can contribute within one's capacity.

I.47 India has set itself a target to achieve net zero by 2070. Toward achieving this target, India has released its LT-LEDS at the COP27 summit. With this, India has joined other so-called large emitters like China, the US, Russia and Japan which have already submitted their strategies. While optimising the trade-offs between growth and low-carbon emissions, the broad features of the strategy include: (a) rational utilisation of national resources with due regard to energy security; (b) increase the use of biofuels, green hydrogen fuel and electric vehicle penetration; (c) development of an integrated, efficient and low-carbon transport system; (d) promotion of adaptation measures in urban design; and (e) CO_2 removal through innovation, technology transfer, climate-specific finance and capacity building with international support.

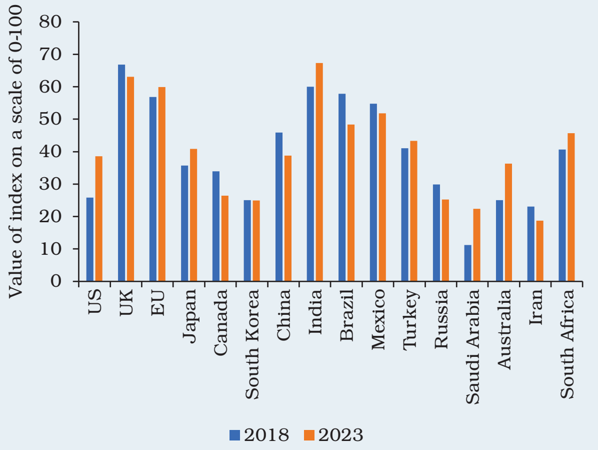
I.48 India has made progress towards meeting the net zero target. The current set of actions on climate change is the result of learning from its own experience and those of other countries, and the awareness of the risks and costs associated with the adverse impact of climate change. India is keen to form knowledge networks by facilitating data sharing and information exchange at the institutional level to share its experience and learnings with the rest of the world by participating in research and development activities. Mitigating the growing GHG concentration in the atmosphere will include harnessing the potential in mangroves to absorb more carbon emissions than landed tropical forests. Accordingly, dedicated commitments have been made towards conservation and management of mangroves.

I.49 The Ministry of Science and Technology launched the National Mission for Sustainable Himalayan Ecosystem in 2010 to understand the implications of climate change on the Himalayan ecosystem in order to conserve and protect its biodiversity. A separate Mission for Green India was launched by the Ministry of Environment, Forests and Climate Change in 2014 to provide livelihoods to 3 million people through forest-based activities and carbon sequestration capacity.

I.50 With the coming into force of the Energy Conservation Act of 2001, the Ministry of Power launched a similar Mission in 2011 known as National Mission for Enhanced Energy Efficiency (NMEEE) to make energy savings. India has co-founded the International Solar Alliance (ISA) with France in 2016 and announced a National Hydrogen Mission to increase the dependency on green energy. Moreover, the Government of India has established an adaptation fund and provided initiatives under its National Action Plan for climate change. India's progress in adaptation and mitigation of climate change is evident from the rise in its Climate Change Performance Index (CCPI) in recent years (Chart I.27).

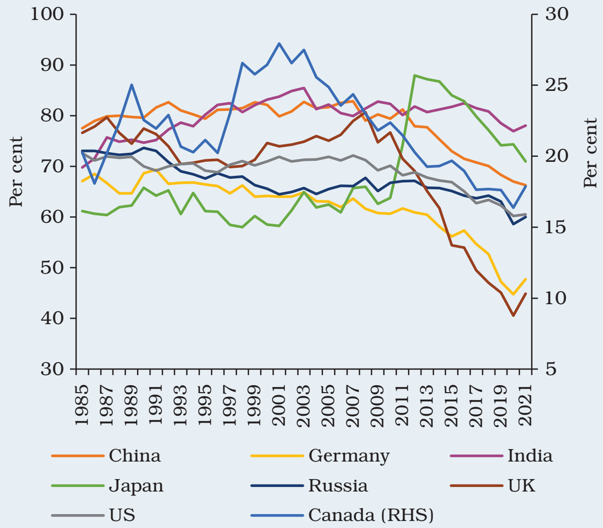
I.51 Currently, about 80 per cent of the electricity generation in India is from fossil fuels (Chart I.28). Future energy transitions for India can be estimated under two different scenarios

Chart I.27: Climate Change Performance Index, Select Countries



Note: The methodology followed in each report may be different but is broadly based on 14 indicators divided into four categories: GHG emissions (weight: 40 per cent), Renewable energy (weight: 20 per cent), Energy use (weight: 20 per cent), and Climate policy (weight: 20 per cent).
Source: Germanwatch CCPI Reports.

Chart I.28: Share of Electricity Production from Fossil Fuels



Source: OWID.

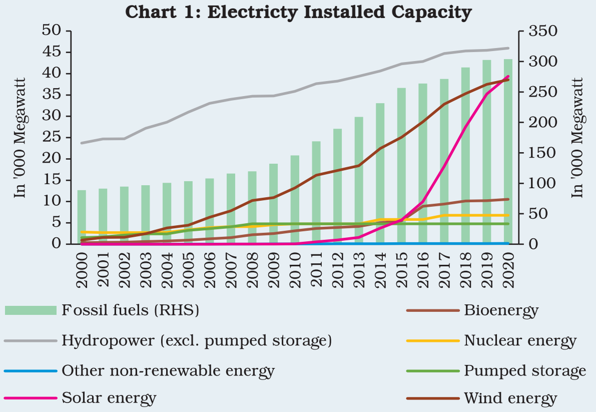
underlining the urgent need for a structured change in the energy sector (Box I.4).

I.52 In sum, India is using the challenge of climate change to propagate action globally and has, in fact, emerged as a leading voice from the emerging world. It is undertaking numerous policy actions as part of the global commitments while pushing outwards the boundaries of its development priorities.

Box I.4
Energy Transition Scenarios for India

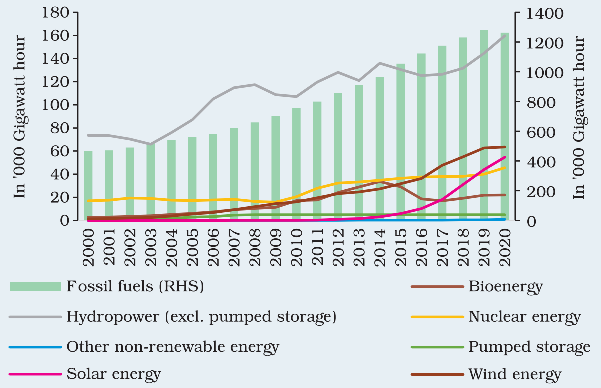
To reduce CO_2 emissions, renewable energy needs to sufficiently replace the carbon-emitting sources of energy. The transition process could be induced by direct or indirect taxes on carbon and subsidies to promote renewable energy. Under different globally coordinated policy scenarios, the amount of renewable energy capacity and generation would differ, calling for public investments of differential magnitudes.

Chart 1: Electricty Installed Capacity



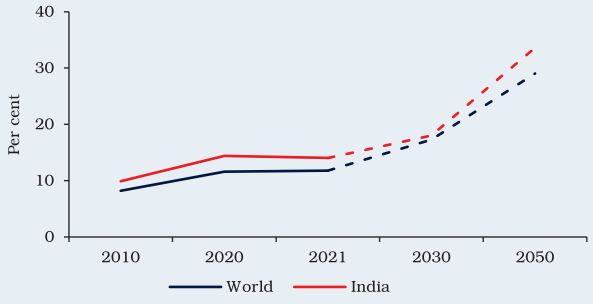
Source: Renewable Energy Statistics, IRENA (2022).

Chart 2: Electricity Generation



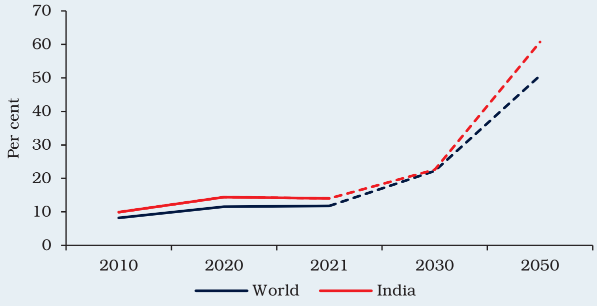
Source: IRENA (2022).

Chart 3: Share of Renewables under the Stated Policies Scenario (STEPS)



Note: The data points are actuals up to 2021 followed by projections based on the global model of the International Energy Agency (IEA).
Sources: IEA (2022); World Economic Outlook (WEO); and Authors' calculations.

Chart 4: Share of Renewables under the Announced Pledges Scenario (APS)



Note: The data points are actuals up to 2021 followed by projections based on the global model of the International Energy Agency (IEA).
Sources: IEA (2022); World Economic Outlook (WEO); and Authors' calculations.

Even though fossil fuels dominate India's energy production at present, there has also been a steady rise in the production of renewable energy over the years (Charts 1 and 2). The transition to renewables needs to pick up at a faster pace.

The share of renewables is going to rise significantly under the Announced Pledges Scenario (APS) as compared to the Stated Policies Scenario (STEPS) for India (Charts 3 and 4)[25].

The rise in energy demand under STEPS for India is estimated at 3 per cent between 2021 and 2030, as fossil fuel use is likely to increase steeply, mainly led by coal during this period. Oil will remain a major source of energy for the transport sector. Under APS, coal demand in India is expected to reduce by around one-third of its predicted value by 2050 due to NDCs. Under this scenario, India will have to generate around 61 per cent of its energy supply from renewable sources. Thus, under APS, India may observe a faster emergence of low-emission alternatives in power, industry and transport sectors, and a sharper fall in coal use and rise in renewables in line with its 2070 net zero goal.

References:

International Energy Agency (2022). World Energy Outlook 2022. License: CC BY 4.0 (report); CC BY NC SA 4.0. https://www.iea.org/reports/world-energy-outlook-2022.

IRENA (2022). Renewable Energy Statistics 2022. International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Renewable_energy_statistics_2022.pdf?rev=8e3c22a36f964fa2ad8a50e0b4437870.

5. Climate Change and the Reserve Bank of India

I.53 Climate change has been appropriately assigned to the domain of fiscal policy. Central banks, given their relatively narrow mandates of price and financial stability, and fewer instruments at their disposal, have hitherto adhered to their core competence. As a result, the newer assignment of climate change to them has provoked an animated debate. It is argued that central banks lack the necessary tools and domain knowledge to address climate change (Hansen, 2022; and Rajan, 2023).

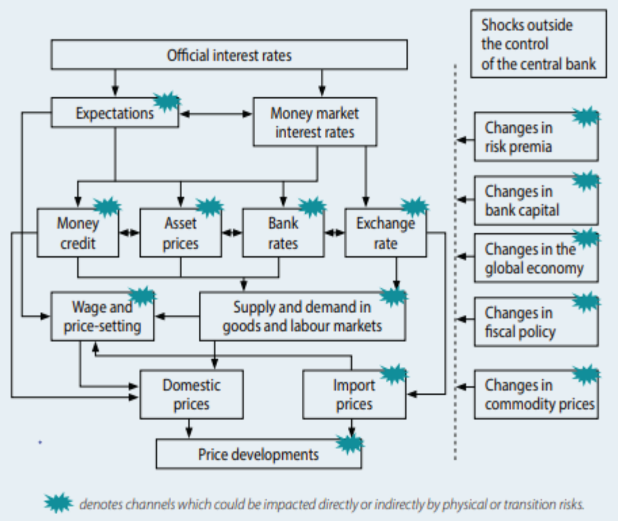
I.54 It is also argued that climate change may take central banks away from the pursuit of price stability, which can affect their credibility in

25 As per the IEA, APS includes the latest NDCs and the long-term net zero goals of the countries, whereas STEPS follows only the current policy setting of countries. Thus, APS signifies a stricter, globally coordinated transition. Renewables include bioenergy, geothermal, hydropower, solar photovoltaics (PV), concentrating solar power (CSP), and wind and marine (tide and wave) energy for electricity and heat generation.

meeting their primary mandate. In fact, undue expectations from central banks about addressing climate change, if unfulfilled, can tarnish their reputation (Issing, 2021). Furthermore, central banks' actions may not always complement governmental actions on climate matters. Hence, they may face (a) "calibration risk" with regard to their ability to adjust their instruments towards managing climate risks without an explicit need for additional mandates and tools; and (b) "capture risk" with respect to their independence from the government's climate policy (Masciandaro and Russo, 2022). Moreover, introducing climate change as an explicit mandate may require complex and cumbersome amendments in the existing institutional structures governing central banks (*ibid*). In sum, climate change in the context of central banks has come to be regarded as "mission creep" - a gradual broadening of their objectives beyond the original scope or focus.

I.55 On the other hand, there is a growing recognition that even if governments are the most influential agency for climate change, all institutions, including central banks and financial sector regulators/supervisors, are stakeholders and especially so in view of the existential threat to their central mandates. Climate change can affect price stability through supply shocks such as food and energy shortages and through a decline in productive capacity. Climate-related risk can also lead to inflation volatility, which can effectively de-anchor inflation expectations. Furthermore, even if mitigation policies such as carbon pricing are forceful, they can affect price stability, potentially precipitating large and long-lasting movements in relative prices (NGFS, 2020). Demand shocks can arise due to the loss of wealth of firms and households on account of frequent natural disasters. Physical and transition risks can affect the balance sheets of financial institutions and banks, limiting the flow of credit to the real economy (Schnabel, 2021). Climate-induced uncertainty can make households save more for precautionary purposes, bringing down the real equilibrium interest rate (*ibid*)[26]. There are several channels through which climate change can affect monetary transmission (Chart I.29).

Chart I.29: Impact of Climate Risk on Monetary Transmission

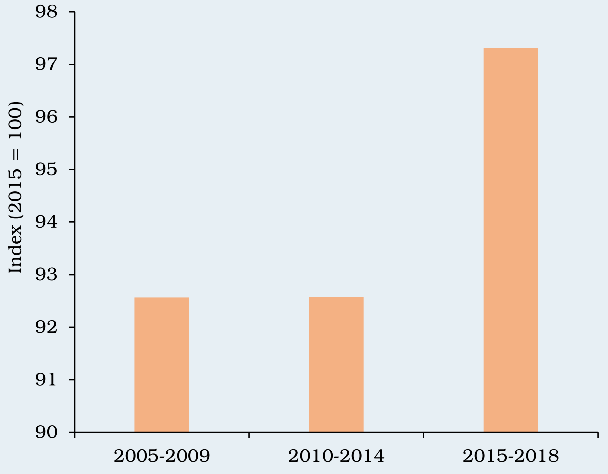


Source: NGFS (2020).

I.56 Central banks also face challenges to their financial stability mandate from climate risk which can affect the valuation of financial assets by influencing investors' risk perceptions (FSB, 2020). This can create volatility in traded assets. Uncertainty in asset prices can, in turn, reduce the effectiveness of hedging, further increasing the vulnerability of banks and financial institutions.

26 However, it is also argued that green investments can result in a low inflation, and hence, a low interest rate environment in the long run (*ibid*).

Chart I.30: Average Carbon Footprint of Bank Loans in Select Countries



Note: Carbon footprint of bank loans (CFBL) is the average CO_2 emission intensities from the fuels burned in each sector, weighted by the sectoral share of outstanding domestic loans of banks.
Sources: IMF; and Authors' calculations.

Depreciation pressures on currencies of countries frequently affected by climate disasters can cause financial instability, higher import costs and negative terms of trade. Transition risks can operate through multiple channels, exacerbating traditional risks in all categories, including credit, market, liquidity, operational and reputational risks for banks and financial institutions. The carbon footprint or financial exposure of banks to climate change has, in fact, gone up significantly in recent years (Chart I.30).

I.57 The consensus is hence coalescing to the position that central banks are uniquely placed to address climate change. They have a critical role in the promotion of green/sustainable finance through a mix of developmental and prudential regulatory policies[27]. With this growing recognition, there have been several global interventions to involve central banks and other financial authorities into climate action (Annex I.2). The Network for Greening the Financial System (NGFS), comprising central banks and supervisors, was established in 2017 to (a) strengthen the global response for meeting the Paris Agreement goals; and (b) enhance the role of the financial system in managing risks from climate change and mobilising green finance for environmentally sustainable development[28]. As of March 2023, NGFS consists of 125 members and 19 observers (NGFS, 2023)[29].

I.58 Climate change is a rapidly emerging area of policy interest in the RBI. Back in 2007, the RBI advised banks to put in place Board-approved plans of action towards helping the cause of sustainable development. In 2015, the RBI included loans for generation of renewable energy and public utilities run on non-conventional energy as part of its priority sector lending (PSL) policy to incentivise the development of green energy sources. More recently, the RBI has taken initiatives aimed at understanding the implications of climate change for India's financial sector for an informed climate-related policy, and the financing of green projects. In April 2021, the RBI joined the NGFS to benefit from and contribute to the best practices in climate risk management and green finance. In its statement, the RBI highlighted three commitments while noting national commitments, priorities and complexity of the Indian financial system: (a) exploring how climate scenario exercises can be used to identify vulnerabilities in

[27] The G20 Green Finance Study Group (GFSG) defines green finance as "financing of investments that deliver environmental benefits in the broader context of environmentally sustainable development", where environmental benefits include GHG reductions or improved energy efficiency, among others (GFSG, 2016).

[28] See https://www.ngfs.net/en/about-us/governance/origin-and-purpose

[29] NGFS Observers are international or regional public financial institutions/regulators/central banks/multilateral development banks who contribute to its work but are not consulted on items for decision; see https://www.ngfs.net/en/about-us/membership.

RBI-supervised entities' balance sheets, business models and gaps in their capabilities for measuring and managing climate-related financial risks; (b) integrating climate-related risks into financial stability monitoring; and (c) building awareness about climate-related risks among regulated financial institutions and spreading knowledge about issues relating to climate change and methods to deal with them accordingly.

I.59 In July 2022, the RBI released its seminal "Discussion Paper on Climate Risk and Sustainable Finance", providing broad guidance for RBI-regulated entities to develop good practices on (a) appropriate governance; (b) climate risk strategy; and (c) risk management structure. It also laid out guidance for voluntary initiatives by regulated entities on green finance, setting up of green branches and green data centres, encouraging greater use of electronic means of communication instead of paper, and renewable energy sources. In January 2023, the RBI issued sovereign green bonds to mobilise resources for the Government for green infrastructural investments. This move was in keeping with *panchamrit*, the five-point strategy for climate action announced by the Government during COP26. More recently, in April 2023, the framework for mobilising green deposits by regulated entities has been released by the RBI with a view to fostering and developing green finance ecosystem in the country.

I.60 There has also been a distinct focus on climate-related issues in the RBI's research in recent times: this Report is a case in point. Applying global learnings on climate change to Indian data, each chapter of the Report uncovers the possible implications of climate change for the Indian economy and in preparing for the future.

6. Concluding Observations

I.61 Affirmative action for greening the earth as a global policy good is gaining traction. Despite its slow pace of implementation, the Paris Agreement of 2016 has offered hope for the transition towards a greener cleaner world. India has set itself a target to achieve net zero by 2070 and is making significant progress in expanding its non-fossil-fuels-based energy capacity. The updated NDCs reaffirm this commitment to work towards a low-carbon emission pathway, while simultaneously endeavouring to achieve sustainable development goals. India's Mission LiFE seeks to empower people to fight against climate change. With the growing recognition that climate change can affect price stability and financial stability, central banks, including the RBI, are assuming an important role in addressing climate change. This Report reflects that new mission.

I.62 Chapter II analyses the effects of climate change on the Indian economy with an assessment of the growth-inflation-emission trade-offs under different scenarios linked to India's NDCs. A highlight of the chapter is the documentation of the specific topographical and economic characteristics of the country that determine its high vulnerability to climate risks while dealing with the challenge of balancing its growth and environmental aspirations.

I.63 Chapter III discusses the risks to India's financial sector from climate change, channels of risk transmission, the national potential to mitigate those risks and provide adequate financing for green transition. This chapter employs a dynamic stochastic general equilibrium (DSGE) model to assess the impact of climate shocks on capital stock, consumption, income, inflation and interest rates, as these variables can influence the financial soundness of banks. It presents the findings of a pilot survey of stakeholders in assessing the level of awareness about the transition risk and the adoption of adequate risk mitigation strategies. The chapter also conducts climate stress tests to assess the banking sector's vulnerability to climate risks.

I.64 Chapter IV explores a range of feasible policy options encompassing various domains such as fiscal policy, technology, international trade, regulatory and monetary policy, markets-based and citizen-centric measures to achieve India's net zero target.

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Annex I.1: Major Global Interventions for Climate Change

Year	Global Intervention	Issues Addressed/Initiatives
1972	Stockholm International Summit	Led to the creation of UNEP
1979	World Climate Conference I	Endorsed plans to establish a World Climate Programme (WCP) under WMO, UNEP, and the International Council of Scientific Unions (ICSU), focusing on climate data, climate applications, climate research and climate impact study programmes
1987	Montreal Protocol	Focused on global reduction of production of substances damaging the ozone layer, such as CFCs
1988	**Creation of IPCC**	**Established for inter-governmental assessment of the science, impacts and response options for climate change**
1992	UN Conference on Environment and Development or the "Earth Summit"	Adoption of (a) A plan of action at the global, national and local levels to address human impact on the environment (UN, 1992) (b) Rio Declaration on Environment and Development aimed at working towards international agreements to "protect the integrity of the global environmental and developmental system"
1992	**UN Framework Convention on Climate Change (UNFCCC)**	**Establishment of Conference of the Parties (COP) for international discussions on stabilisation of GHG concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system**
1995	First Meeting of UNFCCC COP (COP1)	Aimed at an annual review of the Convention and to take decisions to promote its implementation
2005	**Kyoto Protocol**	**The first legally binding climate treaty that required developed countries to reduce emissions by an average of 5 per cent below the 1990-levels over 2008-2012**
2009	Copenhagen Accord	Agreement to reduce global emissions to hold the increase in global temperature below 2 degrees Celsius (UN, 1992)

Year	Global Intervention	Issues Addressed/Initiatives
2016	**Paris Agreement**	**The Agreement focussed on:** **a) Reduction of GHG emissions to limit the global temperature increase to 2 degrees Celsius and further to 1.5 degrees Celsius;** **b) Provision of financing to developing countries for climate change mitigation and adaptation**
2021	COP26	a) Phase down of coal power and phaseout of inefficient fossil fuel subsidies; b) Delivering on climate finance pledge of US$ 100 billion by developed countries; c) Launching "Glasgow dialogue" to address loss and damage associated with climate change
2022	COP27	Reaffirming the commitments of global average temperature reduction, it a) Marked a breakthrough agreement on "Loss and Damage" fund including damage to crops, homes or infrastructure, human health, *etc.*; b) Urged countries to integrate water into their adaptation efforts

Source: Authors' compilation.

Annex I.2: Climate Policies Being Implemented in Select Countries

Type of Policy	Illustration of the Policy Instrument	Country Examples
Fiscal Policy	National carbon taxes; Cap-and-Trade (CaT) or Emissions trading systems (ETS); Emission or energy efficiency standards[30]	• 70 direct carbon pricing instruments operating in 47 jurisdictions with 34 ETS and 36 carbon tax regimes (World Bank, 2022) • EU and Japan have the most stringent energy efficiency standards
	Feed-in tariffs (FIT); Renewable quotas[31]	• 69 countries have implemented some form of FIT (OECD, 2019) • China has implemented a quota system
	Public investment in infrastructure and social development; Partnership between private sector, government, development bank, and long-term institutional investors	EU (Infrastructure Investment Plan); China (Urban Development Investment Corporation)
	Public guarantees as loan commitments; Credit or cash flow guarantees; Multi-sovereign guarantees	World Bank Multilateral Investment Guarantee Agency (MIGA), European Investment Fund Guarantee Scheme
Regulatory Policy	Redressing underpricing by greater transparency of climate risks; Climate-related financial data; Climate-related risk disclosures; Taxonomy of green assets; Climate-related stress tests; Macro-prudential tools	UK, France, Brazil, China
	Green supporting and brown penalising factors in capital requirements; International requirements of minimum amount of green assets on balance sheets; Notional carbon prices; Corporate governance reforms	Lebanon, Brazil, China
	Green credit; Green insurance; Green securities; Credit allocation policies or Directed lending policies for renewables	China (Green Bond Endorsed Project Catalogue), India, Bangladesh
	Integrating climate risk analytics into collateral frameworks; Central bank portfolio management; Green QE; Developing own risk assessments; Ensuring climate risks are appropriately reflected in central bank asset portfolios	UK, Japan, Bangladesh, Netherlands, Norway, ECB (Purchase of EIB bonds)

Source: Krogstrup *et al.* (2019).

30 Procedures/regulations prescribing energy performance of manufactured products, such as maximum energy consumption for an activity.

31 FIT is designed to support the development of renewable energy sources by providing a guaranteed, above-market price for renewable energy producers. In case of quota, the government sets the percentage or amount of energy that comes from renewable sources.

II MACROECONOMIC EFFECTS OF CLIMATE CHANGE IN INDIA*

India's diverse topography makes it highly vulnerable to climate risks, manifested in the form of sustained rise in temperature, erratic monsoon patterns, and rising frequency and intensity of extreme weather events. India's goal of becoming an advanced economy by 2047 and achieving the net zero target by 2070 would require accelerated efforts in terms of reducing the energy intensity of output as well as improving the energy-mix in favour of renewables. Scenario analysis suggests that delayed climate policy actions could be costlier, in terms of larger output losses and higher inflation. Sectoral analysis, for risk mitigation, suggests policy interventions to focus on high emission-intensive sectors to minimise trade-off costs.

1. Introduction

II.1 Climate change has moved to the centre stage of global public policy debate today because of its devastating macroeconomic impact, being experienced in recent years and the potential for harsher consequences in the future. The research focus accordingly has advanced from initial 'detection and attribution'[1] to 'impact assessment and mitigation policies'. While growing scientific evidence has made it possible to forge a consensus[2] on the key aspects of climate change – *i.e.*, global warming is real and that human activities are a significant cause – the rising incidence of climate events across the globe has raised public awareness about this risk.

II.2 Existing research work not only highlights the probable demand-side implications of climate change, but also supply shocks in the medium-to long-run with the potential to cause widespread disruptions to the overall macroeconomic and financial system. For example, the manifestation of climate change through changes in temperature and precipitation patterns along with the rising frequency and intensity of extreme weather events has implications for growth and inflation, with multiple channels of risk transmission. Sectoral implications could include disruptions in cropping cycles and variations in agricultural yield/output. In the industrial sector, there could be an increase in operational costs reducing profitability, owing to the imposition of new climate-friendly regulations, reduced utilisation of old stock of capital and diversion of investment towards greener infrastructure/capital/technology coupled with relocation of production processes and activities due to climate-related losses. Adversities for the services sector could be diverse, such as strains on financial services, say due to an increase in insurance claims, as well as disruptions in travel, transportation and business services. Climate events could also have implications for various factors of production. At a broader level, there could be implications for the labour market in terms of labour productivity decline due to climate-related health hazards, and climate migration, *i.e.*, out-migration from areas that are significantly prone to climate risks to lesser affected regions. Capital could also be impacted due to physical

* This chapter has been prepared by a team comprising Binod B. Bhoi, G V Nadhanael, Sujata Kundu, Vimal Kishore, Chaitali Bhowmick, Madhuresh Kumar, Ranajoy Guha Neogi, Abhishek Ranjan and Debojyoti Mazumder.

1 Using knowledge of past climate events to quantify the nature of ongoing changes.

2 Oreskes, N. (2007).

loss of infrastructure that may depress return on capital and regulatory charges differentiating between green and other assets. Overall, costs are expected to rise for the economy owing to rehabilitation measures and new investment for mitigation and adaptation, which if funded by the government, could entail additional fiscal costs.

II.3 Therefore, while the risks from climate change have generally been classified into two categories – physical risk and transition risk, the channels of risk transmission may be three: (i) direct impact or first-order effects; (ii) indirect impact or second-order effects; and (iii) spillover effects (intra-economy and cross-border impact or contagion risks) [BCBS, 2021; Ciccarelli and Marotta, 2021]. The direct transmission channels originate in sectors which are exposed to climate events more than others, whereas the indirect transmission channels involve the effects arising from sectoral value chains at various levels. It is through the indirect transmission channels that the impact of the climate event may spread to the whole economy. The third channel involves spillovers of impact arising from the interactions between the real economy and the financial sector. It would also involve implications for international trade and capital flows and through them for cross-border contagion risks. While the consensus as of now seems to suggest that the direct effects are likely to increase gradually over time across the globe as global temperature rises, what is still lurking in the shadow is the extent of the impact; the underlying non-linearities; and the timeline over which the impact may materialise (BCBS, 2021). This is more so because it is extremely difficult to obtain precise and reliable estimates of the overall macroeconomic impact of climate change, which are conditional upon not only the nature and magnitude of the climate shock, but also on how economies adapt and mitigate the impact through various policy actions. While there is a broader consensus on green transition as a common goal, the path to its achievement is rugged involving not only balancing known and unknown macroeconomic trade-offs, in particular growth-inflation-financial stability, but also creating a global environment for cooperation to drive joint actions to deal with the common challenge.

II.4 From the perspective of monetary policy, an assessment of climate-related risks – the likely persistence of the impact of the shock, the extent of the impact on target variables and the transmission channels, and future risks – becomes important to insulate the economy from adverse consequences as monetary policy seeks to stabilise the economy after it is hit by unanticipated shocks. It has also been argued that climate change is not merely another market failure but presumably "the greatest market failure the world has ever seen" (Stern, 2006). The other side to the debate is the paradox that "success is failure" (Carney, 2016), implying that rapid and ambitious policy measures over a short-term horizon may not be desirable from the perspective of larger macroeconomic and financial stability. Therefore, from the standpoint of monetary policy, this calls for a careful monitoring and assessment of the visible patterns of climate-related risks and their associated implications for the economy, such that appropriate and timely policy measures may be calibrated.

II.5 Against this backdrop, India is at the cusp of a unique development challenge. With India's greenhouse gas (GHG) emissions[3] increasing over

[3] Include emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and industrial gases such as hydroflurocarbons (HFCs), perflurocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). As per the Centre for Climate and Energy Solutions (C2ES), globally CO_2 accounts for about 76 per cent of total GHG emissions, followed by CH_4 (16 per cent) and N_2O (6 per cent).

four-fold during 1970 to 2021[4], a green transition path calls for a careful long-term planning and well-defined implementable strategies. More so because India is ranked seventh in the list of most affected countries in terms of exposure and vulnerability to climate risk events in 2019 as per the Global Climate Risk Index 2021 (Eckstein, *et al*., 2021). Hearteningly, India is also the highest ranked G-20 country as per the Climate Change Performance Index 2023 (Burck, *et al*., 2022; PIB, 2022). Both high climate risk exposure of the country and lead performance in mitigating risks pose challenges for estimating the macroeconomic impact of climate change in India.

II.6 Accordingly, the key motivations of this chapter are to: (i) assess the impact of climate change on the Indian economy, and (ii) explore the future macroeconomic implications through scenarios linked to India's Nationally Determined Contribution (NDC) commitments. In comparison to a baseline scenario (business as usual [BAU]), a modest green transition scenario (characterised by continuation of remarkable achievements of the past decade) and an ambitious green transition scenario (with the required rate of reduction in emissions consistent with achieving the net zero target by 2070) bring to the fore the often discussed temporal trade-offs between environmental and macroeconomic objectives. These assessments are done taking into account available facts and India-specific peculiarities of the climate-economy nexus. For instance, India's monsoon-dependent agriculture, economically significant long coastline and energy-intensive industrial sector highlight the challenges posed by climate risks.

II.7 Set against these key motivations, this chapter is organised under seven sections: Section 2 provides the geographical and structural characteristics of the Indian economy. It analyses why climate change presents India with a unique and daunting challenge in terms of its emission targets *vis-à-vis* the aspiration for higher economic growth. Section 3 discusses the various forms in which climate change risks manifest in India. Section 4 provides a macroeconomic impact assessment of climate change in India, especially with regard to the physical risks. Section 5 analyses various scenarios of green transition consistent with the country's potential to become an advanced economy by 2047 alongside achieving the net zero emissions target by 2070, while highlighting the underlying growth-inflation trade-offs that may emerge from pursuing both economic and environmental goals. Sector specific green transition challenges are elucidated in Section 6. Section 7 presents concluding remarks with some policy suggestions.

2. India's Exposure to Climate Risks

Geographical Features

II.8 India's high vulnerability to climate events is on account of its unique geographical features and economic structure. The Indian sub-continent has a diverse topography ranging from the snow-clad Himalayas in the north, fertile plains and the deltaic region in the east, long coastline of more than 7500 kilometres covering 9 states from the east to the west in the mainland forming the southern peninsula, and the Thar desert in the north-west (Chart II.1). This diverse topography is not only exposed to different temperature and precipitation patterns, but also makes it vulnerable to extreme weather events posing wide-ranging spatial and temporal implications for the economy.

4 Calculated from Our World in Data based on emissions data from Jones *et al*., (2023).

Chart II.1: Risks Emanating from Climate Change across Geographical Regions in India

Note: Map not to scale.
Sources: Mani *et al.*, (2018); Krishnan, *et al.*, (2020).

II.9 For instance, India's long coastline, also referred to as the coastal plains, features among the most densely populated regions of the world, primarily owing to its fertile soil and accessibility to ports. The coastal plains provide important hinterlands to some of the major ports of the country. Therefore, from a macroeconomic standpoint, India's long coastline assumes significant importance. On the other hand, global warming leaves the coastal plains susceptible to flooding owing to rising intensity and frequency of extreme sea level events, in the form of tides, waves, storm surges and rise in mean sea level. Moreover, risks from global warming also include loss of land and receding coastlines due to coastal erosion, impacting coastal infrastructure, human settlement, and industrial and farm activities. Coastal cities are prone to cyclones and also face acute dangers of frequent flooding and salinisation of farmlands and freshwater supplies (Krishnan, *et al.*, 2020).

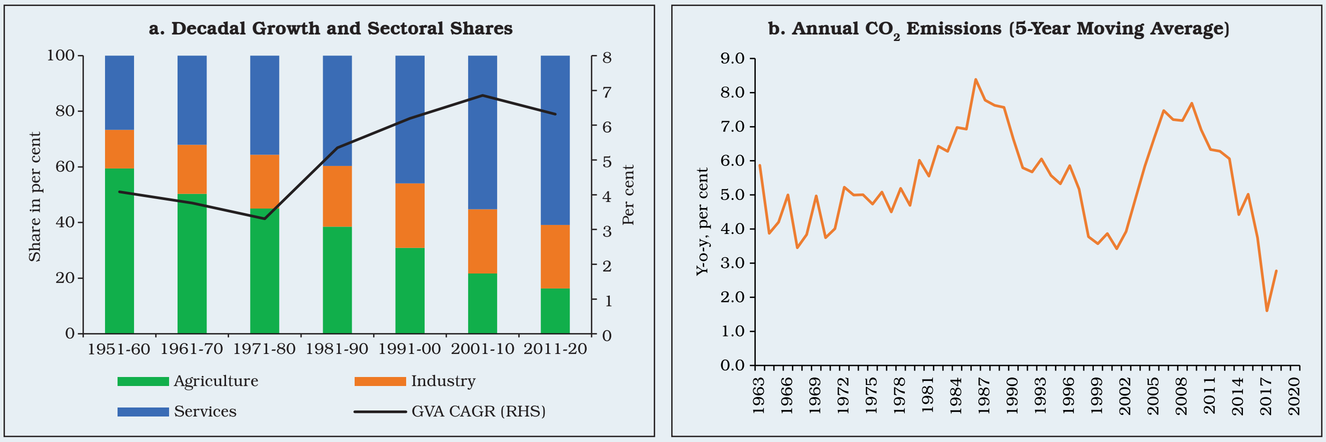
Economic Structure

II.10 India's sectoral composition of GDP is skewed towards services sector, which is globally considered to be emission-light with relatively lower energy intensity of output. Share of services sector in GVA increased from 43.2 per cent during 1980s to 60.9 per cent during 2010s (Chart II.2a). In contrast, the share of agriculture in overall GDP fell from 38.5 per cent to 16.3 per cent over the same period, while that of the industrial sector remained broadly unchanged at a little over one-fifth of overall GVA. The services-led growth path since 1980s was associated with a declining trajectory in overall CO_2 emissions growth for about twenty years till early 2000s (Chart II.2b). There was a brief episode of acceleration in CO_2 emissions growth which took place between 2004-05 to 2009-10, which could be attributed to the spurt in manufacturing activity observed during that period. CO_2 emissions growth started decelerating around 2011-12 and followed a declining trajectory again during the decade of 2010s.

II.11 A deep-dive into India's sectoral break up shows that metal industries, electricity and transports, owing to their dependency, both direct and indirect, on fossil fuels, are the highest emission-intensive[5] sectors, together accounting

[5] CO_2 emission intensities represent the amount of CO_2 released into the atmosphere as a result of direct fuel combustion per unit of output.

Chart II.2: Sectoral Composition in GVA and CO_2 Emissions in India

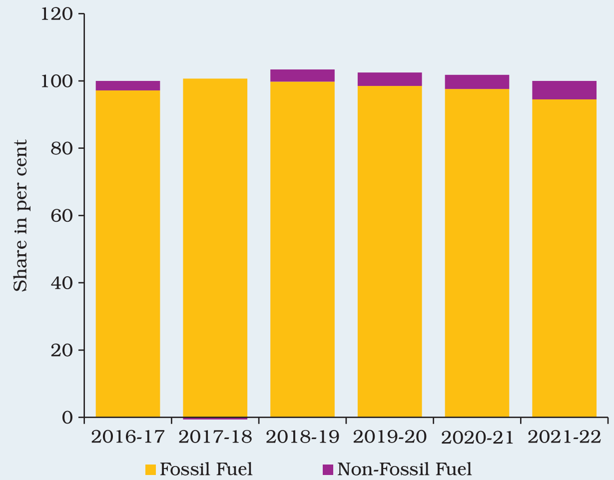


Sources: National Statistical Office (NSO); and Our World in Data.

for around 9 per cent of India's total GVA in 2018-19[6] (Table II.1). In contrast, wholesale and retail trade, financial and professional services, including information and computer related services, professional, scientific and technical services, comprising more than 27 per cent of India's overall GVA, are among the relatively low emission-intensive sectors. Although industrial sector emissions are higher as compared with agriculture and services sectors, emission intensity of agriculture sector, which involves both energy related emissions and non-energy related emissions (such as N_2O and CH_4) is, in fact, higher than certain industries such as textiles, machinery and equipment as well as construction activity. Thus, the sectoral composition of the Indian economy – smaller share of the industrial sector and prevalence of low energy-intensive services – helps contain India's emissions.

II.12 With energy production driving around three-quarters of global GHG emissions, changing the energy-mix – away from non-renewables to renewables – is critical. In terms of the overall energy-mix, fossil fuel-based energy sources, *viz.,* coal, oil and natural gas, continue to dominate energy consumption in India (Chart II.3). At a disaggregated level, within

Chart II.3: Share of Fossil Fuel and Non-Fossil Fuel based Energy Sources in India's Primary Energy Consumption



Note: Data may not add up to 100 due to rounding off.
Source: Energy Statistics 2023, Ministry of Statistics and Programme Implementation (MoSPI).

[6] Table II.1 corresponds to data for 2018-19 as the latest data on emission intensity for India as per the IMF Climate Change Indicators Dashboard are available till the year 2018.

Table II.1: Sector-wise Share in GVA and CO_2 Emission Intensity (2018-19) in India[7]

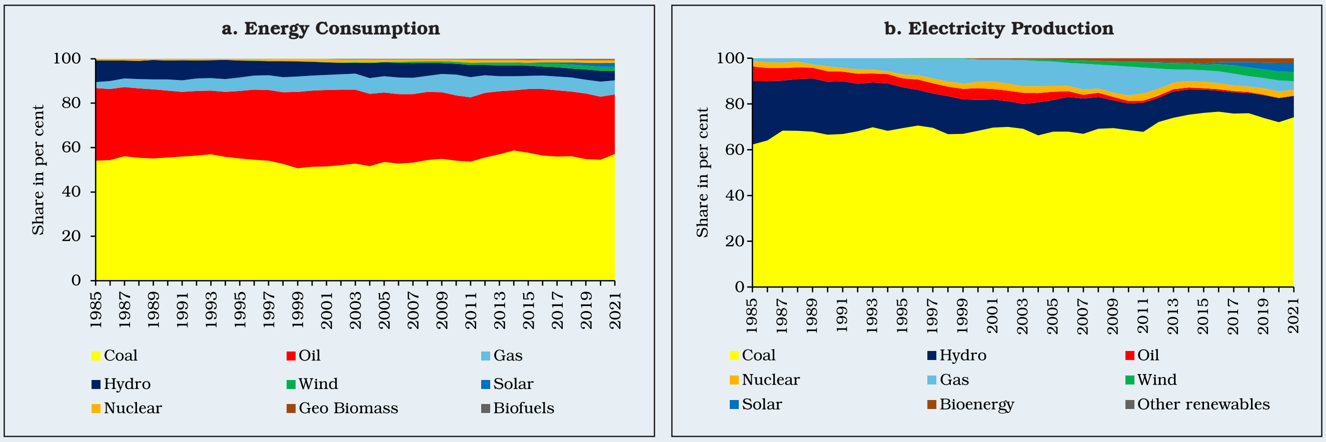
Sector	Share in GVA	CO_2 Emission Intensity (Metric Tons of CO_2 Emissions per US$ 1 Million of Output)
Agriculture, forestry and fishing	14.8	-
Agriculture, hunting, forestry	13.8	84.7
Fishing and aquaculture	1.0	4.1
Mining	2.6	-
Mining and quarrying, energy producing products	-	382.1
Mining and quarrying, non-energy producing products	-	185.2
Manufacturing	18.3	-
Food products, beverages and tobacco	2.0	11.9
Textiles, apparel and leather products	2.4	37.8
Metal products	2.6	2796.6
Machinery and equipment	4.6	67.0
Electricity, gas, water supply and other utility services	2.3	-
Electricity, gas, steam and air conditioning supply	-	7263.8
Water supply; sewerage, waste management and remediation activities	-	110.4
Construction	8.1	26.1
Wholesale and retail trade; repair of motor vehicles	12.3	67.8
Accommodation and food services	1.1	22.0
Transport	3.9	-
Air transport	0.07	1210.4
Land transport	4.0	378.8
Water transport	0.1	1587.7
Financial, real estate, ownership of dwelling and professional services	22.5	-
Financial services	6.0	27.4
Real estate and ownership of dwellings	6.5	48.6
Professional services	8.9	127.9
Public administration and defence	5.7	16.1
Other services	7.1	-
Education	3.7	23.2
Arts, entertainment and recreation	0.3	31.8
Human health and social work activities	1.5	17.5
Other service activities	1.6	77.4

-: denotes categories for which data are not reported.
Sources: NSO; and IMF Climate Change Dashboard.

fossil fuels, coal is the major source followed by oil (Chart II.4a). The share of coal in India's electricity production is around 60 per cent (Chart II.4b).

[7] Sectoral GVA share and sectoral emission intensity are compiled from two different sources which differ in their respective sectoral classifications and aggregation. Therefore, in case of some sectors, exact mapping of both the indicators could not be done.

Chart II.4: India's Energy-Mix at a Disaggregated Level

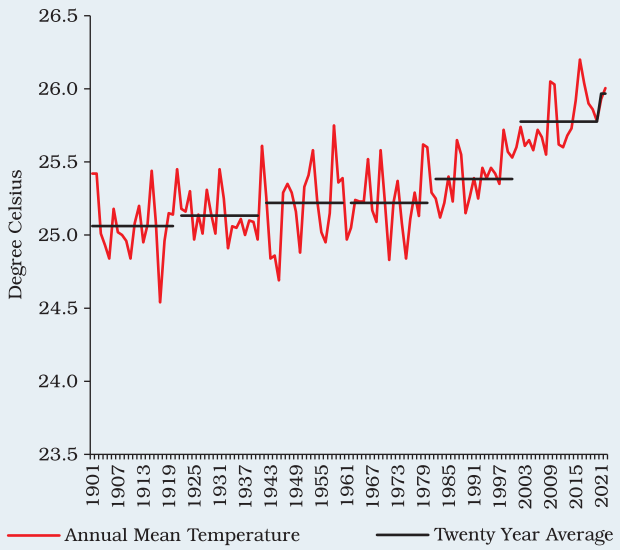


Source: Our World in Data.

3. Manifestation of Climate Change in India

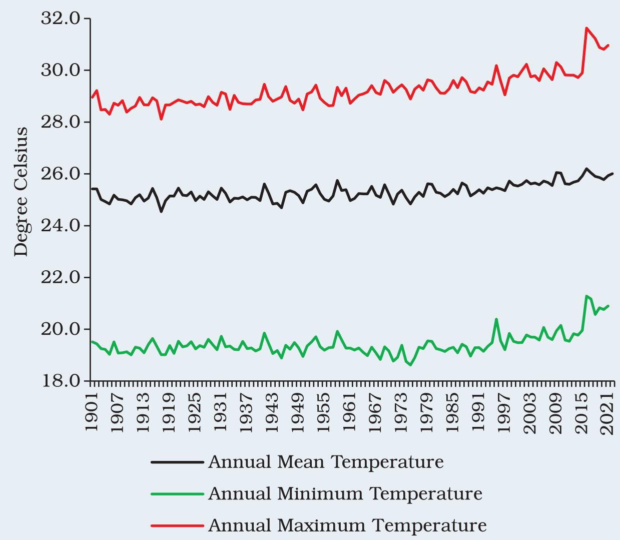
II.13 Major indicators that signal about climate-related stress are distinct temperature and precipitation anomalies. India has witnessed these anomalies quite frequently in recent years. While annual average temperature in India has been increasing gradually, the rise has been significantly sharp during the last vicennial than during any other 20-year time interval since 1901 (Chart II.5). In terms of minimum and maximum temperatures, during 1901-2021 the annual mean temperature showed an increasing trend of 0.63 degree Celsius per 100 years with a rise in the maximum temperature of 0.99 degree Celsius per 100 years. The rising trend in the minimum temperature was relatively lower than that in the maximum temperature, with minimum temperature increasing by 0.26 degree Celsius per 100 years (IMD, 2021) [Chart II.6].

Chart II.5: Average Annual Temperature in India



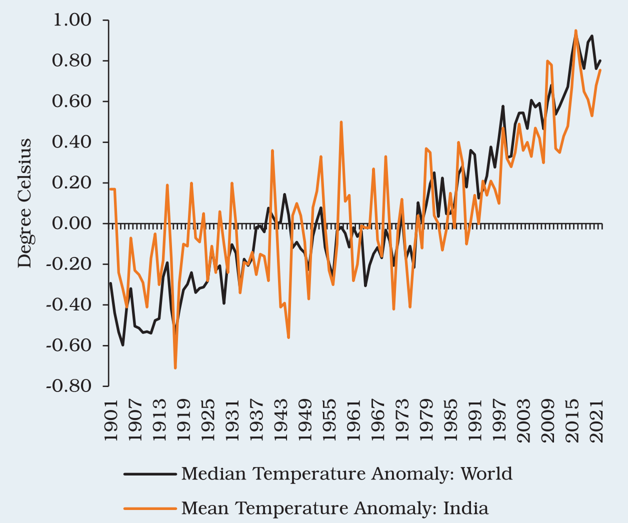
Sources: Data.gov.in; and India Meteorological Department (IMD).

Chart II.6: Minimum and Maximum Temperature in India



Sources: Data.gov.in; and IMD.

Chart II.7: Global and Indian Temperature Anomaly
(From 1961-1990 Average Temperature)



Sources: Our World in Data; data.gov.in; and IMD.

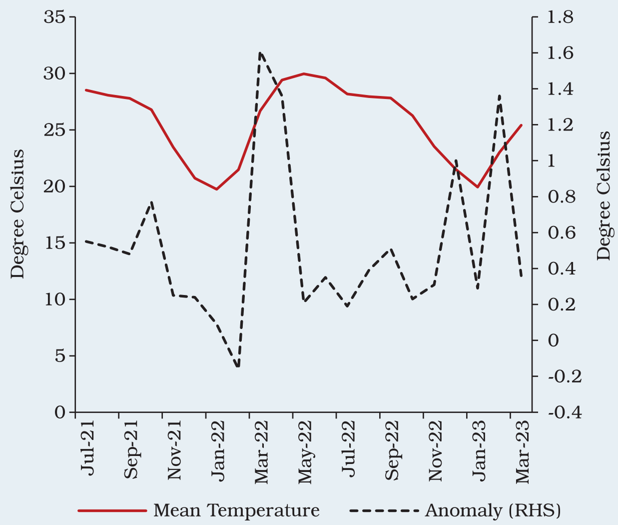
II.14 Such rapid changes in India's temperature profile have led to the rising temperature anomaly[8], as is also observed globally (Chart II.7).

II.15 The past decade (2011-2021) has been an outlier in terms of major temperature irregularities from the normal trend. The decade has been the warmest on record with temperatures shooting up in the range of 0.34-0.37 degree Celsius above the long period average (LPA). Further, 11 out of the 15 warmest years in India since 1901 have occurred during 2007-2021. Moreover, 2022 and 2021 have been the fifth and the sixth warmest years on record since 1901[9], with the annual mean temperature up by 0.51 degree Celsius and 0.44 degree Celsius, respectively, above the 1981-2010 average level. 2016 has been the warmest year on record so far for India since 1901, with a temperature anomaly of 0.71 degree Celsius above the 1981-2010 average.

II.16 In 2022, with the onset of summer, temperature shot up above the normal across several regions in the country, especially in the northern states of Punjab, Haryana, Delhi, Rajasthan and Uttar Pradesh, with the range being 3 degree Celsius to 8 degree Celsius. March 2022 recorded the highest average maximum temperature with an anomaly of 1.9 degree Celsius above the normal[10] and second highest mean temperature with an anomaly of 1.6 degree Celsius since 1901 for the month of March (Chart II.8). Additionally, April 2022 also recorded the second highest mean temperature for the month of April since 1901 (highest occurred in 2010).

II.17 Such high temperature with the onset of summer led to severe heatwave conditions in the country with implications for agricultural output. For instance, the wheat crop in the *rabi* season

Chart II.8: Mean Temperature and Anomaly from Normal Temperature



Source: IMD.

8 Temperature anomaly is defined as the difference between the observed temperature and normal temperature (LPA) for that period.

9 As per the IMD, nation-wide record-keeping on temperature commenced from 1901.

10 March 2022 also recorded the third highest average minimum temperature since 1901 with an anomaly of 1.4 degree Celsius for the month of March.

of 2022 was adversely impacted, leading to lower production. Moreover, heatwaves also led to increased number of forest fires. By the end of April 2022, almost 70 per cent of India was affected by its spread (IMD, 2022). Moreover, during May 2022, the heatwave extended into the coastal and the eastern regions of the country. High temperatures recorded during the summer months adversely affected grain filling and caused early senescence, thus reducing foodgrain yields during the year. In 2023, India experienced the hottest February on record (in terms of maximum temperature), with the IMD predicting an enhanced probability of heatwaves occurring in the central and northwest regions of India during the summer of 2023.

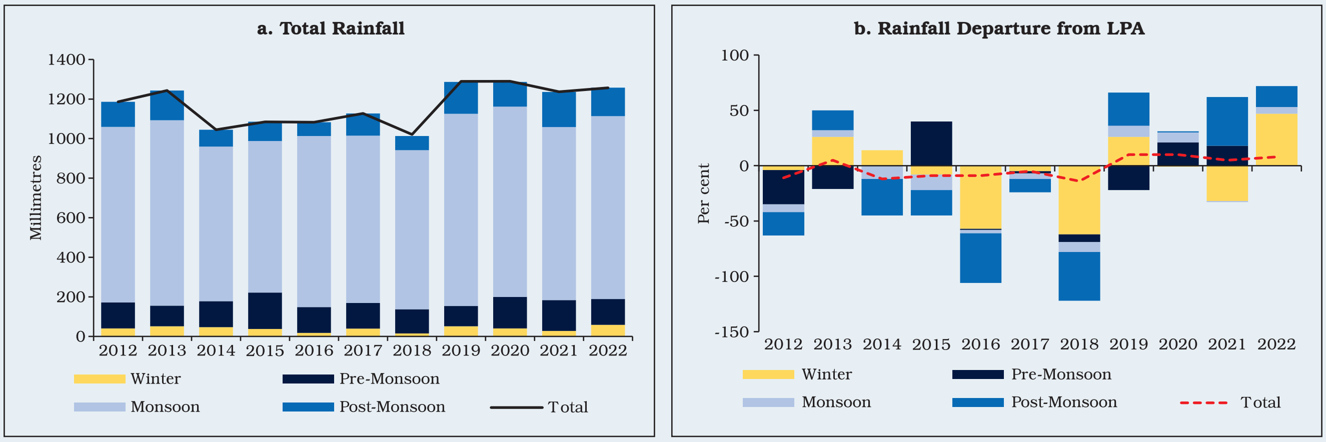
II.18 The precipitation pattern in a region is heavily conditional on its geographical characteristics.[11] In this regard, a dominant feature of the Indian sub-continent is the south-west monsoon (SWM) season (June-September), also referred to as the Indian summer monsoon. Around 75 per cent of India's annual rainfall is concentrated during the four months of the SWM season, which is vital for the agricultural output during the *kharif* cropping season, as almost half of the country's net sown area is still unirrigated. Further, rainfall during this season is important to fill up the reservoirs in the country which helps in the much-needed irrigation during the *rabi* cropping season. Even though India has become self-sufficient in foodgrains, anomalies in SWM, whether temporal or spatial, impact food price dynamics and the inflation outlook.

II.19 Over the years, the pattern of SWM season appears to have undergone subtle changes.[12] Notably, while the average annual rainfall at the all-India level during the last vicennial (2000-2020) saw a rise over that during 1960-1999, over a longer time horizon since 1901, annual average rainfall in India has gradually declined. Importantly, the average rainfall received during the SWM season has declined by around 8 per cent during 2001-2020 as compared with that during 1941-1960. Moreover, evidence suggests that while dry spells have become more frequent during the last several years, intense wet spells have also increased. During 2019-2022, the overall rainfall in the country has been higher than the LPA but its distribution, including the pre- and the post-monsoon seasons, has been skewed. For instance, in 2019, the post-monsoon rainfall turned out to be 30 per cent higher than the LPA, whereas in 2020 the pre-monsoon rainfall surpassed the LPA by 21 per cent (Chart II.9). In 2021, both the pre-monsoon and the post-monsoon seasons recorded rainfall higher than the LPA, at 18 per cent and 44 per cent, respectively. Further, in 2022, although the annual rainfall was 108 per cent of its LPA, there were significant spatial dispersion in rainfall during the SWM season. For instance, the south peninsular and central regions of India received above normal rainfall (122 per cent and 119 per cent higher than their LPA, respectively). In contrast, the north-western parts of India received just normal rainfall (101 per cent of its LPA), whereas the north-eastern parts of the country received below normal rainfall (82 per cent of its LPA).

[11] Therefore, analysis on changes in precipitation pattern in a region is usually done on the basis of the LPA of rainfall in that particular region. LPA is the average rainfall recorded in a region for a given interval (month or season) over a long period (30 years or 50 years), which acts as a benchmark while studying temporal changes in the precipitation pattern in a region.

[12] As per the IMD, the normal dates for the onset and withdrawal of SWM are June 1 and October 15, respectively.

Chart II.9: Total Rainfall and Rainfall Departure from LPA



Source: IMD.

II.20 Over the years, the SWM season has also seen onset and withdrawal dates shifting, with the withdrawal being generally delayed and often coinciding with the north-east monsoon or the winter monsoon season (Table II.2). For instance, during 2019, despite a delayed onset (June 8, 2019) and a highly deficient phase during June (33 per cent below LPA), the monsoon season ended with a 10 per cent above normal rainfall, which was the highest recorded rainfall in the past 25 years (the highest during the period 1990-2019 being 12.5 per cent in 1994).

Table II.2: Onset and Withdrawal of Monsoon in India

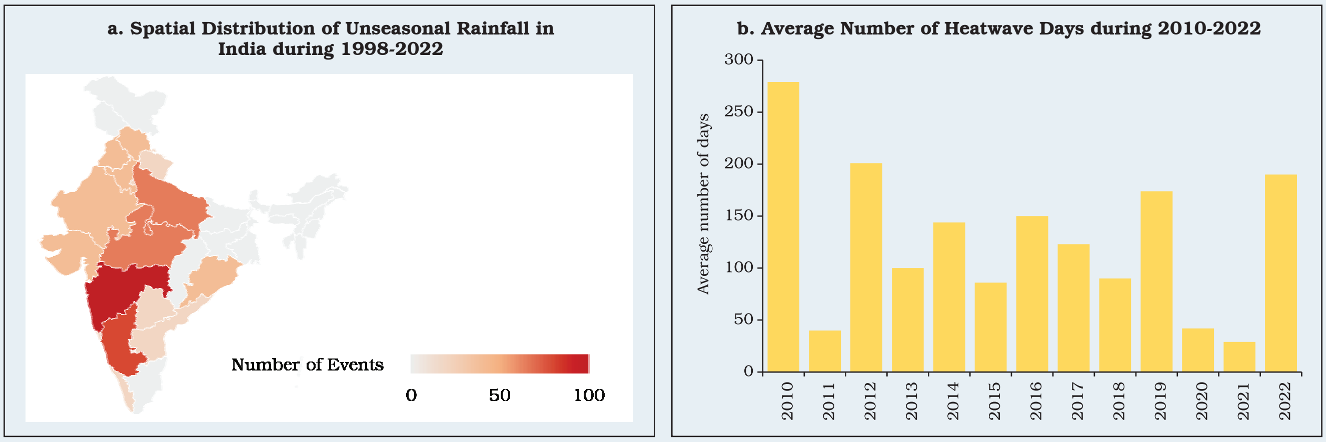
Year	Date of Arrival	Delay in Arrival	Date of Withdrawal from India	Delay in Withdrawal
2012	5 June	4 days	18 October	3 days
2013	1 June	0 days	21 October	6 days
2014	6 June	5 days	27 October	12 days
2015	5 June	4 days	19 October	4 days
2016	8 June	7 days	28 October	13 days
2017	30 May	(-)2 days	25 October	10 days
2018	29 May	(-)3 days	21 October	6 days
2019	8 June	7 days	16 October	1 days
2020	1 June	0 days	28 October	13 days
2021	3 June	3 days	25 October	10 days
2022	29 May	(-) 2 days	23 October	8 days

Source: IMD Annual Reports.

II.21 Climate change is also being manifested in the form of rising intensity and frequency of extreme weather events such as excessive/ unseasonal rainfall (often leading to floods), severe temperature fluctuations (*e.g.*, heat waves and cold waves) and high wind speeds (*e.g.*, cyclones). Since the early 2000s, extreme weather events have been very frequent in India. For instance, unseasonal rainfall and heatwaves have become a regular phenomenon (Chart II.10). While Maharashtra, Karnataka, Uttar Pradesh and Madhya Pradesh have witnessed frequent unseasonal rains over the years, states such as Rajasthan, Haryana, Punjab, Delhi, Uttar Pradesh and Jharkhand have been the most impacted by heatwaves with the onset of summer and in the pre-monsoon months.

II.22 Moreover, the frequency of cyclonic storms has increased in India over the years

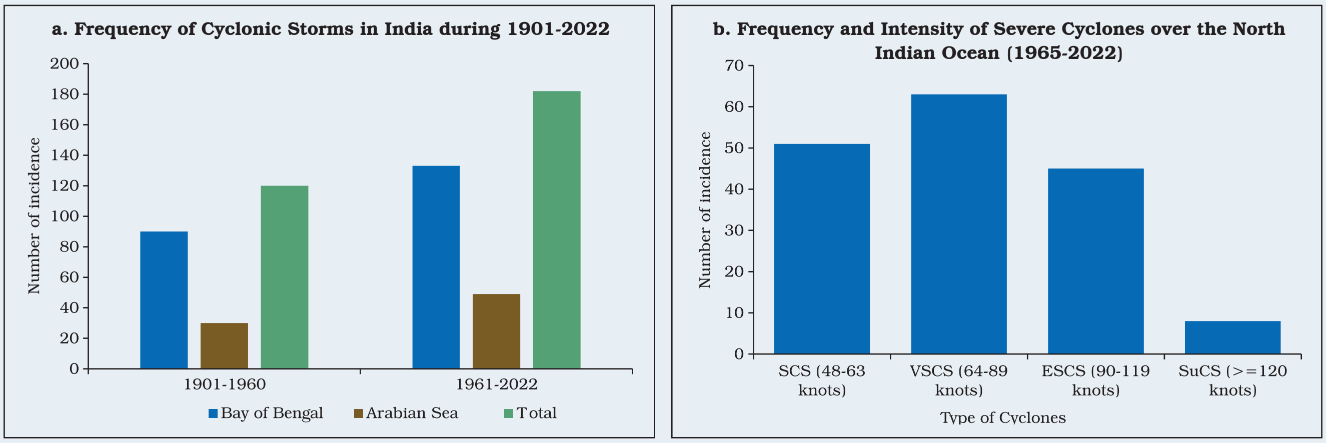
Chart II.10: Frequency of Unseasonal Rains and Heatwaves in India



Sources: Down to Earth (Assisted by the Centre for Science and Environment); and Environment Statistics, MoSPI.

(Chart II.11a).[13] For instance, as compared with the normal of 11-12 cyclonic disturbances and 4.8 cyclonic storms observed in the North Indian Ocean (NIO) during 1960-2020, there were 8 cyclonic storms during 2019. Importantly, their intensity has also increased with a greater number of very severe cyclonic storms (VSCS) and extremely severe cyclonic storms (ESCS) as compared with severe cyclonic storms (SCS) (Chart II.11b). In 2021, out of the five cyclonic storms that occurred, one was ESCS (*Tauktae*) and another was VSCS (*Yaas*) in May (pre-monsoon season) over the Arabian Sea and the Bay of Bengal, respectively.

Chart II.11: Frequency and Intensity of Cyclonic Storms in India during 1901-2022



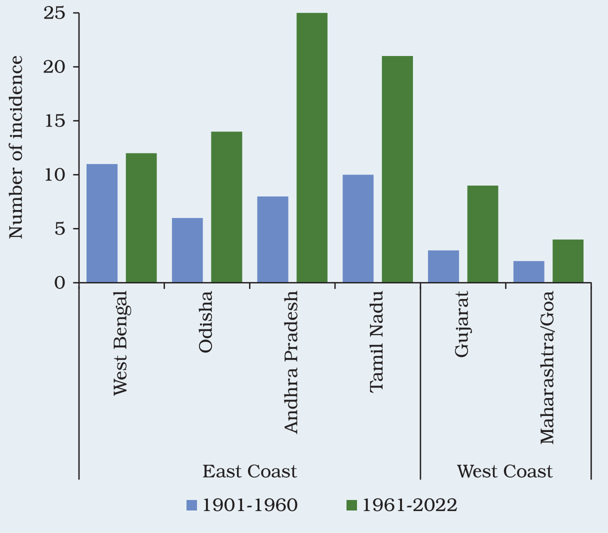
Source: IMD.

13 As per the IMD, the maximum sustained surface wind speed in a cyclonic disturbance is in the range of 17 knots (31 km per hour) to 33 knots (61 km per hour). In the case of a cyclonic storm, the maximum average surface wind speed is in the range of 34 knots (62 km per hour) to 47 knots (88 km per hour). With regard to the intensity of severe cyclonic storms (SCS), the IMD classifies severe cyclones into the following four categories: severe cyclonic storms (SCS: 48-63 knots), very severe cyclonic storms (VSCS: 64-89 knots), extremely severe cyclonic storms (ESCS: 90-119 knots) and super cyclonic storms (SuCS $\geq$ 120 knots).

II.23 The distribution of cyclones between the east coast and the west coast has also changed over the years with increased frequency of cyclonic storms over the Arabian Sea (Ghosh *et al*., 2021). Historically, cyclones in the Arabian Sea were fewer as compared with that in the Bay of Bengal. During 2019, out of the 20 cyclonic disturbances/storms that occurred, a majority of them were in the Arabian Sea (west coast) [IMD 2019].[14] A spatial distribution of severe cyclones reveals that the number of cyclones that occurred in the states of Odisha, Andhra Pradesh and Tamil Nadu in the eastern coast of India during 1961-2022 was much higher than that during 1901-1960 (Chart II.12). Additionally, in the west coast, the incidence of SCS in Gujarat increased significantly during 1961-2022 as compared with Maharashtra and Goa. An increase in the frequency of ESCS over the Arabian Sea and the NIO has been attributed to anthropogenic warming (Murakami *et al*., 2017).

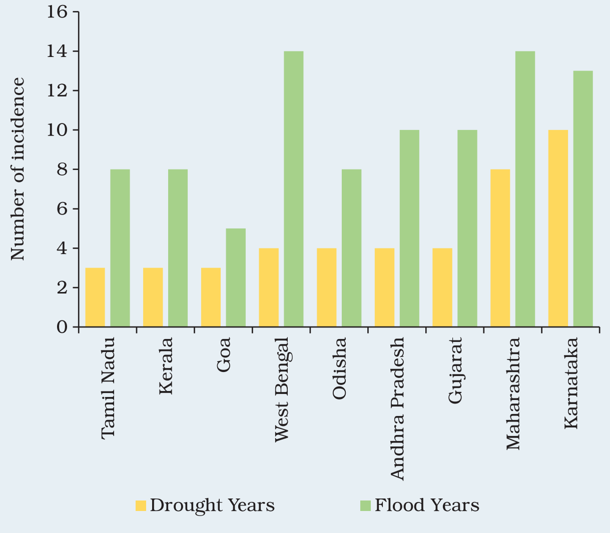
II.24 Additionally, the incidence of droughts and floods has also seen a rise in the recent years. Floods and droughts are generally classified as hydroclimatic extremes. In India, the number of droughts has seen a spike, with their severity being higher during 1961-2021 as compared with the period 1901-1960 (Ghosh *et al*., 2021). In particular, central India and southern peninsula regions are more prone to droughts. Among the coastal states, Karnataka and Maharashtra are the major states that have witnessed a higher frequency of droughts during 1951-2021 (Chart II.13). Further, as per the UN Office for Disaster Risk Reduction, the number of floods in India shot up to 90 during the decade of 2006-2015 as compared with 67 during 1996 to 2005. Frequent floods are one of the significant contributors to the average annual losses in India in economic terms from climate related disasters (World Bank, 2021). Studies have indicated that anthropogenic geographical alterations, including

Chart II.12: Spatial Distribution and Frequency of Severe Cyclones



Source: IMD.

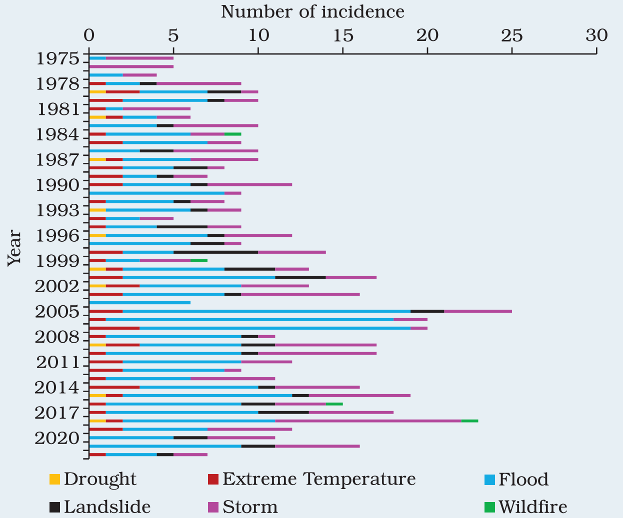
Chart II.13: Frequency of Drought/Flood Years in the Indian Coastal States during 1951-2021



Sources: IMD; Nandargi and Aman (2017); and Krishnan *et al*., (2020).

[14] Some of the severe cyclones during 2019 were ESCS *Fani* and *Maha* and VSCS *Vayu, Hikaa* and *Bulbul*.

Chart II.14: Number of Natural Disasters in India



Note: Storms include events such as tropical cyclones, hailstorms, thunderstorms and dust storms; extreme temperature includes events such as heatwaves and cold waves.
Source: Emergency Events – Database (EM-DAT).

incessant unplanned urbanisation, to be one of the prime reasons behind the rising number of city floods in India (Yang *et al*., 2015; Liu and Niyogi, 2019; Krishnan, *et al*., 2020).

II.25 Overall, India is relatively more exposed to floods and storms (*i.e.*, cyclones and hailstorms) than droughts and heatwaves (Chart II.14). Such incidences pose significant risks to agricultural production (Krishnan, *et al*., 2020) and food price volatility (Dilip and Kundu, 2020; Ghosh *et al.,* 2021; and Kishore and Shekhar, 2022).

4. Macroeconomic Impact of Climate Change in India

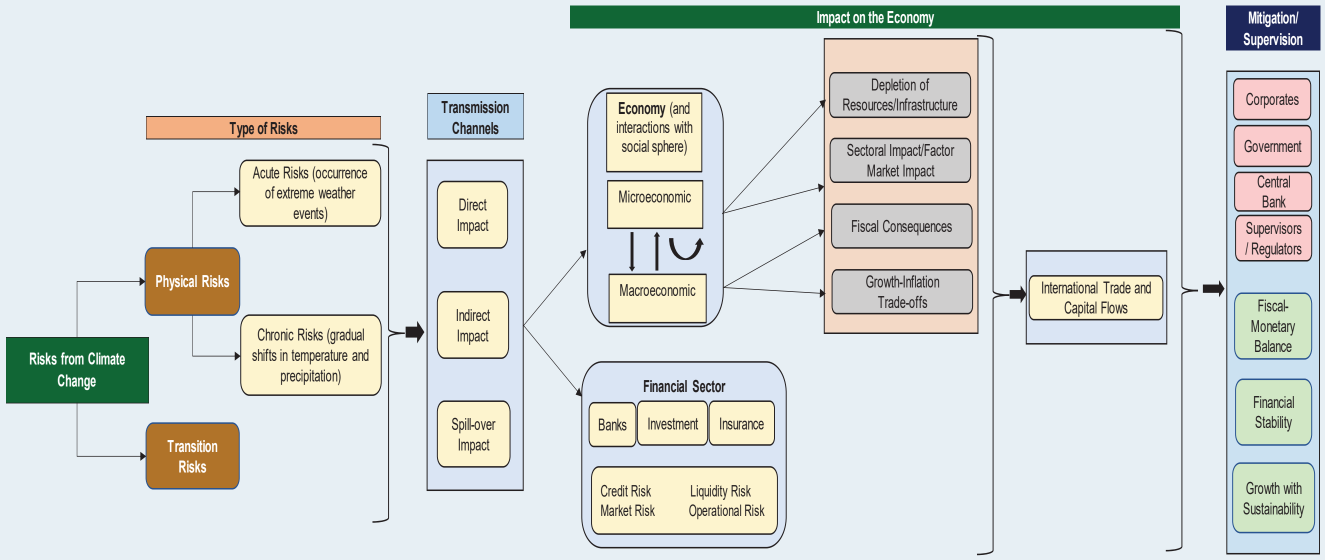
II.26 The impact of climate change on the economy could manifest through its adverse impact on the supply potential of the economy as well as by altering demand conditions. Climate change events are often characterised as adverse supply shocks, which reduce the economy's aggregate output and raise prices, thus posing adverse implications for the potential growth of the economy. Further, uncertainty following a climate change event also adds to the volatility in both output and prices. Changing weather patterns may also impact consumer behaviour and preferences, thus influencing demand conditions (Andersson *et al*., 2020; Ciccarelli and Marotta, 2021).

II.27 Fighting climate change could also cause a global inflation shock (Morison, 2021), exacerbating the output-inflation trade-offs faced by central banks and increasing risks to medium-term price stability (Schnabel, 2021). The potential impact of climate change mitigation policies on energy production and prices could be adverse (Volz, 2017).

II.28 The impact of physical and transition risks on the economy could be direct, indirect and through spill-over effects (Illustration II.1). Physical risk drivers are often categorised into two types: acute risks – related to the occurrence of extreme weather events, and chronic risks – associated with gradual shifts in temperature and precipitation patterns (McKinsey Global Institute, 2020; NGFS, 2022b), though acute risks can also arise due to chronic risks. For example, a rise in global temperature may lead to acute changes in the climate by causing heatwaves and wildfires (Jones *et al*., 2020; Abatzoglou *et al*., 2019). Further, a warmer atmosphere can hold more moisture, leading to an increase in heavy and concentrated rainfall in several regions (IPCC, 2018). These could impact overall output as acute climate events such as destructive flash floods cause physical damages to properties, infrastructure and crops.

II.29 Transition risk drivers, on the other hand, are the economy-wide changes arising from the transition towards a low-carbon economy. These may relate to the public-sector policies; innovation and technologies; or investor and consumer sentiments/preferences facilitating

Illustration II.1: Risks from Climate Change and Their Impact on the Economy



Sources: Andersson *et al*., (2020); BCBS (2021); and NGFS (2022b).

a greener economy. Therefore, the impact of a climate-related transition risk would be conditional upon a host of factors and would involve multiple underlying dependencies relating to the climate-economy nexus. The impact is also more indirect than physical risk.

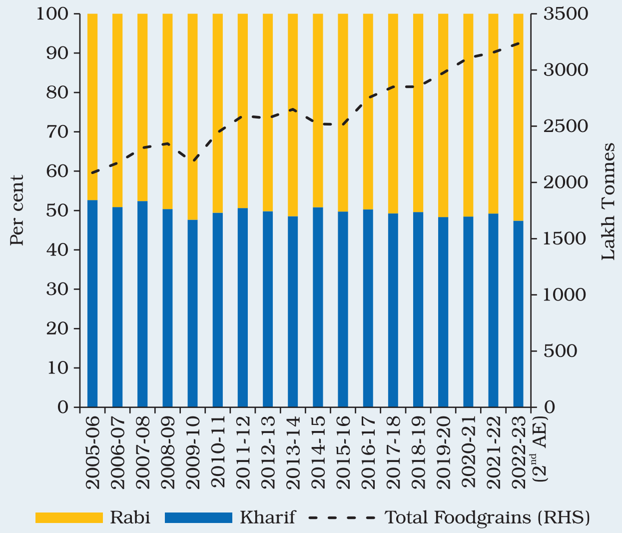
II.30 Multiple channels through which climate change impacts the Indian economy has been documented in the literature, which is still evolving. India, being among the top 10 economies in terms of vulnerability to climate risk events, is already witnessing the adverse impact of climate change on its people's lives and livelihood. For instance, in 2019, India lost nearly US$ 69 billion due to climate related events, which is in sharp contrast to US$ 79.5 billion lost over 1998-2017 (UNISDR, 2018). Floods in India during 2019 affected nearly 14 states causing displacement of around 1.8 million people and 1800 deaths. Overall, around 12 million people were impacted by the intense rainfall during the monsoon season in 2019 with the economic loss estimated to be around US$ 10 billion. Additionally, the SWM rains in recent years have often been accompanied by significant temporal and spatial dispersions causing crop damages, thereby leading to higher food inflation and its volatility (Dilip and Kundu, 2020; Ghosh *et al*., 2021).

II.31 The IPCC Working Group (WG)-II (IPCC, 2022b) report states that India is one of the most vulnerable countries globally in terms of the population that would be affected by the sea level rise. By the middle of the present century, around 35 million people in India could face annual coastal flooding, with 45-50 million at risk by the end of the century (World Bank, 2021). Further, the agriculture sector and fisheries would face significant adverse consequences due to the rising sea level and ground water scarcity. Literature indicates that most of India has been experiencing adverse effects of temperature on living standards, as the households most affected are dependent primarily on the agriculture sector for their livelihood (Mani *et al*., 2018). Further, the incidence of flash flooding is expected to increase, if global temperature soars to 2 degree Celsius above the pre-industrial levels (Ali and Mishra, 2018). In terms of ecosystem services, around 600 million of India's population are facing severe water stress, with 8 million children below 14 years in the urban India at risk due to poor water supply (Niti Aayog, 2019).

II.32 India, along with countries such as Brazil and Mexico, face high risk of reduction in economic growth, if global warming raises temperature by 2 degree Celsius as against 1.5 degree Celsius (IPCC, 2018). Climate change manifested through rising temperature and changing patterns of monsoon rainfall in India could cost the economy 2.8 per cent of its GDP and depress the living standards of nearly half of its population by 2050 (Mani *et al.,* 2018). India could lose anywhere around 3 per cent to 10 per cent of its GDP annually by 2100 due to climate change (Kompas *et al*., 2018; Picciariello *et al*., 2021) in the absence of adequate mitigation policies. Furthermore, Indian agriculture (along with construction activity) as well as industry are particularly vulnerable to labour productivity losses caused by heat related stress (Somnathan *et al*., 2021). India could account for 34 million of the projected 80 million global job losses from heat stress associated productivity decline by 2030 (World Bank, 2022). Further, up to 4.5 per cent of India's GDP could be at risk by 2030 owing to lost labour hours from extreme heat and humidity conditions. Moreover, heatwaves could also last 25 times longer, *i.e.,* rise in severity, by 2036-2065 if current rate of carbon emissions is not contained (CMCC, 2021). These estimates, thus, underscore the importance of timely adoption and faster implementation of climate mitigation policies to reduce the adverse impact on the Indian economy.

II.33 Despite the rising frequency of extreme weather events, India has been reporting record

Chart II.15: Total Foodgrains Production in India

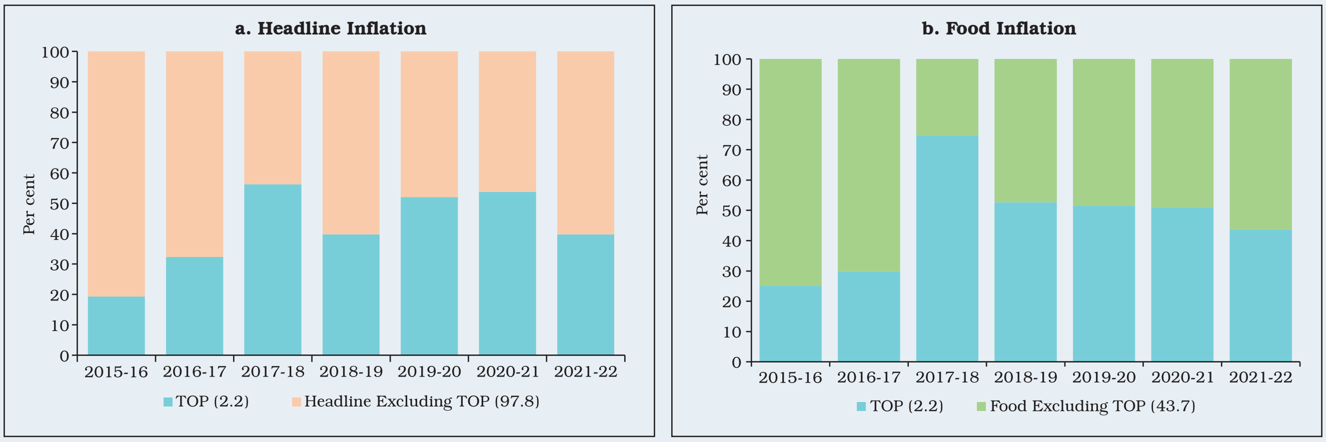


Note: AE stands for Advance Estimates.
Source: Ministry of Agriculture, GoI.

production of foodgrains and horticulture in recent years, reflecting a faster growth in *rabi* production (Chart II.15). As most of the excess and unseasonal rainfall events and cyclones take place during the monsoon or post-monsoon seasons, their impact on *kharif* crop is more than on *rabi* crop in terms of crop loss. Consequently, the impact of climate change on inflation through the production channel appears to be mild at the aggregate level due to geographically well-distributed foodgrains production as well as the localised nature of climate events.

II.34 In contrast, horticulture crops, especially perishables like vegetables, are more exposed to extreme weather events, such as cyclones and unseasonal rainfall during the post monsoon period, thereby temporarily impacting their prices (Kishore and Shekhar, 2022). For example, inflation in onion prices shot up to 327 per cent in December 2019 led by unseasonal rains; potato prices by 107 per cent in November 2020 due to unseasonal rains; and tomato prices by 158 per cent in June 2022 due to heatwave and cyclone

Chart II.16: Contribution of TOP to Headline and Food Inflation Volatility[15]



Note: TOP is an acronym for Tomato, Onion and Potato. Figures in parentheses represents weight in CPI basket in per cent.
Sources: NSO; and Authors' estimates.

led crop damages. In fact, even with a low share of these three vegetables (Tomato, Onion, Potato – TOP) in CPI (2.2 per cent), they contribute a large part of the volatility in food and headline inflation (Chart II.16). Of late, farmers are also adapting to such climate events by adjusting their sowing and harvesting schedules, while R&D in agriculture has focused on developing climate resilient crops to minimise the adverse impact on food production, prices and farmers' income.

II.35 Overall, the impact of changing temperature and precipitation patterns on the agricultural sector is highly non-linear and manifests with a greater intensity for non-irrigated regions in extreme circumstances. Estimates indicate that when a district experiences unusually high temperature (in the top 20 percentile of the temperature distribution), there is a 4 per cent reduction in agricultural yield during the *kharif* season and a 4.7 per cent reduction during the *rabi* season (GoI, 2018). Similarly, when a district receives significantly less rainfall than usual (in the bottom 20 percentile of the rainfall distribution), there is a 12.8 per cent decrease in *kharif* yield and a smaller, yet noticeable decrease of 6.7 per cent in *rabi* yield. With the rising anthropogenic emissions, the frequency of such extreme events could increase even further, with implications for agriculture yield, farmers' income and food inflation.

II.36 Set against this backdrop, the macroeconomic impact of some of the key extreme weather events, such as floods, cyclones and droughts has been analysed in the context of India during the last 10 years, *i.e.*, 2012-13 to 2021-22. Similar to Ghosh *et al.,* (2021), 5 states along the western coastline (Gujarat, Maharashtra, Goa, Karnataka and Kerala) and four states along the eastern coastline (West Bengal, Odisha, Andhra Pradesh and Tamil Nadu) together with their eight neighbouring inland states have been considered. Difference-in-difference (D-i-D) panel data regression results indicate that natural disasters adversely impact economic activity,

[15] Contribution of subgroup (say, A) to variance in total (A+B) is calculated using the following formula: Contribution (A) = W(A) W(A) Var(A) + W(A) W(B) Cov (A, B) where W is the weight of the sub-group, Var is variance and Cov is covariance.

Table II.3: Difference-in-Difference Panel Data Results

D-i-D Coefficients	Inflation	GSDP	NSDP Per Capita	GSVA Agriculture	NSVA Agriculture	GSVA Manufacturing	NSVA Manufacturing	GSVA Services	NSVA Services	CAPEX
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
C	7.34***	5.01***	3.24***	10.69***	11.72***	2.58	1.97	6.08***	4.09***	20.94***
	(1.93)	(0.87)	(0.80)	(2.30)	(2.58)	(1.88)	(2.06)	(0.79)	(0.63)	(4.53)
γ	-0.29	1.99*	2.85**	-7.89***	-9.06***	8.17***	10.40***	1.03***	1.99*	-4.34
	(0.35)	(1.12)	(1.11)	(2.42)	(2.72)	(2.51)	(2.99)	(0.30)	(0.99)	(5.22)
δ	-2.19	1.19	1.27	-9.60***	-11.26***	6.03	7.13***	1.36	2.20***	-9.03*
	(1.93)	(1.05)	(0.98)	(2.77)	(3.04)	(2.17)	(2.71)	(0.81)	(0.80)	(4.63)
β_{DID}	1.04**	-2.71**	-2.73**	8.32***	10.06***	-11.43***	-14.03***	-1.31**	-2.80**	4.63
	(0.44)	(1.24)	(1.23)	(2.93)	(3.21)	(2.71)	(3.40)	(0.56)	(1.06)	(5.75)

Note: ***, **, * represent significance at 1 per cent, 5 per cent and 10 per cent levels, respectively.
Figures in parentheses indicate robust standard errors.

i.e., lower output growth, while raising inflation (Table II.3).[16] The result contrasts with some of the earlier studies that suggest an increase in the GDP due to the post disaster investment and multiplier effects (Caballero and Hammour, 1994). Further, the results do not indicate a negative impact on agricultural GVA.[17] While India has attained a degree of self-sufficiency with respect to food production, Government policy interventions towards developing climate-resilient crops and changing cropping pattern - such as introducing drought/flood/temperature tolerant varieties in paddy and pulses especially in the coastal states; water-saving paddy cultivation methods, advancement of *rabi* planting dates in areas with heat stress; and community nurseries as solutions for delayed monsoon arrival - have played a major role in increasing the resilience of India's agriculture sector against climate related stress (NICRA, 2016). With regard to inflation, literature indicates that the impact of extreme weather events is generally short-lived (Freeman *et al.*, 2003; NGFS, 2020; Dilip and Kundu, 2020; Ghosh *et al.*, 2021), although heterogenous with respect to the type of the hazard, and varies between advanced and developing economies (Parker, 2018). Nonetheless, the fact that inflation and its volatility are driven by such shocks that make predicting the short-term inflation path difficult, pose major challenge for the conduct of forward-looking monetary policy. The results do not indicate a statistically significant rise in capital expenditure in the coastal states during the calamity year, instead there is an indication that the overall capital expenditure falls[18] when a calamity hits, thus substantiating the fall in economic growth. Further, a need would also arise for relief and rehabilitation/reconstruction measures in the

16 The impact of extreme weather events (floods, droughts and cyclones) was examined on economic activity (proxied by growth in gross state domestic product (GSDP), net state domestic product (NSDP) per capita, capital expenditure (CAPEX), gross value added (GVA) and net value added (NVA) for agricultural, manufacturing and services sectors) and inflation by estimating the following equation: $y_{st} = C + \beta_{DID}(Coastal_s * Calamity_t) + \gamma\, Coastal_s + \delta\, Calamity_t + \epsilon_{st}$, where, y_{st} represents the dependent variable, s and t represent state and time, respectively. The coefficients could be interpreted as follows: Mean of non-coastal states in normal times: C; Mean of coastal states in normal times: $C + \gamma$; Mean of non-coastal states in calamity times: $C + \delta$; Mean of coastal states in calamity times: $C + \beta_{DID} + \gamma + \delta$.

17 Similar results have also been noted in the literature (Albala-Bertrand, 1993; Loayza *et al.*, 2012; Ghosh *et al.*, 2021).

18 CAPEX in the year of calamity and not in the subsequent years is analysed. Furthermore, the calamity relief funds such as State/National Disaster Relief Funds are part of the revenue expenditure and not CAPEX.

period following a natural disaster, which would require diversion of budgeted funds, thus having implications for the Government's fiscal deficit.

II.37 While the above analysis helps in assessing the extent of the impact of extreme weather events on some of the key macroeconomic indicators at the all-India level, it would also be interesting to examine the impact of one particular climate event on household-level indicators of economic well-being. An analysis using household-level data from the National Sample Survey Organisation (NSSO) reveals evidence of adverse effects on consumption, with the median household experiencing a fall in consumption by 16 per cent (Aggarwal, 2019). The rising incidences of cyclones in India are of significant concern of late as they are inflicting massive loss to infrastructure, life and property in and around the coastal states. While the loss of life from cyclones has come down over the years[19] due to better disaster management, early warning systems, and resilient infrastructure such as cyclone shelters, the economic loss has often been unavoidable as was evident in the case of cyclone *Amphan* (Box II.1).

Box II.1

Economic Impact of Cyclone *Amphan* on the Coastal Districts of West Bengal and Odisha

The super cyclonic storm *Amphan* was a natural disaster that originated in the Bay of Bengal and affected the coastal districts of West Bengal and Odisha in India and the adjoining Bangladesh in May 2020. The economic impact of cyclone *Amphan* on the coastal districts of West Bengal and Odisha is compared *vis-à-vis* their non-coastal neighbouring districts. While the coastal districts of West Bengal and Odisha have been used for estimating the treatment effect (economic impact) of the cyclone, their adjoining non-coastal districts that lie within 100 kilometres from the eastern coast of India are used for the comparison purpose. In order to examine the impact of the cyclone on economic activity, following Bayer *et al.,* (2022) the difference-in-difference (D-i-D) panel data regression method is used. Further, economic activity has been represented by an array of measures, such as household consumption, district level deposit and credit, and employment demand under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA).

For empirical estimation, RBI's district-level credit and deposit data available at quarterly frequency during Q3:2019-20 to Q4:2020-21, monthly data on household-level expenditure and its sub-categories during January-December 2020 available from the Consumer Pyramids Household Surveys (CPHS) database maintained by the Centre for Monitoring Indian Economy (CMIE), and monthly data on the number of households that worked and those that demanded work under the MGNREGA[20] during January-December 2020 from the MGNREGA Public Data Portal maintained by the Ministry of Rural Development, GoI, are used.

The following equation is estimated to study the impact:

$$\ln\ (y_{dt}) = constant + \beta_{DID}(Treated_d * Post_t) + \gamma\ Treated_d + \delta\ Post_t + \epsilon_{dt} \quad ...(1)$$

where, ln (y_{dt}) represents the log of the dependent variables, where d and t denote district and time, respectively. The above equation is also run with district level and month/quarter level fixed effects instead of the $Treated_d$ and $Post_t$ variables, while keeping the variable ($Treated_d * Post_t$) unchanged. Results of the regression analysis are presented in Table 1.

The results indicate an increase in credit in districts affected by the cyclone, implying that firms and households need to finance disaster related rehabilitation/restoration expenses. This can come either from their own savings or by borrowing

(Contd...)

[19] As per the Guideline on Management of Cyclones (April 2008), 9893 people died and more than 15 million people were affected during BOB 06 (1999) in Odisha, whereas during cyclone *Amphan* (2020) in Odisha and West Bengal, 129 people lost their lives, and 4.9 million people were displaced (IFRC 2021; WMO 2021).

[20] Under MGNREGA, which is a demand-driven wage employment programme of the GoI, at least 100 days of guaranteed employment in a financial year is provided to every household residing in a rural area. The programme covers all adult members of rural households who volunteer to do unskilled manual work.

Table 1: Difference-in-Difference Regression Results

D-I-D Coefficients	Credit (₹ crore)	Deposit (₹ crore)	Total Consumption (₹)	Food Consumption (₹)	MGNREGA Employment (Person days)
β with Post and Treated	0.037** (0.077)	0.004 (0.007)	0.012* (0.009)	-0.007 (0.006)	-0.346 (0.318)
β with Time and District fixed effects	0.037** (0.018)	0.004 (0.440)	-0.006* (0.008)	-0.022*** (0.007)	-0.346*** (0.078)

Note: ***, **, * represent significance at 1 per cent, 5 per cent and 10 per cent levels, respectively.
Figures in parentheses indicate robust standard errors.

from the financial institutions, but the results show no significant change in savings. Moreover, a significant decline in food consumption is observed, especially when district and time fixed effects are accounted for. This may be due to the need for reconstruction following cyclone-induced damages, with the reconstruction dependent on bank credit and/or the fund received under post-cyclone rehabilitation schemes of the Government. On rural employment side, a decline is observed in the employment demand under MGNREGA. This decline could be because of temporary migration post cyclone, as *Amphan* displaced approximately 5 million people.

To sum up, the results indicate that natural disasters or one-off extreme weather events such as *Amphan* could lead to a rise in district-level credit offtake following the occurrence of the event, which may be used for rebuilding and rehabilitation. Therefore, an increased frequency of such natural disasters could increase debt levels of both firms and households in the high-risk regions.

Reference:

Beyer, R., Narayanan, A. and Thakur, G. (2022). Natural Disasters and Economic Dynamics: Evidence from the Kerala Floods. *Policy Research Working Paper No. 10084*, World Bank.

II.38 Moreover, for a holistic understanding of the economic impact of climate change, it is also imperative to look beyond average macroeconomic impact and understand various dimensions of distributional consequences. Impact on different sectors could be distinct depending on the nature of activity. Irrigated areas may be wealthier and, at the same time, less vulnerable to rising temperatures. Ownership structure of agricultural assets, not only land but also human capital, could influence return on assets and thus, condition households' response to climate events.

II.39 Another dimension of climate change could be individuals' response to climate events by way of geographical relocation. Evidence based on the all-India Census at the inter-state level reveals that climate related shocks have a significant impact on bilateral migration across states (Dallmann and Millock, 2017). For instance, drought frequency and severity in the origin state increases out-migration, especially for states with relatively higher share of agriculture in total output. Further, inter-state migration is also influenced by both agricultural income and total income in the destination state relative to the state affected by the climate event.

5. India's Transition Towards Net Zero[21]

II.40 The IPCC has recognised that the challenges faced due to global warming are mainly on account of the cumulative historical and current GHG emissions of the developed countries. However, the cumulative impact has

[21] The estimates and the growth-inflation-emissions trade-offs presented in this section based on the various scenario analyses are indicative in nature and sensitive to assumptions. The relationship could be more complex and non-linear.

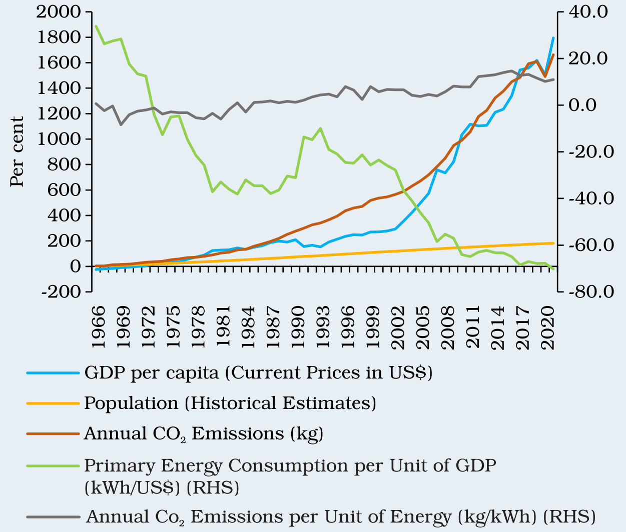
been assessed to be iniquitous with the developing countries bearing the brunt of climate change even as they may be constrained by their limited capacity to respond to its challenges (IPCC-Working Group III, [IPCC, 2022a]). Given the cataclysmic consequences of global warming, it is imperative, however, to reduce GHG emissions by both developed and developing countries alike. Emerging market and developing countries, including India, face the additional trade-off that they must continue to prioritise their own growth and developmental aspirations, while pursuing their climate related nationally determined goals. Against this backdrop, scenarios have been developed in this section on India's roadmap to net zero by 2070 conditional on different assumptions for real GDP growth on the one hand, and changes in the share of green energy in total energy demand as well as changes in the energy intensity of the GDP on the other to explain the nature of policy trade-offs involved.

II.41 Overall, carbon emission is a product of population and CO_2 emissions per person. This can be decomposed into four factors following the 'Kaya Identity'[22] (Kaya, 1997). These include (i) Population; (ii) Income (GDP per capita); (iii) Energy intensity of GDP and (iv) Carbon intensity of energy; wherein (iii) and (iv) are determined by technology.[23] The Kaya Identity is expressed as:

$$Emissions = Population * GDP\ per\ capita * \underbrace{\frac{Energy\ consumption}{GDP}}_{\text{Energy Intensity of GDP}} * \underbrace{\frac{CO_2\ emission}{Energy\ consumption}}_{\text{Carbon Intensity of Energy}}$$

II.42 In India, like most other countries, a large-scale increase in GDP stood out to be the key driver of emissions – a stronger driver than the increase in population (Chart II.17). Within

Chart II.17: Existing Path of the Kaya Factors
[Cumulative Percentage Change over Initial Period (1965)]



Sources: Authors' estimates; and Our World in Data.

the technology factor, India was able to reduce its energy intensity of GDP steadily overtime by bringing both structural changes in the economy and technological efficiency. The pace of decline in energy intensity took a leap in early 2000s. The decline has continued in the recent years as well. In contrast, the emission intensity of energy has increased, especially in the last decade (2011 onwards). Although overall emission intensity of GDP (product of energy intensity of GDP and carbon intensity of energy) has declined, further improvement is required to ensure a declining path of emissions in alignment with India's NDC. As maximum feasible expansion of GDP is necessary, technology would have to play a key role in India's net zero transition. This would involve a combination of more efficient energy-mix and technological advances in the industrial sector leading to lower emission intensity of GDP. Empirical evidence based on cross-country studies broadly suggests that an increase in the share of

[22] The "Kaya identity" is a simple mathematical framework to assess the main factors governing global CO_2 emissions.

[23] (ii), (iii) and (iv) are determinants of per capita emission.

renewable energy in total energy consumption can have a significant impact in reducing GHG emissions provided the share of renewables in total energy consumption is sufficiently high (Chen *et al.*, 2022; Hao, 2022). In the Indian context, based on the emission factors of different sources of energy obtained from the IPCC Emission Factor Database, it has been estimated that a one per cent increase in the share of renewable energy in the energy-mix reduces CO_2 emissions by around 0.63 per cent. This contributes positively towards achieving the NDC target. Alternative scenarios relating to the future path of GHG emissions have been developed to measure the viability of achieving net zero emissions by 2070, while balancing the dual objectives of achieving high growth and mitigating climate risks.

II.43 The baseline scenario assumes that the Indian economy will continue to grow at its past trend rate, *i.e.*, compound annual growth rate (CAGR) of real GDP achieved during the past decade (2011-12 to 2019-20) of 6.6 per cent, without any action taken towards meeting the commitments under its NDC (Table II.4). Moreover, UN's population projections for India are used and it is also assumed that the energy intensity of GDP defined as total primary energy consumption per unit of GDP[24] would continue to decline by 2.3 per cent annually (the annual average rate of decline as observed during 2011-12 to 2019-20). Furthermore, total carbon sequestration from various types, such as biological, which refers to storage of carbon in grasslands, forests, soil and oceans; and technological, such as creating carbon capture, usage and storage (CCUS), is assumed to remain at the 2016 level of 0.3 gigatonne, with no further enhancements. Under these baseline assumptions, net emissions would continue to rise over time, widening the gap from net zero target, which underscores the need for active policy interventions to close the gap and move to the target (Table II.5).

Table II.4: Scenario Assumptions

Variables	Baseline	Alternate Scenario 1	Alternate Scenario 2	Alternate Scenario 3
Real GDP Growth	CAGR of 6.6 per cent (realised during 2011-20)	6.6 per cent	9.6 per cent during 2023-24 to 2047-48 and 5.8 per cent thereafter	9.6 per cent during 2023-24 to 2047-48 and 5.8 per cent thereafter
Decline in Energy Intensity of GDP	CAGR 2.3 per cent (realised during 2011-20)	Gradually raised	CAGR 2.3 per cent	Gradually raised
Carbon Absorption Capacity in the Economy	0.3 gigatonne (realised in 2016)	Raised to 3.3 gigatonnes	0.3 gigatonne (realised in 2016)	Raised to 3.3 gigatonnes

Notes: 1. The required rate of decline in energy intensity increases gradually to 5.9 per cent during 2031-32 to 2040-41 and tapers off to around 5.3 per cent by 2070 in alternate scenarios 1 and 3.

2. The decadal share of green energy in alternate scenario 1 (alternate scenario 3) increases from around 5.5 per cent in 2021-22 to 9.1 in 2030-31 and thereafter increases rapidly to around 70 per cent (82 per cent) by 2070-71.

3. Emission factors for green and non-green energy sources have been assumed to be 0.0 gigatonnes per tera-watt hour and 0.00029 gigatonnes per tera-watt hour, respectively, based on data available for total emissions and energy-mix from Our World in Data.

II.44 The first alternate scenario (scenario 1) assumes that India will maintain its past trend GDP growth (6.6 per cent), while adhering to its immediate objectives under the NDCs – reducing emission intensity and expanding the share of renewable sources in electrical energy to 50 per cent by 2030, as well as the long-run objective of the net zero emission by 2070. Achieving net zero by 2070, however, would require even higher levels

[24] Energy intensity is calculated as the ratio of total primary energy consumption to real GDP in ₹ Crore.

Table II.5: Energy Transition and GHG Emissions Towards Net Zero by 2070 *vis-à-vis* 2021-22

Scenarios	Gross GHG Emissions Level by 2070 (Gigatonnes)	Rate of Change in Emissions (Per cent)		Rate of Reduction in Emission Intensity (Per cent)		Rate of Reduction in Energy Intensity (Per cent)	
		Cumulative	CAGR	Cumulative	CAGR	Cumulative	CAGR
Baseline	19.2	469.4	3.6	-73.0	-2.7	-67.6	-2.3
Scenario 1	3.3	-1.0	-0.02	-95.7	-6.2	-91.9	-5.0
Scenario 2	32.4	859.6	4.7	-75.2	-2.8	-67.6	-2.3
Scenario 3	3.3	-1.5	-0.03	-97.5	-7.2	-92.1	-5.1

Note: Gross GHG emissions for India at 2021-22 was 3.4 gigatonnes.
Source: Authors' Estimates.

of energy efficiency which could be achieved only through a sharper decline in energy intensity of GDP over the decades, besides a more efficient energy-mix. This would require the annual rate of decline in energy intensity to increase gradually from its current level of 2.3 per cent to 5.0 per cent by 2070. At the same time, the share of green energy in total energy consumption would need to reach to about 70 per cent by 2070 from around 5.5 per cent[25] in 2021-22.[26] Furthermore, this scenario remains compliant with the declared NDC target of enhancing natural carbon sink capacity by about 3 gigatonnes by 2030 along with efforts towards expanding forest and tree cover. Achievement of net zero under this scenario would lead gross GHG emissions to peak by 2032-33 and decline thereafter to deliver net zero GHG emissions by 2070. The level of energy consumption by 2070 would be 1.8 times higher than that of 2021-22 level as against 7.2 times higher under the baseline (BAU) scenario.

II.45 A second alternate scenario (scenario 2) assumes that India would achieve a higher growth trajectory to become an AE by 2047. The per capita income threshold defined by the IMF for country-group classification of 'Advanced Economies'(AEs), 'Emerging Market Economies' (EMEs) and Low-Income Developing Countries' (LIDCs) has been used to estimate the required level of GDP by 2047-48. As per this classification, India currently belongs to the group of EMEs (per capita GDP at US$ 2,450 in 2022-23) and its per capita GDP would have to cross the estimated threshold[27] of US$ 33,632 in 2047-48 for it to become an AE. This translates into a required annual real GDP growth of 9.6 per cent between 2023-24 to 2047-48. With respect to climate goals, however, the BAU assumption is maintained as

25 Based on the data available from Our World in Data, the share of green energy in total primary energy consumption turns out to be around 9 per cent for 2021-22, which is different from the share obtained at around 5.5 per cent from the Energy Statistics India, 2023, GoI. The difference is likely on account of fuel-group composition and adjustments owing to production efficiencies of fossil fuels. However, broad conclusions from the scenario analyses remain robust to this difference in green energy share.

26 This share is achieved by a remarkable growth in renewable energy generation during 2011-12 to 2021-22 when the CAGR was 12.4 per cent.

27 Within the AEs classified by the IMF, the Slovak Republic has the lowest per capita income of US$ 20,565 in 2022. Accordingly, US$ 20,500 is used as the threshold per capita income for AEs as a broad approximation. It is assumed that real GDP in AEs would grow at an average annual rate of 2 per cent (nominal rate of 4 per cent) up to 2047-48, because of which the per capita income target for India would be rising every year. If the average annual growth in AEs turns out to be higher, then correspondingly the 2047-48 per capita income target would be higher for India. To arrive at the required annual real GDP growth for India, it is assumed that the inflation differential of 2 per cent *vis-à-vis* AEs will continue till 2047-48, and accordingly the INR would depreciate by 2 per cent every year with the remaining 2 per cent of the 4 per cent inflation target being explained by productivity differential (The Economic Times, 2014). The pre-COVID period, 2011-12 to 2019-20, was considered for computing decadal average growth rate.

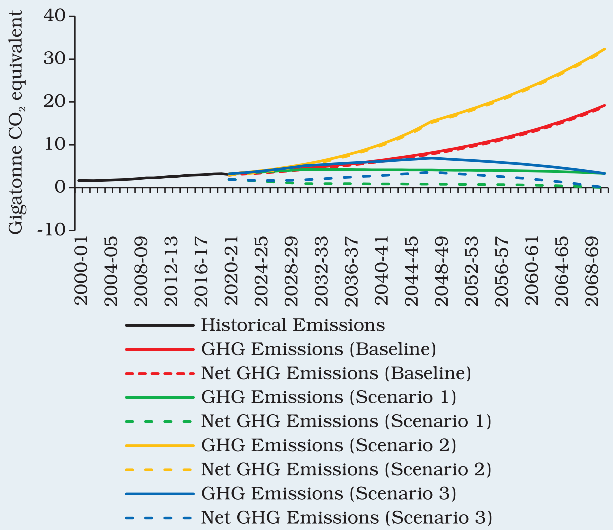
in the baseline. Higher growth together with no environmental commitments would translate into even higher trajectory of energy requirement and emissions leading to deviation further away from net zero target by 2070. Under this scenario, total primary energy requirement and net GHG emissions are estimated to be 12.5 times and 10.5 times higher, respectively, as compared with their levels in 2021-22.

II.46 The third alternate scenario (scenario 3) accommodates the twin-objectives of becoming an AE by 2047 and achieving the net zero target by 2070. This requires an even more aggressive effort as compared with the targets stated under its current NDCs in terms of both energy intensity and energy-mix. Under this scenario, the annual rate of decline in energy intensity would need to increase to 5.4 per cent and the share of green energy in total energy consumption would have to increase to about 82 per cent by 2070 (Chart II.18). The implied level of energy consumption by 2070 would be 3.1 times higher as compared with 2021-22 level.

II.47 According to the Climate Action Tracker (CAT), an independent scientific project that tracks government climate action plans across countries,[28] India's updated NDCs, which include reducing emission intensity of its GDP by 45 per cent by 2030; achieving 50 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030; and creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030, will not be sufficient to meet the level of reductions needed for limiting global warming to 1.5°C. With its updated NDCs, India's fair share rating nevertheless improved from "highly insufficient" to "insufficient" (CAT, November 15, 2022) [Chart II.19].

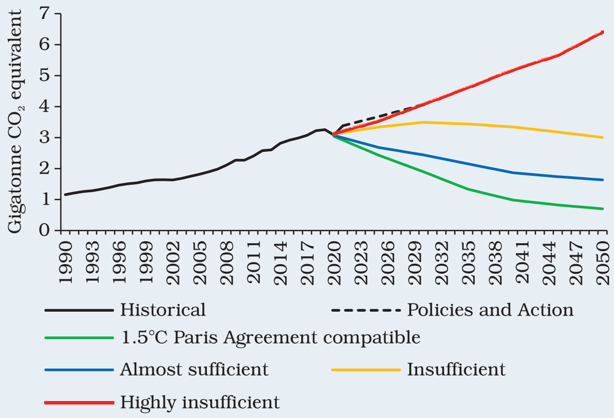
II.48 There is also an alternate view that the effective way to combat climate change is not by sacrificing growth rather to let nations grow

Chart II.18: Estimated GHG Emissions - Scenarios



Sources: Authors' estimates; Energy Statistics India 2023, MoSPI; and Our World in Data.

Chart II.19: GHG Emissions Modelled Pathways for India as per the Climate Action Tracker



Note: The difference in GHG emissions represented in Chart II.18 and Chart II.19 could be primarily attributed to differences in GDP growth assumption. CAT estimates 2030 GDP using IMF GDP growth estimates for 2022-2027 and trend estimates for the rest of the decade, based on World Bank GDP data for 1990-2021.
Source: CAT.

[28] CAT quantifies and evaluates climate change mitigation targets, policies and actions of 39 countries. It models emissions required by countries to meet the Paris Agreement of limiting long term temperature increase to 1.5°C.

so that they would have more resources for abatement and shifting to greener technology (Schelling, 1992). The Economic Survey 2023, GoI also recognised that continued development may be the best defence against climate change as securing external funding could be difficult. Such growth strategies, however, may conflict with environmental objectives in the medium- to long-run. Therefore, a more balanced approach, wherein the trade-off of maximising growth without compromising on the environmental commitments, is called for (Box II.2).

Box II.2
Economic Growth, Energy Consumption and Emissions: The Trade-offs

Given the debate on growth and GHG emissions trade-off, a simple environmental Solow-type growth model (Solow, 1999; Xepapadeas, 2005) is presented here to simulate the per capita real GDP scenarios for the Indian context under different levels of energy usage and their corresponding GHG emissions. Higher per-capita GDP should normally require higher energy. But, using this framework, it is identified and showed that suitable changes in technology and energy-mix can achieve the dual objective in a less costly manner. A standard production function as follows is considered:

$$Y = F(K, AL, BE) = K^{a_1}(AL)^{a_2}(BE)^{a_3} \quad ...(1)$$

where, K is capital, L represents the labour, E is the energy input, energy augmenting technology is B and labour augmenting technology is A. The total energy input contains both brown energy (Ec) and green energy (Eg). Output elasticities of capital, labour and energy are a_1, a_2 and a_3, respectively. In this set up, apart from the factors of production, the efficiency in their usage determined by technology also contributes to growth. Such improvements are reflected in energy augmenting technology growth $\left(\frac{\dot{B}}{B} = b\right)$ and labour augmenting technology growth $\left(\frac{\dot{A}}{A} = g\right)$ (Xepapadeas, 2005)[29]. The production function follows all the standard properties of constant returns to scale. Per capita capital (k) dynamics is represented as:

$$\dot{k} = s * y - (n + \delta) * k \quad ...(2)$$

where, s is the savings rate, y is the per capita output, n is the population growth $\left(\frac{\dot{L}}{L}\right)$, and δ is the rate of depreciation.

Using this framework, the steady-state is solved for a given E and then various scenarios are simulated under different levels of energy input (E) and energy-mix for the Indian context. Given the baseline parameter specifications

Table 1: Parameter Specification of the Model

Parameters	Observed Value	Sources
Capital income share (a_1)	0.67	KLEMS
Labour income share (a_2)	0.3	KLEMS
Energy cost share (a_3)	0.03	KLEMS
Labour augmenting technology growth (g)	7.1%	KLEMS
Population growth (n)	1.01%	World Bank
Depreciation rate (δ)	0.1	Banerjee and Basu (2019)
Savings rate (s)	0.31	NSO
Energy augmenting technology growth (b)	2.6%	Estimated using World Bank Data

Note: Labour income share, energy cost share and labour productivity are used from KLEMS data for manufacturing sector for the period 2011-12 to 2017-18. The capital income share is obtained as the residual. The savings rate is the average from 2011-12 to 2020-21. Energy augmenting technology growth represents the observed growth in the inverse of energy intensity of GDP during 2011-12 to 2019-20.

(Table 1), the growth rate of the economy is estimated as 6.6 per cent. This growth rate, however, does not enable India to attain the per capita income level of an AE by 2047.

Therefore, an alternate scenario wherein India's objective of becoming an AE by 2047 is considered. A scenario where the labour augmenting and energy augmenting technology growth rates are 10 per cent and 6 per cent, respectively, the output elasticity of energy at 0.06 and the labour income share at 0.64 (which resembles that of AEs)[30] results in a growth rate of 9.4 per cent which meets the target of India becoming an AE by 2047 (Chart 1). In this scenario, the energy usage works out to be 1.9 times of the present level.

To understand the effect of growth on GHG emissions under different combinations of energy-mix, the model further explores the contours of emission paths (Chart 2).[31]

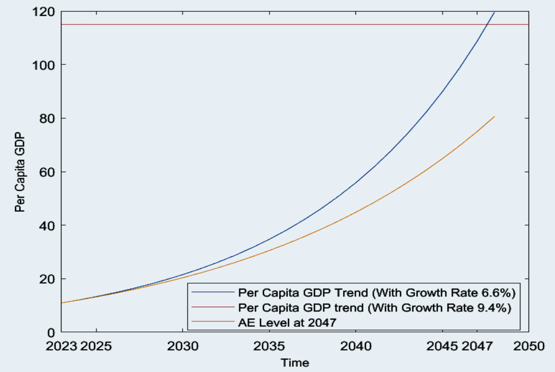
(Contd...)

29 Dot on top of any variable denotes derivative with respect to time.

30 Source: Average of the US, the UK, Sweden, the Netherlands, Germany, Switzerland, Canada based on data available from Penn World Table.

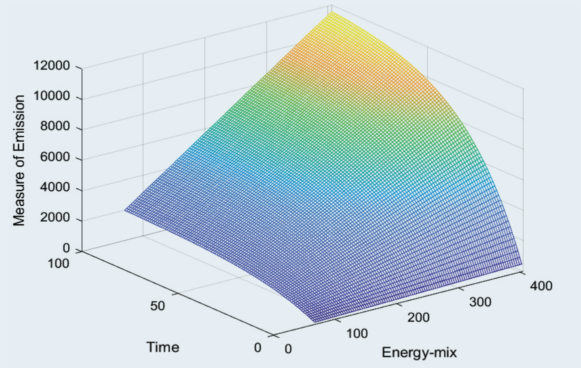
31 The pollution dynamics is assumed as, $\dot{P} = g(Ec, Eg) - m * P$. Required parameters for the emission/pollution dynamics are estimated using data from World Bank on per capita CO_2 emission and Power System Operation Corporation Limited. The parameters for emission/pollution dynamics have been estimated from the available data.

Chart 1: Per capita GDP Trend



Source: Authors' estimates.

Chart 2: Emission Dynamics



Source: Authors' estimates.

By increasing the share of green energy, it would be possible to achieve both the objectives of reducing emissions without compromising on the growth target. In this context, it is worthwhile to note that the commitment of NDC mandates that 50 per cent of the electrical energy must come from renewables by 2030. The estimates suggest that it is possible for India to become an AE by 2047-48 by having only 1.65 times GHG emissions as compared with the current level if 60 per cent of total energy usage is covered by greener sources. Going further ahead, if the economy continues to move in the direction of improving the energy-mix by having 85 per cent of energy from greener sources, it is also possible to reach net zero by 2070 while attaining the per capita income level of AEs. Table 2 summarises the model results in terms of emission and compares that with the results of the linear model presented earlier in this section. The growth model shows that the dual objective of net zero emission target and becoming an AE is possible with a lesser energy consumption as compared with the linear model. This is enabled by the assumed improvement in labour productivity and energy efficiency.

Overall, the analysis suggests that coordinated policy actions together with technological improvements and structural changes may be necessary for India to simultaneously meet its dual goals of becoming an AE with net zero emissions.

Table 2: Summary of the Emission Possibilities

Key Results	2021-22		2029-30		2047-48		2070-71	
	Linear Model	Growth Model	Linear Model	Growth Model	Linear Model	Growth Model	Linear Model	Growth Model
Total energy consumption (Terrawatt/hour)	9070.1	9070.1	14689.6	11060.1	27238.6	17904.0	27699.6	19047.0
Net emissions (Gigatonnes)	1.7	1.7	1.8	1.1	3.6	1.8	0.0	0.0

Note: Net emissions are derived as total emissions less projected carbon absorptions as part of NDC: 1.5 gigatonnes in 2021-22; 3.1 gigatonnes by 2029-30 and 3.3 gigatonnes by 2047-48 which continues thereafter. Net emissions are also determined by the energy-mix, the path of which could be different across models.

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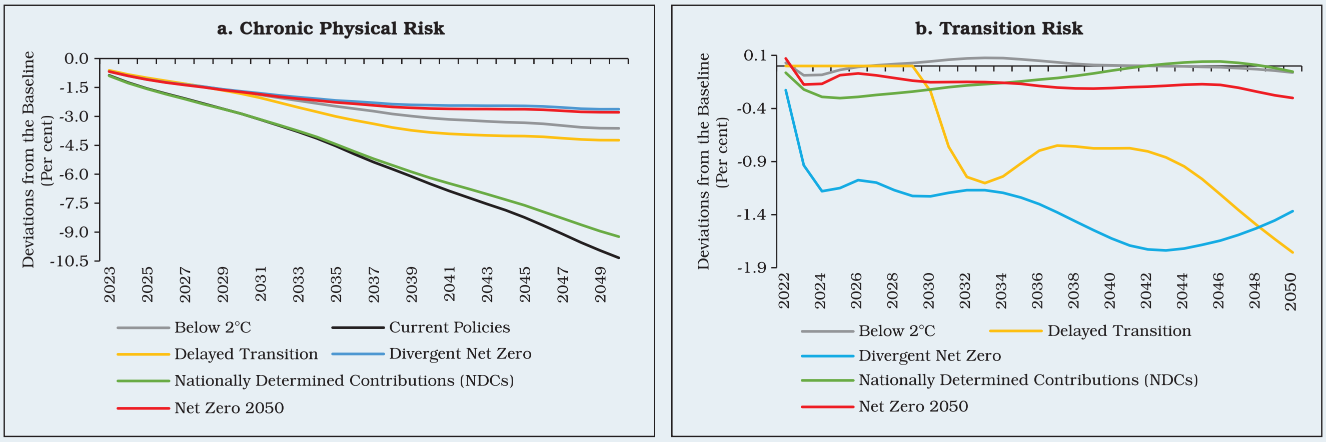
II.49 The Network of Central Banks and Supervisors for Greening the Financial System (NGFS) has linked the standard integrated assessment models (IAMs) with a global macroeconomic model – referred to as the National Institute Global Econometric Model (NIGEM) – to produce policy insights over the short-run, wherein the framework considers both physical and transition risks from climate change. The NIGEM analyses the

Chart II.20: Impact on India's GDP



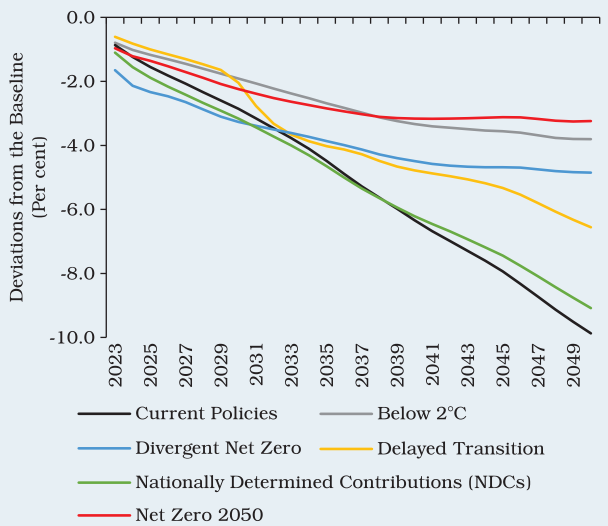
Sources: NGFS; NIGEM; and Authors' estimates.

macroeconomic impact under six standard global scenarios (Annex II.1).

II.50 Taking into account the global NGFS scenarios, overall macroeconomic implications for India are illustrated through the NIGEM model. The model reveals that more the ambitious mitigation goals are at a global level, lesser would be the negative impact of physical risks on GDP *vis-à-vis* the baseline of no impact of climate change (best case scenario) [Chart II.20a]. However, the dynamics are different when transition risks are considered (Chart II.20b). The divergent net zero and delayed transition scenarios cause larger negative impact on GDP on account of temporal and sectoral imbalances in impact realisation and transmission. The other scenarios, *i.e.*, 'below 2°C', 'Net Zero 2050' and 'NDCs' have broadly similar dynamics and lead to lower sacrifice of growth. Thus, in these scenarios, higher physical risk can cause a decline in GDP, by around 1 to 3 per cent from the baseline level in 2030. However, by 2047, the impact can be far more negative at around 3 to 9 per cent depending on the extent of risk mitigation.

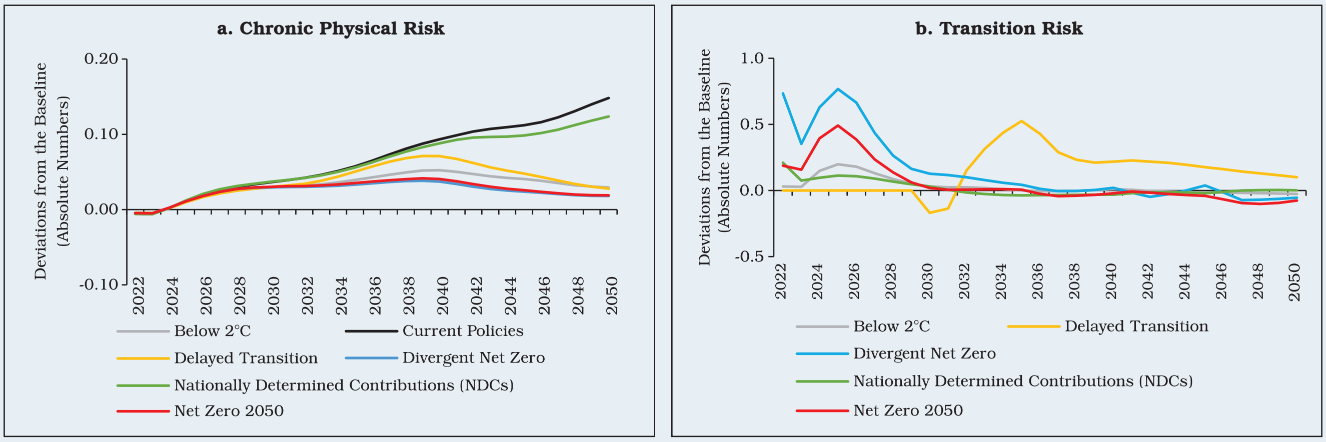
II.51 Since the economy is impacted by both types of risks, the combined effect needs to be visualised for policy insights (Chart II.21). Global scenarios of 'current policies' and 'NDCs' have the highest negative impact on output, mainly due to dominance of physical risk impact in the case of India. The reason for 'NDCs' having a more negative impact than 'Net Zero 2050' and 'Below 2°C' is that,

Chart II.21: Combined Impact of Physical and Transition Risks on India's GDP



Sources: NGFS; NIGEM; and Authors' estimates.

Chart II.22: Impact on India's Inflation



Sources: NGFS; NIGEM; and Authors' estimates.

whereas NDCs act as constraints on the individual countries, the other scenarios are comparatively more restrictive at the global level and thus, entail lower physical risk across countries over time. In essence, global commitments and coordination towards climate risk mitigation remains crucial, without which individual economies, including India, may be significantly impacted due to the possibility of globally inconsistent mitigation efforts and insufficiency of individual NDCs.

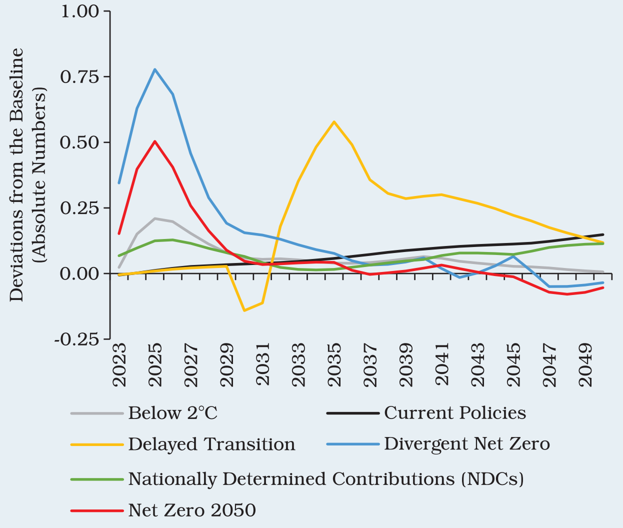
II.52 Physical and transition risks also impact inflation through macroeconomic linkages. In the case of physical risks, both inflation and its volatility increase over time, but the extent of increase is maximum under the scenarios of "current policies" and "NDCs" (Chart II.22a) [these scenarios also involve higher growth sacrifices as discussed earlier]. Since physical risks are expected to rise over time impacting aggregate supply, in the absence of sufficient risk mitigating measures, the impact on inflation is assessed to be more under lesser ambitious mitigation goals. In case of transition risks, however, inflation increases in the initial years owing to the imposition of carbon tax and other mitigation policies which raise the cost of production initially, but the impact gradually wanes towards the baseline, *i.e.*, the deviation tends to zero (except for the delayed transition scenario) [Chart II.22b]. This could possibly be due to the falling cost of green transition over time on account of wider availability and adoption of technology[32] as well as economic agents' expectations getting progressively aligned with the nation's transition path.

II.53 Overall, the effect of climate risks on inflation is dominated initially by the impact of green transition before getting overwhelmed by physical risks (Chart II.23). This is because physical risks are expected to rise over time with climate change, whereas transition risks would take effect from the time when a risk mitigating policy is implemented.

II.54 A comparative picture of the impact of physical risks and transition risks for EMEs like India with that of an AE like the US suggests that the adverse impact of climate change in India is

[32] In other words, the relative price of renewable energy falls over time acting as a downward pull to aggregate inflation.

Chart II.23: Combined Impact of Physical and Transition Risks on India's Inflation



Sources: NGFS; NIGEM; and Authors' estimates.

significantly higher due to greater susceptibility to physical risks (Box II.3).

II.55 Thus, in terms of the NGFS scenarios factoring in India's NDC commitments, a transition towards a less carbon economy has a limited impact on growth and inflation. Therefore, while in the short-run, sticking to the 'NDC scenario' produces a minimal impact on India's inflation, a delayed response can shoot up inflation over the medium-term. In terms of the impact on GDP, although the NDC commitments come with a greater negative impact for India due to its high sensitivity to physical risk, concerted efforts globally towards climate risk mitigation would significantly help smoothen green transitioning over time.

II.56 Overall, how India's carbon emission trajectory may evolve in future would depend on GDP growth and policy actions (in line with NDC or otherwise), and the trade-offs in the short-run *versus* medium-to long-run. First, as per the baseline – GDP growth of 6.6 per cent and no policy actions – GHG emission level will rise from 3.4 gigatonnes in 2021-22 to 4.5 gigatonnes in 2030-31 and further to 8.2 gigatonnes by 2047-48. Second, the current level of actions as per NDC

Box II.3
Climate Change Impact on GDP – A Comparative Assessment

Since the NGFS sets out differential targets for countries across the globe, with stricter restrictions especially for the AEs, the transition risk impact could be higher for them in the short-term. On the other hand, as the Indian economy is more vulnerable to physical risks from climate change (as elaborated in section 2) the impact may be more for India.

Due to the higher sensitivity to physical risks as reflected in India's high vulnerability ranking as discussed earlier, the Indian economy gets deeply impacted in the long-term under a lenient risk mitigation plan, *i.e.,* under the scenarios of "current policies" and "NDCs". Additionally, the impact on India is not too different from the global average, except under these two scenarios (Table 1). Moreover, India is different from most of the AEs in terms of the composition of energy basket, with the dominance of coal under fossil fuel, which could partly explain the differential impact. For example, in the case of the US, the energy-mix and electricity production structure are significantly different from India, with relatively higher use of renewables and non-coal based sources.

Table 1: Impact on GDP

Scenarios (Deviations from Baseline in Per cent)	Impact on GDP (USA)	Impact on GDP (World)	Impact on GDP (India)
Below 2°C in 2030	-1.93	-1.67	-1.91
Below 2°C in 2050	-2.29	-3.02	-3.80
NDC in 2030	-2.59	-2.14	-3.16
NDC in 2050	-5.56	-5.74	-9.08
Current Policies in 2030	-1.55	-1.63	-2.86
Current Policies in 2050	-5.09	-6.05	-9.87

Source: NGFS, NIGEM.

Reference:

NGFS. (2022a). NGFS Scenarios for Central Banks and Supervisors.

commitments, will still be insufficient to achieve net zero by 2070. Net zero by 2070 calls for accelerated actions on top of NDC commitments such as (i) further reduction in energy intensity progressively by 2.8 per cent annually until 2030-31 and by around 5.5 per cent thereafter and (ii) increase in the share of green energy in primary energy consumption to 9 per cent by 2030-31, 27 per cent by 2047-48 and 70 per cent by 2070. This will result in rise in GHG emissions at a slower pace from the current level of 3.4 gigatonnes in 2021-22 to 4.2 gigatonnes in 2030-31 before declining modestly to 4.1 gigatonnes by 2047-48.

II.57 Second, the objective of becoming an AE by 2047 implies a higher annual GDP growth of 9.6 per cent, which would pose additional challenges for achieving the net zero target. With GDP growth of 9.6 per cent and no policy actions as above, GHG emission level may rise from 3.4 gigatonnes in 2021-22 to 5.5 gigatonnes in 2030-31 and further to 15.5 gigatonnes by 2047-48 and 32.4 gigatonnes by 2070-71. Under this scenario, achieving net zero by 2070 calls for even further accelerated actions than what was needed under 6.6 per cent growth rate. Over and above the NDC commitments, it would require (i) a sharper decline in energy intensity at the rate of 5.6 per cent per annum from 2031-32 (ii) increase in the share of green energy in primary energy consumption from around 5.5 per cent in 2021-22 to 9.1 per cent by 2030-31, 28.7 per cent by 2047-48 and around 82 per cent by 2070-71.

II.58 An assessment of physical and transition risks using the global NIGEM-NGFS model suggests that under current policies, India's GDP may be lower by 2.9 per cent from the baseline in 2030, and 8.7 per cent by 2047. With each country following their own NDCs, India's GDP may be lower by 3.2 per cent from the baseline in 2030 and by 8.1 per cent by 2047, suggesting not much gain. However, a net zero by 2050 strategy instead of by 2070 results in lower loss of output – by 2.2 per cent from the baseline in 2030 and 3.2 per cent by 2047 – implying this may be a better policy option globally. As per current policies/ NDCs, the impact on inflation is expected to be minimal, even though its volatility is expected to increase. Overall, delayed and lenient policy actions generate adverse impact on both growth and inflation outlook in the medium-to long-run.

6. Sectoral Green Transition Challenges

II.59 The impact of climate change could be different across sectors. Further, as sectors have different technology pathways for decarbonisation, a uniform approach may not be the best strategy. In view of the difficult policy trade-off between containing near-term adverse output impact by delaying policy actions *versus* larger output losses in the medium-run due to delayed policy actions, a sector-specific approach to climate risk mitigation can help in minimising the trade-off costs. A pragmatic approach would be to target those sectors i) which have higher contributions to the current levels of emissions, and ii) which are more amenable to mitigation strategies - both in terms of costs as well as marginal gains.

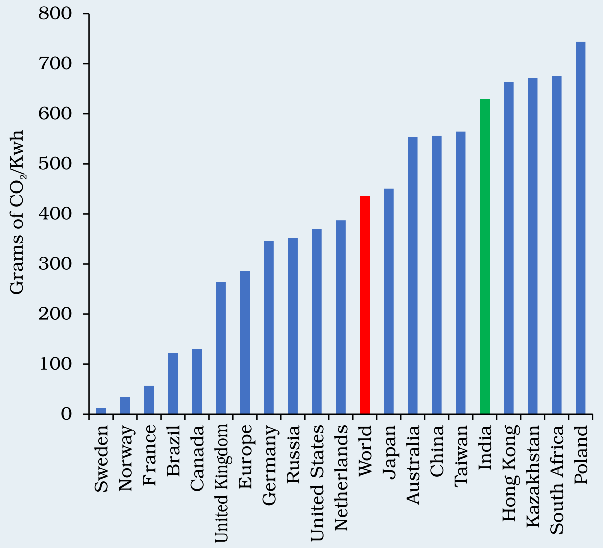
II.60 In this context, four key sectors – electricity, mobility, industry and agriculture – have been identified which are responsible for the bulk of the GHG emissions in India. Within the industrial sector, the policy options and implications of decarbonisation in select hard-to-abate sectors such as steel, cement and chemical industries are specifically examined. The objective is to assess the current production structure and technology as well as the emerging trends in consumption so as to provide insights on how the envisaged transition path at the macro level can be realised.

Electricity Sector

II.61 For addressing climate change concerns on a sustainable basis, transforming the electricity sector will be crucial given that around 70 per cent of electricity in India is produced from thermal power plants. This makes the Indian electricity grids highly carbon-intensive among major economies (Chart II.24).

II.62 India has embarked upon an ambitious plan of achieving 500 GW of total renewable energy capacity by 2030 and raising the share of renewable electricity generation to 50 per cent. One of the key factors that may help in facilitating this transition without a major increase in the cost to the overall macroeconomy will be the advancement in technology, which has led to notable fall in the prices of renewable energy in recent years. Globally, the price of electricity from solar and onshore wind has declined by 89 per

Chart II.24: CO_2 Intensity of Electricity Grids (2019)



Source: Our World in Data.

Table II.6: Electricity Tariff in India in 2021-22

Source	Tariff (₹/kwh)
Conventional (APPC)*	3.85
Nuclear	3.42
NHPC Ltd.	3.36
Solar	1.99
Wind	2.44

*Average Power Purchase Cost (APPC).

Note: The tariffs for solar and wind are the lowest tariffs discovered in various auctions conducted by Solar Energy Corporation of India (SECI).

Sources: Central Electricity Authority (CEA); NHPC; and SECI.

cent and 70 per cent, respectively, during 2009-19 (UNDP, 2022). In India too, electricity tariffs are lower for solar and wind (Table II.6).

II.63 Globally, not a single fossil fuel plant features among the 20 cheapest power plants (Table II.7). Furthermore, the levelised cost of electricity (LCOE) generated from solar power and wind, including integration costs, is expected to fall further by around 40-55 per cent and 20-25 per cent, respectively, by 2030 (BP, 2022). This could propel the transition to a cleaner energy-mix. India has one of the largest synchronous inter-connected grids in the world which operates on one frequency to balance electricity demand and supply over a huge geographical area, making the task of adapting to variable renewable energy (VRE) sources relatively easier. However, massive investments are required in inter-state transmission systems (ISTS) to avoid congestion during peak hours. India plans to invest ₹2.8 lakh crore in ISTS for renewable energy evacuation by 2030 (The Economic Times, 2022b).

Mobility Sector

II.64 Mobility sector, with a share of around 14 per cent in India's overall CO_2 emissions, is the fastest growing source of emissions in India. A breakup of energy consumption and CO_2 emission in this sector indicates that road mobility

Table II.7: Plant Level Levelised Cost of Electricity (LCOE) Calculation

Country	Plant Category	Total Capital Costs (US$/MWh)	Operations and Maintenance Costs (US$/MWh)	Fuel Costs (US$/MWh)	LCOE (US$/MWh)
Sweden	Nuclear	5.9	12.9	9.3	28.2
Denmark	Wind	22.9	6.3	0.0	29.2
Switzerland	Nuclear	7.4	12.9	9.3	29.6
France	Nuclear	8.4	12.9	9.3	30.7
Norway	Wind	20.9	9.8	0.0	30.8
USA	Nuclear	5.2	18.7	9.3	33.3
Brazil	Wind	27.6	6.0	0.0	33.6
France	Solar	30.4	3.5	0.0	33.9
USA	Solar	30.4	4.2	0.0	34.6
USA	Wind	26.5	8.7	0.0	35.2
India	**Solar**	**31.9**	**3.7**	**0.0**	**35.6**
India	**Wind**	**32.2**	**3.7**	**0.0**	**35.9**

Note: There is no fuel cost for wind and solar energy. The fuel cost for nuclear energy is assumed to be same across countries.
Source: International Energy Agency (IEA).

contributes the maximum to CO_2 emission (Table II.8).

II.65 In terms of transport infrastructure, passenger kilometers (kms) and freight ton-kms in roadways have grown by 10 times and 5 times, respectively, during 2000-2017, whereas in the railways they have grown by 2.5 times and 2 times, respectively (Chart II.25). The *Gati Shakti* scheme launched by the Indian government to develop a multi-modal transportation system aims to integrate various modes of transport such as roads, railways, airways, and waterways to reduce logistics costs and improve efficiency. By improving the efficiency of the transportation system, the scheme will help reduce vehicular emissions and promote sustainable transportation.

Table II.8: Transport Sector - Energy Consumption and Emission (2019)

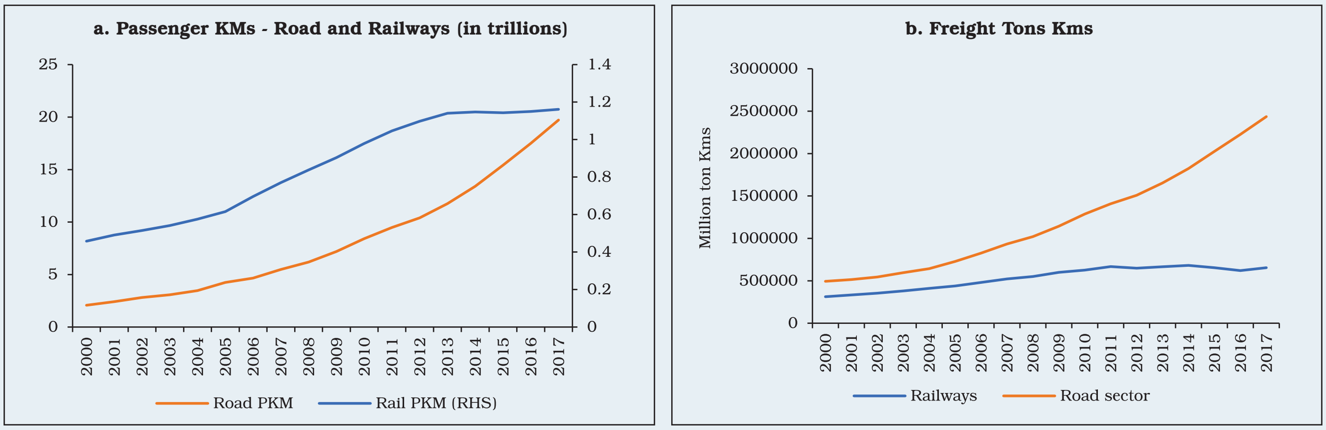
	Energy Consumption (Twh)	CO_2 Emission (Million tons)
Road	1144.0	292.9
Petrol	337.8	87.5
Diesel	691.4	184.5
Gas	114.0	20.9
Aviation	120.0	24.8
Railways	43.7	22.7
Electricity	20.0	16.4
Diesel	23.7	6.3
Total	1307.7	340.4

Sources: Energy Statistics of India; Indian Railways; PIB; and Authors' estimates.

II.66 In order to reduce overall emissions arising from the transport sector, there is a need for a greater focus on developing railway infrastructure, metro network in cities apart from increasing the share of electric vehicles (EVs) in both passenger and commercial vehicles segments. The Union Government has taken several initiatives in this direction.

II.67 India has 742 kms of metro rail lines operational in 19 cities and about 1037 kms is under construction in 27 cities across the country (The Economic Times, 2022a). With India's rapid pace of urbanisation and the completion of under construction metro lines, the annual ridership is expected to increase substantially.

Chart II.25: Passenger and Freight Movements by Modes of Transport

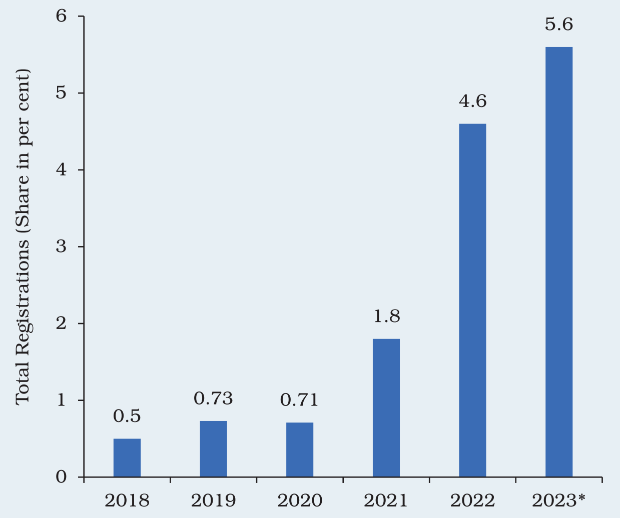


Note: PKM stands for passenger kms.
Source: OECD.

II.68 Further, mass electrification of the road transport system aided by a range of policy initiatives and technology trends, especially *via* the EVs, would help curtail emissions significantly. Globally, the sales of EV cars have crossed 10 million mark in 2022 with a y-o-y growth of 55 per cent. The share of EVs in total new sales is rising rapidly in India and the sales have crossed 1 million in 2022 (Chart II.26). Currently the two and three wheelers, which are mostly used for passenger transport and comprise around 76 per cent share of vehicles in India, dominate the EV sales (up to March 2023, Vahan). Moreover, 64 per cent of petrol consumption in India is by two/three wheelers (MoPNG, 2015). In recent years, the three-wheeler e-rickshaw has become the first mile and last mile connectivity option in all the cities displacing the traditional petrol/diesel run three wheelers for short run commute.

II.69 EV penetration, however, faces challenges of high upfront cost of EV *vis-à-vis* their internal combustion engine (ICE) counterparts and the lack of adequate EV charging infrastructure. As of April 27, 2023, India had 7010 public EV charging stations, which is low by global standards. The Government over the last ten years has undertaken a series of measures to incentivise adoption of EVs in the country, through tax incentives for EV owners and development of public EV charging infrastructure.

Chart II.26: EV Registrations in India



* Up to February 2023.
Source: Vahan Registration.

II.70 Within the mobility sector, shipping and aviation are hard-to-abate due to the lack of cost-effective low-carbon alternatives. Bio-fuels, although expensive, is the most mature technology available today which could decarbonise aviation and shipping.

Industrial Sector

II.71 The industrial sector may be the most difficult to decarbonise as it is highly energy-intensive in nature and also has large fixed investment. Decarbonisation in this sector would require major changes in production processes, expensive retrofits, development and deployment of new technologies, as well as changes in business practices and policies. Despite these challenges, India has managed to contain the extent of emissions with a fall in energy intensity of output (Table II.9). With this, the energy elasticity of growth, measured as ($\frac{\Delta E/E}{\Delta GVA/GVA}$), stood at 0.53 in registered manufacturing sector during 2009-2020.

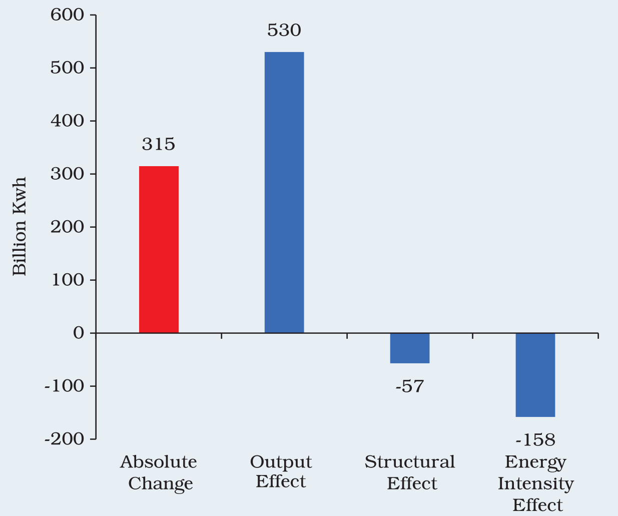
II.72 Decomposition analysis of industrial energy usage following Kant *et al.,* (2022) indicates that *ceteris paribus*, the output effect alone would have led to a rise of 530 billion kWh

Table II.9: Manufacturing Firms in India: Energy Intensity, Output and Emissions

Year	Energy (billion kWh)	CO_2 (million tonnes)	GVA (at 2011-12 prices, ₹ trillion)	Energy Intensity (kWh per rupee GVA)	Carbon Intensity (gram of CO_2 per rupee GVA at 2011-12 prices)
2009-10	921	320.1	7.49	0.12	43.0
2019-20	1237	491.8	12.32	0.10	39.9

Source: Authors' estimates; For methodology see Kant *et al.,* (2022).

Chart II.27: Decomposition of Energy Use Transition



Note: The red bar shows the overall change in CO_2 emissions while the blue bar indicate the decomposition of emission from the manufacturing sector.
Source: Authors' estimates.

in energy consumption, but the actual increase was contained at 315 billion kwh mainly because of the improvement in the energy intensity and the structural effect reflecting the shift in the composition of industries towards less energy-intensive industries (Chart II.27). Improvements in energy efficiency can be attributed to the continuous techno-economic improvements in the industries. The favourable structural effect is indicative of the rising share of less energy-intensive industries in industrial GVA. This structural effect is expected to play a much bigger role going forward as high-end manufacturing like electronics is more knowledge intensive rather than material and energy intensive.

II.73 Overall, Indian industries largely depend on coal for their energy requirements (Table II.10). Within industry, metals, non-metallic minerals and chemicals together account for 78 per cent of the total industrial coal usage, while others primarily use electricity (Table II.11). However, a gradual shift is underway within these energy-

Table II.10: Share of Fuels in Indian Manufacturing Sector

Fuel (as per cent of energy-mix)	2009-10	2013-14	2019-20
Coal	40.8	47.2	45.5
Gas (LPG, Biogas, Natural Gas, Coal Gas)	17.9	9.3	11.2
Diesel	3.8	2.6	5.5
Furnace Oil	9.8	6.4	8.5
Kerosene	0.2	0.4	0.3
Electricity	16.3	21.5	22.9
Other (Wood, Solar, Fuel Oil)	11.3	12.6	6.0

Source: Authors' estimates.

intensive manufacturing industries, with the share of electricity rising from 12.6 per cent to 18.0 per cent during 2009-2019.

Steel

II.74 Globally, India is the second largest producer of steel with 124.4 million tons of crude steel production even though the per capita consumption at 74.7 kg is significantly lower than the world average of 229 kg (World Steel Association, 2019-20). The industry is expected to grow rapidly, with steel production increasing three-fold by 2040 (IEA, 2021). Currently, around 56 per cent of India's steel production is based on the less polluting and less-energy intensive electric arc furnace (EAF) method as compared with the more energy-intensive and coal-dependent integrated blast furnace and basic

Table II.11: Fuel Usage in Indian Manufacturing Sector (2019-20)

Industrial Sector	Total Energy Consumption (Gwh)	Share in Total Consumption (Per cent)				
		Coal	Petroleum	Gas	Electricity	Other
Metals	409200	61.8	9.8	5.1	20.7	2.5
Non-Metallic Minerals	202902	62.0	8.2	13.8	12.1	3.9
Chemicals	166697	33.7	9.5	29.8	18.4	8.5
Textiles	83219	45.2	10.4	2.0	35.6	6.8
Food	78085	23.6	23.0	5.3	29.3	18.8
Refinery	49917	1.3	27.9	52.7	6.7	11.4
Paper	45151	66.3	9.7	0.3	15.3	8.3
Electricity, Gas, Steam, AC	30529	83.7	3.1	2.7	8.3	2.2
Electric Equipment	29261	0.1	55.4	1.6	41.7	1.1
Rubber	28534	15.9	22.5	2.4	54.9	4.3
Pharma	24478	20.2	24.2	3.9	40.7	11.0
Motor Vehicles	20002	0.2	28.5	16.4	52.9	2.1
Fabricated Metals	12561	5.9	35.1	8.1	45.9	5.0
Machinery	11523	2.8	34.0	3.4	53.1	6.8
Beverages	10607	31.4	20.3	0.4	21.0	26.8
Apparel	5890	7.2	41.1	1.1	40.1	10.5
Transport Equipment	5539	0.9	40.4	6.9	47.7	4.1
Motor Vehicle Repair	4604	0.0	77.8	5.9	15.5	0.7
Wood	2909	16.8	21.0	0.2	44.9	17.1
Other	2745	0.2	34.5	3.3	58.2	3.9
Leather	2698	7.9	29.8	1.1	53.6	7.6
Electronics	2292	0.0	25.5	1.9	72.2	0.4
Warehousing	1972	0.0	40.8	1.6	56.8	0.7
Media	1683	0.3	31.6	0.8	59.6	7.7
Tobacco	1096	29.3	28.8	1.9	29.5	10.5
Farming	1073	3.9	20.0	3.9	70.4	1.8
Waste Disposal	924	3.6	34.3	13.2	30.5	18.5

Source: Authors' estimates.

oxygen furnace (BF/BOF). Nonetheless, with India's demand for steel expected to rise in the coming years, there is a need to diversify towards low carbon-intensive production processes, such as harnessing VRE and its integration with EAF, in order to decarbonise steel sector.

Cement

II.75 India is the second largest consumer of cement globally, after China. World-wide, the cement industry is one of the major hard-to-abate industries owing to the extremely high temperature required in the kiln (around 1600 degree Celsius) and the chemical process of breaking down limestone into calcium oxide and CO_2. Near-term emission reductions may be achieved through alternative cement constituents, such as calcined clays, which would reduce the clinker-to-cement ratio in blended cements.

Chemical Industries

Ethylene

II.76 Ethylene, which is used as a raw material in the manufacture of plastics, requires oil-based feedstock for its production. In India, nearly 67 per cent of the production is naphtha-based and the rest is gas-based. There are no process emissions as the carbon gets captured in the products, even though the captured carbon is ultimately released in the atmosphere through the incineration of plastics over the lifetime of the product. Furthermore, ethylene production uses very high temperature which is difficult to electrify using current technologies. To decarbonise ethylene production, oil-based feedstock may be replaced by bio-based feedstock like bio-naptha. India's plans to achieve a 20 per cent[33] blending rate for ethanol by 2025 and further ramping up of biodiesel production could act as a catalyst as bio-naphtha is generated as a by-product in the process and could be used as a feedstock. Bulk of the biofuel production is based on the first-generation technology that converts edible biomass such as sugarcane, rice, maize for ethanol and jatropha for biodiesel which is land and water intensive. Further, upgrading production technology by switching to the second-generation bioconversion technology, which uses cellulose-based, non-edible biomass and agricultural waste, could also lead to an overall reduction in emissions. Efforts to better utilise biomass from agri-residues[34] and re-cycling of plastics are effective ways to reduce emissions in this industry.[35]

Manufacture of Ammonia

II.77 Ammonia has multiple industrial applications, however, around three-quarters of its production is primarily utilised for manufacturing fertilisers. Ammonia production, which operates at a very high temperature and is difficult to electrify, uses fossil fuel as a feedstock. While the hydrogen used in this process is currently derived from natural gas, it is possible to use renewable hydrogen as a feedstock instead. However, renewable hydrogen is more expensive to produce than hydrogen from natural gas. Going forward, as electricity prices moderate with the use of cheaper renewable sources, hydrogen sourced from electrolysis could become cheaper than natural gas.

[33] India achieved the target to blend 10 per cent ethanol in petrol in 2022 well ahead of schedule.

[34] The current availability of biomass in India is estimated at about 750 million metric tonnes per year (MNRE, 2022). Further, the surplus biomass availability is estimated at about 230 million metric tonnes per annum covering agricultural residues.

[35] Around 34.7 lakh tonnes per annum of plastic wastes were generated by India during 2019-20, of which 50 per cent is recycled in India (Central Pollution Control Board, 2019).

II.78 Initiatives are already underway in this direction. Greenfield investments in setting up ammonia plants at the site of wind-solar hybrid projects would ensure economic viability. For example, the Government of Rajasthan is in the process of setting up a green ammonia facility and a renewable energy power plant, which is expected to produce one million tonnes of green ammonia per annum. Also, from the demand-side, rationalising the overall use as well as using nano urea could potentially reduce the consumption of urea.

Agricultural Sector

II.79 Apart from being affected by climate change, agriculture itself is a major source of GHGs. Around 14 per cent of GHGs are emitted by the agriculture sector in India. The agriculture sector is the main source of CH_4 and N_2O emissions. CH_4 emissions occur mainly due to livestock rearing (enteric fermentation and manure management) and rice cultivation. N_2O is principally emitted due to the application of fertilisers to agricultural soils. Within agriculture, 54.6 per cent of GHG emissions are due to enteric fermentation, followed by 17.5 per cent from rice cultivation, 19.1 per cent from fertiliser applied to agricultural soils, 6.7 per cent from manure management, and 2.2 per cent due to field burning of agricultural residues. The CH_4 emitted from enteric fermentation and rice cultivation is re-converted to CO_2 in the upper atmosphere and is re-captured by plants which goes as feed to livestock. Nevertheless, due to high global warming potential of CH_4, it is not considered as climate neutral in the short-run. Demand side interventions like judicious use of fertilisers can reduce N_2O emissions.

II.80 Further, the agriculture sector accounts for about 17 per cent of total electricity consumed along with 5.9 lakh tonnes of diesel which is mainly used in energising 20 million water pumps across the country. The dedicated agricultural feeder systems in many states could be exclusively run on renewables when the generation is high and may be switched off at low variable renewable generation period.

II.81 In sum, a national sector-specific approach to green transition can succeed only if reasonable and sustained progress is achieved across all key carbon emitting sectors, which would require active participation by all stakeholders, ranging from state and local governments to private corporates and NGOs. Alongside significant technological breakthroughs required to achieve green transitioning in the hard-to-abate industrial sectors, policy focus on sectors with low emission intensity such as textiles, fisheries, land transport and services could play a complementary role by supporting India's growth and employment objectives. India has demonstrated its capacity to achieve transformational changes in some sectors, such as renewables and agriculture (developing climate-resilient cropping patterns and seeds), and with sustained policy focus high and sustainable growth objective could be achieved notwithstanding unavoidable trade-offs in the short and medium-run.

7. Concluding Observations

II.82 Research on climate change has gradually evolved to assume prominence in public policy debate. Fuelled by the changing temperature and precipitation patterns, and a rising incidence of extreme weather events globally, public awareness about the consequences of climate change has gained ground, so much so that climate policies have increasingly become target-oriented with economies aiming to achieve net zero emissions within a defined timeline.

II.83 India's diverse topography makes it vulnerable to significant risks from climate change, evidences of which are increasingly visible in rapid changes in temperature; variations in SWM rains; rising frequency and intensity of extreme weather events such as unseasonal rainfall, heatwaves, cyclones and floods. Further, the aspiration of becoming an AE by 2047 could pose a unique development challenge for India, wherein it has to balance between economic and environmental goals. In this regard, India's climate action policy has embraced climate targets defined in terms of its NDCs, while paving a step towards achieving net zero emissions by 2070 by declaring low carbon transition pathways in key economic sectors.

II.84 While the manifestation of climate change has become evident, its impact on the Indian economy could be manifold, by denting the supply potential of the economy as well as by altering demand conditions. Empirical analysis indicates that natural disasters adversely impact economic activity, *i.e.*, lower output growth, while raising inflation. Moreover, disaster-affected regions could also witness a decline in their consumption of essential commodities owing to the diversification of funds for post-disaster reconstruction/ rehabilitation needs.

II.85 Further, scenario analyses to chalk out India's transition to the net zero target by 2070, while attaining the status of an AE by 2047 suggest that India would require aggressive efforts in terms of reducing its energy intensity of output as well as improving the energy-mix as compared with the current NDC commitments. While the share of green energy in overall energy consumption has to reach to about 82 per cent from its current level of around 5.5 per cent in 2021-22, the energy intensity of output has to decline by 5.1 per cent on an annual average basis as compared with the current rate of decline of 2.3 per cent in 2021-22. In such a scenario, the implied level of energy consumption by 2070 would be 3.1 times higher as compared with the 2021-22 level.

II.86 Aiming to achieve an overall macroeconomic policy balance would help provide the much-needed resilience and sustainability to the economy, given the enormous scale and wide-ranging nature of the policy measures needed for climate action. Moreover, the implications of policy actions could be widespread ranging from sector-specific imbalances in the short-run to economy-wide frictions and adjustments in the medium to long run. Empirical estimates using a standard environmental Solow-type growth model to analyse the relationship between economic growth, energy usage and emissions indicate that the economy may optimise on output and GHG emissions by having the right energy-mix – a shift to green energy from brown energy. Further, the twin objectives of becoming an AE by 2047 and achieving the net zero target by 2070 could still be possible if factors of production other than energy – labour and capital – witness productivity gains on the back of government policies and technological breakthroughs.

II.87 Additionally, India's susceptibility to physical risks emanating from climate change raises significant concerns on policy trade-offs surrounding growth-inflation. Scenario analysis indicates that the Indian economy may be deeply impacted, with inflation rising and output falling in the medium-term under a lenient mitigation plan. Risk mitigating domestic policies and global concerted efforts could, however, help in containing the adverse impact on growth and inflation.

II.88 Finally, in view of the difficult policy trade-offs between containing near-term adverse output impact due to NDC commitments *vis-à-vis* larger output losses in the medium-run due to no policy action, a sector-specific approach to climate risk mitigation is called for. Further, since different sectors of the economy have different emission intensities, it is advisable to not have a uniform climate mitigation strategy across sectors. In this regard, alongside significant technological breakthroughs required to achieve green transitioning in the hard-to-abate industrial sectors, policy focus on sectors with low emission intensities such as textiles, fisheries, land transport and services could support India's growth and employment objectives. India has already demonstrated its capacity to achieve major transformations in certain sectors, such as renewables and agriculture (developing climate-resilient cropping patterns and seeds). With continued policy support and focus, attaining the twin objectives of becoming an AE by 2047 and achieving the net zero emission target by 2070 may not be too ambitious, notwithstanding unavoidable trade-offs in the short and medium run.

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Annex II.1: The NIGEM Model – Key Features

The NIGEM approach takes into account the standard NGFS scenarios as the benchmark (Annex Table 1). The deviations of various macroeconomic variables under different possible transition scenarios are then examined. The standard scenarios of NGFS are defined in terms of global GHG emissions, which are considered as the global baseline scenarios for macroeconomic impact assessment (NGFS, 2022a).

Annex Table 1: Standard NGFS Scenarios Setting the Global Benchmark	
Below 2 degree Celsius	This scenario assumes that optimal carbon prices as per the long-term path are set immediately after 2020 and keeps the 67th percentile of warming below 2 degree Celsius throughout the 21st century.
Current Policies	Existing climate policies remain in place without any change in policy ambitions.
Delayed Transition	This scenario assumes that the next 10 years see a "fossil recovery" and thus, follow the trajectory of the current policy scenario until 2030. This is related to Below 2 degree Celsius scenario but follows a very skewed path due to late start.
Divergent Net Zero	This scenario assumes that optimal carbon prices, in line with the long-term targets, are implemented immediately after 2020 after a limited temporary overshoot before reaching net zero. This is related to net zero 2050 but follows a divergent path - mitigation efforts are unevenly distributed across sectors, with stronger mitigation action taking place in the Transport and Buildings sectors-reflecting lack of coordination.
Nationally Determined Contributions (NDCs)	This scenario foresees that currently pledged unconditional NDCs are implemented fully and respective targets on energy and emissions in 2025 and 2030 are reached in all countries. This scenario also factors in the net zero 2070 goal of India as per its NDC.
Net Zero 2050	This scenario foresees global CO_2 emissions to be at net zero in 2050. It limits the temperature rise to 1.5 degree Celsius. Furthermore, countries with a clear commitment to a specific net-zero policy target at the end of 2020 are assumed to meet this target.

III

CLIMATE CHANGE AND FINANCIAL SECTOR*

The financial sector faces the dual challenge of recalibrating its operations and business strategies to support the green transition process while also strengthening resilience to rising vulnerability to adverse climate events so as to safeguard financial stability. On the first challenge, estimates suggest that the green financing requirement in India could be at least 2.5 per cent of GDP annually to address the infrastructure gap caused by climate events, and the financial system may have to mobilise adequate resources and also reallocate current resources to contribute effectively to the country's net-zero target. On the second challenge, results of a climate stress-test reveal that public sector banks (PSBs) may be more vulnerable than private sector banks (PVBs) in India. Globally, however, measurement of climate related financial risks remains a work in progress. A pilot survey of key stakeholders in the financial system in India suggests that notwithstanding rising awareness about climate risks and their potential impact on the financial health of entities, risk mitigation plans are largely at the discussion stage and yet to be widely implemented.

1. Introduction

III.1 There is a broad consensus in the literature that financial systems are exposed to both physical and transition risks from climate change, which propagate through both macroeconomic and microeconomic channels (Basel Committee on Banking Supervision, 2021). Physical risks arise from extreme/acute weather events such as floods, storms, rising sea levels or increasing temperatures which may damage properties and impact lives and livelihoods. On the other hand, transition risks ensue due to economic and societal costs associated with the process of transitioning to a low-carbon economy. Such risks arise due to public policy changes aimed at containing green transition costs, innovation that results in new technology, trade policy restrictions impacting the availability and affordability of existing as well as new technologies, and changes in investor and consumer sentiment impacting the demand pattern of the economy.

III.2 The impact of these risks may materialise with uncertain time lags; their frequency and severity may vary considerably over geographies and over time; and they may become increasingly difficult to predict. As the frequency of tail events increases, estimation of default probabilities would become more difficult and uncertain, resulting in higher interest rates and insurance premiums (Basel Committee on Banking Supervision, 2021). In view of higher expected credit loss, lending institutions may turn risk averse, with higher provisions and risk capital, which may adversely impact credit growth, although the economy may need higher, not lower, credit to support successful green transition. The amplification of financial risks, *i.e.*, '*credit risk*', '*market risk*', '*liquidity risk*', and '*operational risk*' – through macroeconomic and microeconomic channels may pose a serious threat to financial stability, *via* losses to levered financial intermediaries, disruptions in the functioning of financial markets, sudden and

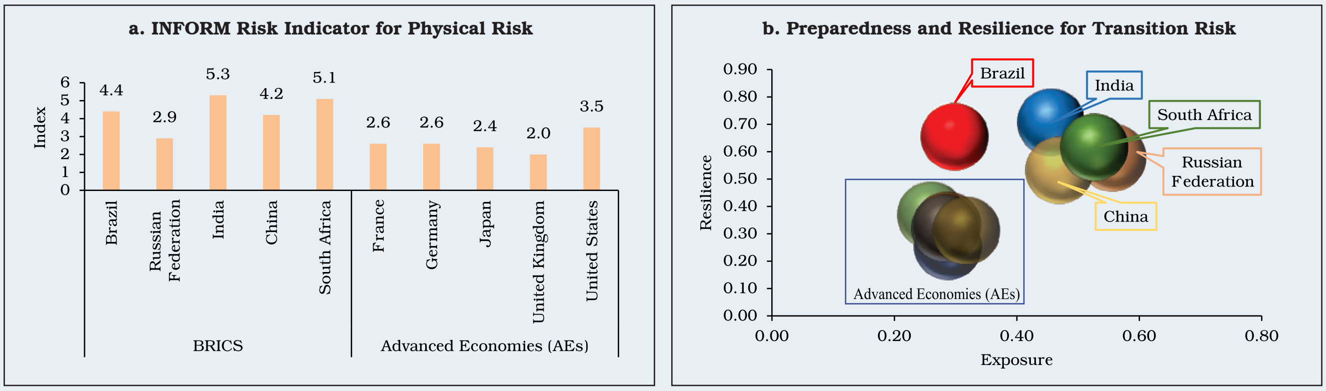
* This chapter has been prepared by a team comprising Saurabh Ghosh, Snehal Herwadkar, Siddhartha Nath, Pawan Gopalakrishnan, Satadru Das, Vidya Kamate, Sambhavi Dhingra, Rajnish Kumar Chandra and Mayank Gupta. Data support provided by Shashank D. Bhujade is gratefully acknowledged.

large repricing of assets, and distorting policy transmission channels.

III.3 The IMF's INFORM climate risk index[1] indicates that among BRICS countries and major advanced economies (AEs), India is most vulnerable to climate-induced physical risks (Chart III.1.a). In terms of preparedness and resilience to transition risks, the indicator developed by Peszko *et al.* (2020)[2] suggests that while most AEs have high resilience and low exposure, BRICS countries are less resilient and highly exposed. India is the least resilient among BRICS countries but is also less exposed than many in the same group (Chart III.1.b).

III.4 While the financial sector would be at the receiving end of the climate risk on the one hand, it also has the potential to catalyse risk mitigation on the other. It is, therefore, important to evaluate both these dimensions to design policies that could enhance the contribution of the sector to green transition while preserving financial stability. In this vein, the remainder of the chapter is organised as follows: in order to better understand the channels through which environmental shocks are transmitted to the financial sector, Section 2 provides a brief summary of the major risks. In Section 3, a dynamic stochastic general equilibrium (DSGE) model is developed to estimate the likely impact of climate shocks on the Indian financial system. The findings of a pilot stakeholder survey conducted to gauge participants' awareness of the challenges associated with climate change and their level of preparedness are summarised in Section 4. The findings of a climate stress test applied to the current asset portfolio of Indian banks are covered

Chart III.1: Physical and Transition Risk Indicators



Note: The resilience index ranges from 0 to 1, with 0 being high resilience and 1 being low resilience. The exposure index also ranges between 0 and 1 but in this case, 0 indicates low exposure while 1 indicates high exposure.
Sources: 1. INFORM Risk; IMF staff calculations (Chart III.1.a).
2. Peszko *et al.* 2020, Chapter 5 (Chart III.1.b).

1 The Index for Risk Management (INFORM) was developed jointly by the Inter-Agency Standing Committee Reference Group (on Risk, Early Warning and Preparedness) and the European Commission, and was later adopted by the IMF to measure climate-risks. Three dimensions captured by the Climate Risk index are climate-driven hazard and exposure, vulnerability, and lack of coping capacity. The index ranges between 0 and 10, with higher values indicating greater physical risk.

2 The index captures preparedness of countries based on their exposure and resilience to transition risks. The exposure index is constructed using indicators such as carbon intensity of manufacturing exports and share of fossil fuel exports in GDP, among others. The resilience index is derived from 11 key macroeconomic variables, such as GDP, institutional quality, financial and human capital development.

in Section 5. Section 6 is devoted to estimation of green finance requirements for India. Section 7 brings out the debates surrounding effectiveness of some of the risk mitigation techniques in the financial sector that are used internationally, with an analysis of India's progress in this regard. Section 8 concludes by offering some future directions.

2. Financial Risks due to Climate Change

III.5 Attempts to understand, measure and model financial risks associated with climate change are of recent origin. Although the conventional risk management tools may serve as a springboard, climate risk drivers contain unique features that could challenge the incorporation of these risks into existing processes (BCBS, 2021). This section is devoted to a granular analysis of these risks with a special focus on India.

Credit Risk

III.6 Both physical and transition risk drivers from climate events can reduce a borrower's capacity to service or repay debt and erode a lender's ability to fully recover losses if the pledged collateral values are insufficient. Banks, that are highly exposed to sectors more dependent on fossil fuels, or sectors which contribute highly to emissions due to the nature of their products, such as automobile and thermal power, are more exposed to transition risks.

III.7 In the absence of a full-fledged taxonomy, an appropriate approach could be adopted to classify industries into green and brown for the purpose of analysis. This may be done on the basis of a sector's energy intensity, measured by the ratio of energy input cost to the value of the sector's gross output. A higher ratio indicates that the sector is more energy intensive and thus less green[3]. A granular analysis of data suggests that Indian banks' exposure to high energy intensive sectors like generation and distribution of energy (utility sector[4]) and metals is relatively high (Box III.1).

III.8 Another metric for classification of industries into green and brown is the ratio of sectoral energy consumption to its gross value

Box III.1
Measuring Indian Banks' Transition Risk using Energy Intensity Metrics

The energy use intensity of the utility sector, transport and storage operations, metal and metal products, manufacturing of non-metallic mineral products, paper products and production of automobiles, as estimated from the KLEMS[5] data for India, are higher than other activities in the economy. Mapping of energy intensities with sectoral deployment of bank credit (at end March 2022) suggests that banks' exposure is relatively higher in utilities, metal industries, and transport and storage operators (Charts 1 a and b).

Although at the aggregate level, the exposure of the banking sector to climate change risks appears moderate, a spatial analysis highlights sharp contrasts in exposures

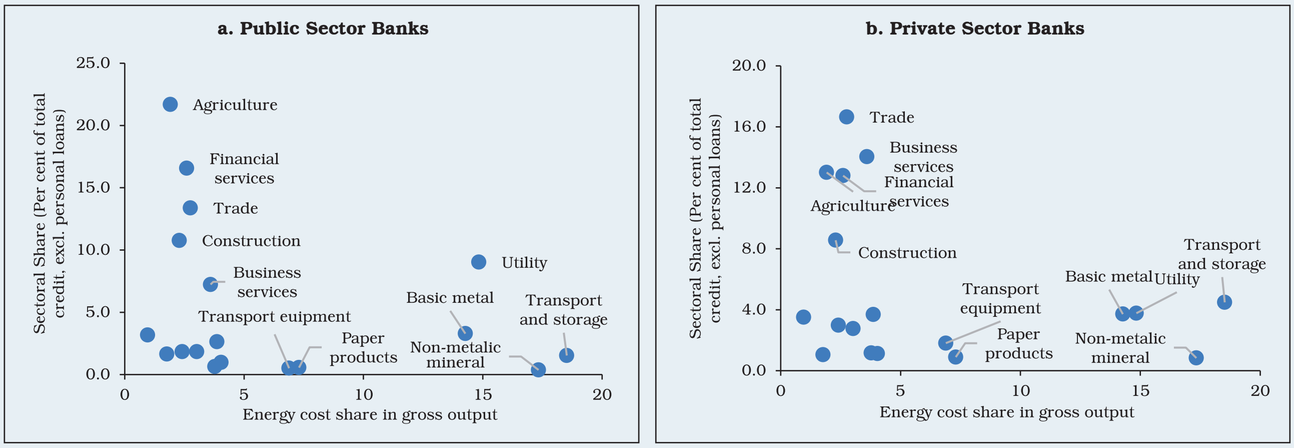
(Contd...)

3 The energy sector includes both fossil fuels and electricity, of which the latter comprises both non-conventional and conventional sources. The India KLEMS database 2019-20 is used to extract data on energy intensity. Non-availability of separate data on non-conventional electricity is acknowledged as a limitation of this analysis.

4 Includes generation and distribution of electricity, gas and water supply.

5 KLEMS refers to Capital, Labour, Energy, Material and Services. This database provides historical estimates of income shares for each of these factors of productions, along with the Total Factor Productivity.

Chart 1: Sectoral Energy Use Intensity and Deployment of Bank Credit

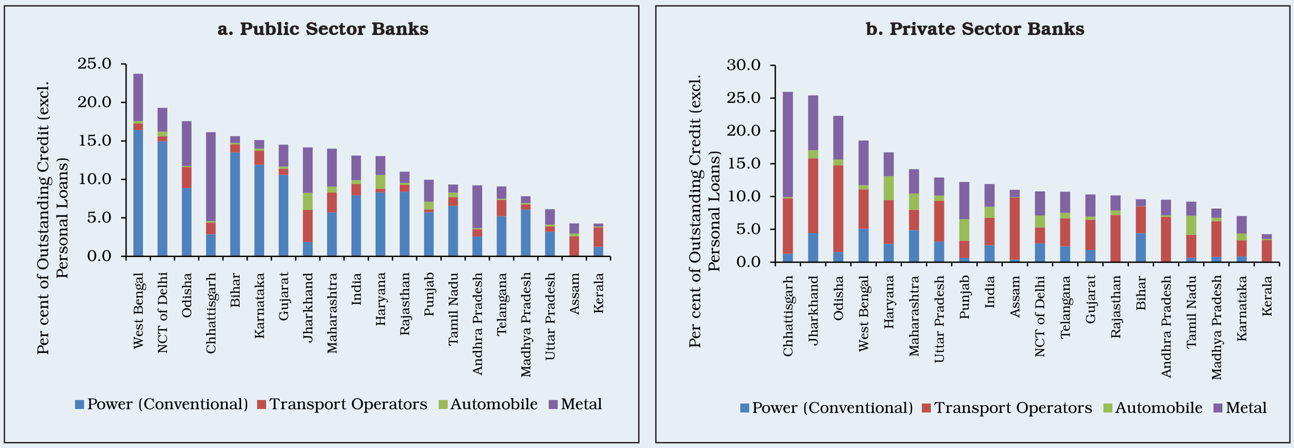


Source: Authors' calculations based on India KLEMS database 2019-20 and Basic Statistical Returns March 2022, Reserve Bank of India.

across bank groups and across states. While the transition risk for the PSBs stems largely from their exposure to the conventional energy sector, especially in West Bengal and NCT of Delhi, their private sector counterparts are exposed more to the transport operators' sector, most notably in Jharkhand and Odisha (Chart 2.a and b). Both the bank groups are exposed to the metal industries. Except for PVBs' exposure to automobile sector in Haryana, Punjab, Maharashtra and Tamil Nadu, the aggregate exposure of banking sector to the automobile production is limited.

Basic metals and utilities are sectors with low interest-coverage ratio as well as comparatively high GNPA ratio (Ghosh *et al.,* 2022). Their higher transition risk suggests that, going forward, these sectors may pose higher climate credit risk for the Indian banking system.

Chart 2: Spatial Distribution of Sectoral Bank Credit

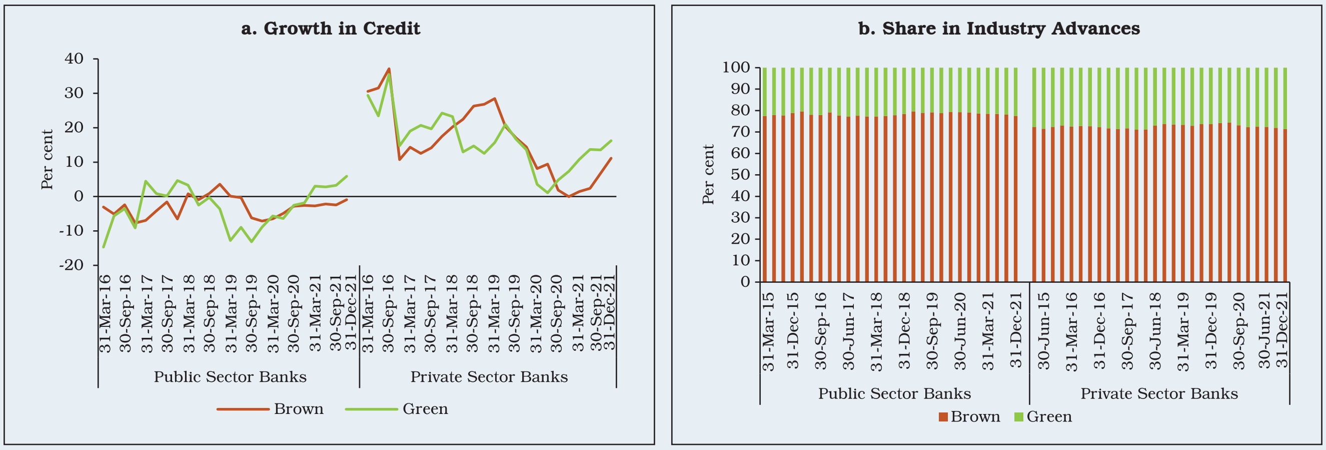


Source: Authors' calculations based on Basic Statistical Returns, March 2022, Reserve Bank of India.

Reference:

Ghosh, S., S. Nath, A. Narayanan, and S. Das (2022). Green Transition Risks to Indian Banks. *Reserve Bank of India Bulletin*, March.

Chart III.2: Bank Credit to Green *vis-à-vis* Brown Industries

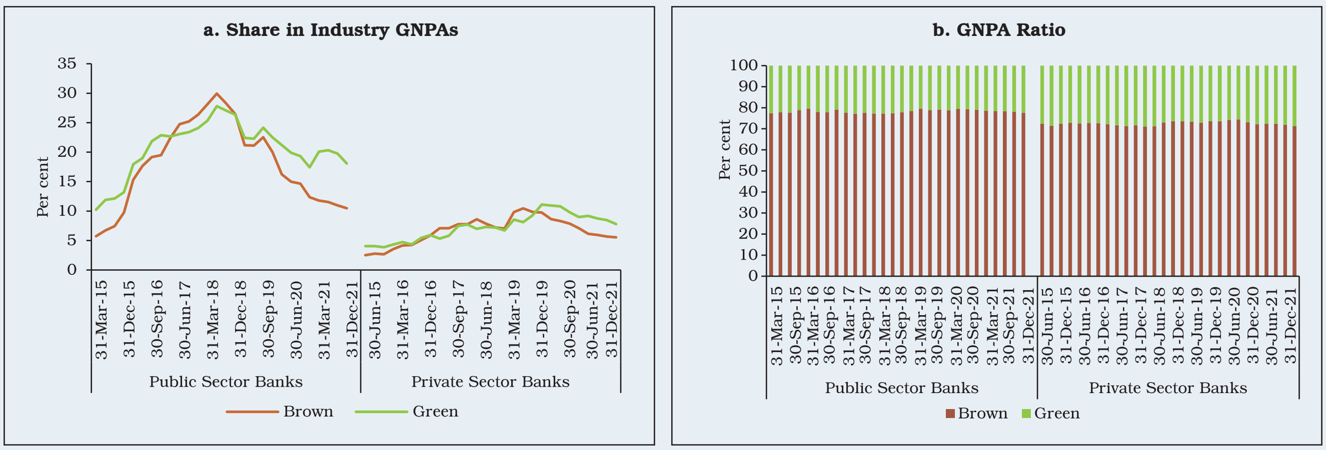


Source: Off-site returns (domestic), RBI.

added (GVA), which is gross output minus the cost of intermediate inputs. An analysis employing this classification suggests that hearteningly, in the recent years, bank credit to green industries has accelerated at a pace faster than that to brown industries, which is a sign of improved recognition of climate risks. The acceleration has primarily been driven by PVBs (Chart III.2.a and b). The GNPA ratio of green industrial loans, however, has been higher during the same period, especially for PSBs (Chart III.3.a and b).

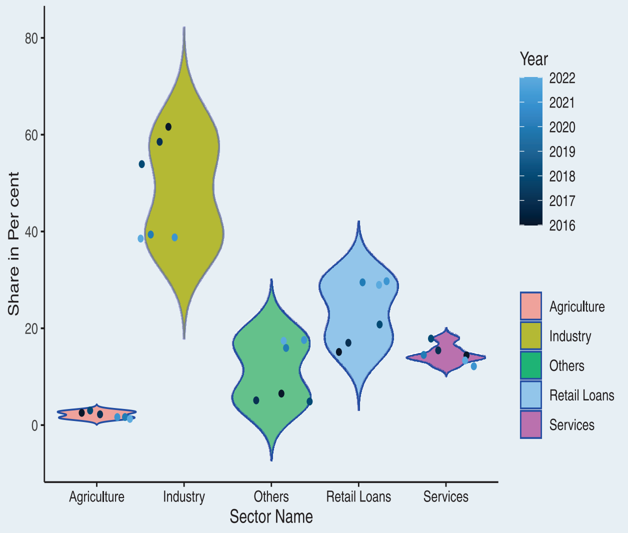
III.9 The Non-Banking Financial Companies (NBFCs) complement and supplement the banking sector in India through their grassroot level presence and ability to deliver tailor-made products to meet varied needs of the customers. On the liabilities side, while NBFCs have been the largest net borrowers of funds from the financial system, on the asset side, the highest chunk of their lending is directed to the industrial sector (Chart III.4).

Chart III.3: GNPAs of Green *vis-à-vis* Brown Industries



Source: Off-site returns (domestic), RBI.

Chart III.4: Sectoral Distribution of NBFC Credit



Source: Database on the Indian Economy, authors' calculations.

III.10 NBFCs extend about half of their gross credit to the power and vehicle/auto segments, which have high carbon footprints. Moreover, around six per cent of NBFC credit is directed to micro, small and medium enterprises (MSMEs), which typically depend on conventional fuel to operate. Given that NBFCs have strong backward and forward linkages with rest of the financial system and the real sector, any large-scale default arising on account of physical or transition risk in any of these segments might translate into macro-financial instability. Therefore, in addition to the banking sector, there is a need to closely monitor NBFCs for their transition risks, both direct and indirect (Box III.2).

Box III.2
Role of NBFCs in Propagating Climate Change Impact

A stylised partial equilibrium model to analyse real sector outcomes in response to a climate shock to NBFCs is developed in line with Ghosh and Mazumder (2023). The interrelationship between banks and NBFCs is the backbone of this model. While NBFCs are assumed to be non-deposit taking, scheduled commercial banks (SCBs) are deposit-taking financial institutions that extend loans to NBFCs. By assumption, SCBs lend to the large firms, and NBFCs fill-in the funding gap for small borrowers *albeit* by charging higher interest rates than SCBs (Chart 1).

In the model, climate change impacts large as well as small firms. The direct impact on SCBs is due to their stressed lending to large borrowers. In addition, the indirect channel works through climate change impact on small firms, which produce intermediate goods. Some of these firms may turn bankrupt, and default on their NBFC obligations. Although NBFCs by themselves are considered relatively small, the simulation results of the model show that the impact of a climate event could propagate to other sectors of the economy, given the NBFC-SCB borrowing interlinkages. When a climate shock first increases the riskiness of a small firm and then gets transmitted to a large firm, economy wide delinquency increases. Model simulation results indicate that faced with an adverse weather event and increase in

Chart 1: Model Framework—Climate Shock to NBFCs

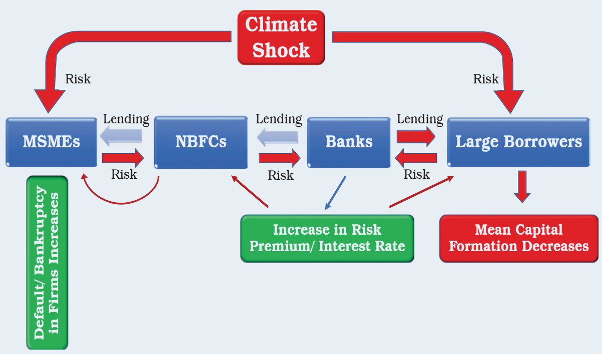
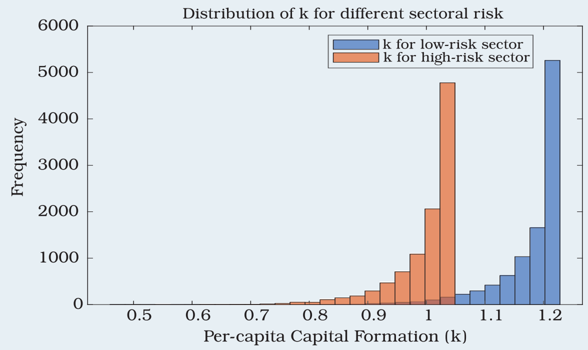


Chart 2: Impact of climate shock on capital formation



Source: Authors' calculations.

(Contd...)

risk, the distribution of capital stock shifts to the left (shift from blue distribution to orange in Chart 2) indicating its adverse effects on capital formation.

To sum up, notwithstanding a low share in total credit, any large-scale default in loans extended by NBFCs on account of weather events amplify delinquencies, given NBFCs' backward and forward linkages. Multiple propagation channels could increase the severity of a climate shock. Therefore, a careful vigil on NBFC sector is necessary during the process of transitioning towards a greener economy.

Reference:

Ghosh, S., and D. Mazumder (2023). Do NBFCs propagate real shocks?. *Journal of Asian Economics*: 101590.

Market Risk

III.11 Market risk captures the change in value of financial assets due to changes in interest rates, exchange rates, asset prices, and their volatility. Climate transition risks can reduce financial asset values, leading to a breakdown in correlations and resultant dilution in the effectiveness of hedges. A study on the relationship between climate change and Asian stock markets suggests that the former has a statistically significant negative impact on long term return volatility of about 20 per cent of stocks (Oloko *et al*., 2022).

III.12 In addition, transition risk may result in higher risk premiums for carbon-intensive borrowers, thereby lowering valuations of financial assets that are used as collateral. Some studies argue that the securities accepted as a guarantee under the Euro system collateral framework are not “aligned” with the climate targets of the Paris Agreement, and are, therefore, exposed to transition risks (Weber *et al.,* 2021).

Liquidity Risk

III.13 Climate risks can raise the liquidity risk of banks by impacting their capacity to raise funds and their ability to liquidate assets to meet their obligations. One of the main routes through which liquidity risk can transmit is through the credit channel. Credit lines, such as cash credit and overdrafts offered by banks to firms, are considered as liquidity insurance. In times of crisis, competing claims on liquidity from firms and the lenders may give rise to a tension between the two. Such tensions generally manifest as higher spreads on credit, higher charges for covenant violations, and barriers to drawdown of credit lines (Acharya *et al*. 2020, 2021). Such situations may follow severe climate events in which firms may ask for significant liquidity support while banks may be constrained to provide that support due to a degradation of their asset quality (Schu¨wer *et al*., 2019 and Rauf, 2023). Rauf further finds that affected banks are expected to face liquidity shortage and may restrict drawdowns of credit lines in the future.

Operational Risk

III.14 Operational risk arises mainly from inadequate controls within a bank, employee mistakes, and breakdowns in internal processes and systems, which in turn impact a bank's reputation. Climate events may exacerbate operational and reputational risks as corporations and banks could be subject to legal and regulatory compliance risk, especially from climate-related lawsuits. Further, extreme weather events may impact the financial sector by forcing office closures or damaging crucial resources such as data centres. Stronger enforcement of regulatory and disclosure requirements by the regulator coupled with a competitive market structure may help mitigate the adverse impact of climate change. For instance, a natural disaster could have a greater impact on the financial stability if the market for insurance of a particular vulnerable sector is concentrated. If, however, the market has many strong and active participants, the resulting higher shock-absorbing capacity of the insurance market may support smoother adjustments to adverse climate events (Alvarez *et al.,* 2020).

3. Modelling the Macro-Financial Transmission of Climate Risk

III.15 To understand how physical shocks or a transition towards a greener economy may impact capital formation, interest rates and real output, central banks widely use the '*Environment-DSGE Models*'. Specific examples include the 'Economic Projection and Policy Analysis (EPPA) Model' developed by the 'MIT Joint Program on the Science and Policy of Global Change' and the quarterly National Institute Global Econometric Model (NiGEM) (NGFS 2021). These models can help analyse the transition risks to financial stability arising from adopting a net-zero strategy, and the dual role of central banks, who, on the one hand, contribute to the net-zero goal and on the other, strive to preserve financial stability.

III.16 A workhorse DSGE model which is calibrated for India, where climate risks percolate through the stock of capital, shows that natural disasters impact consumption more than income (Box III.3). The results highlight the role of economic and financial policies to smoothen consumption and thereby help the economy to converge to its steady-state.

Box III.3
Climate Risk Impact Assessment in a DSGE Model for India

A parsimonious DSGE model is constructed where the economy consists of a high risk-averse representative household, a final good sector, a continuum of intermediate goods producers, and a policy authority. The policy authority meets the requirement of its spending through lump-sum tax revenues and bond issuances. The policy authority is also guided by a standard Taylor Rule where the monetary policy rate (and also by assumption, the bond yield) is a function of the output gap and inflation gap. This model closely follows Christiano *et al.* (2005) and Smets and Wouters (2007).

In this model, climate risks percolate into the real sector *via* physical damage to capital. The main objective of this exercise is to evaluate whether the damaged capital stock replenishes itself through forces in the capital markets in a short horizon or if there is a need for policy intervention. This is modelled based on the following capital law of motion faced by the representative j^{th} intermediate firm:

$$K_{jt} = \left(1 - \delta - \epsilon_t^I\right)K_{jt-1} + I_{jt}$$

where, ϵ_t^I is an adverse shock to the capital accumulation. Simulation of the model shows that when the economy is hit with a massive one-time adverse climate shock to capital, contractionary effects are large and persistent (Chart 1).

Output contracts instantaneously by more than 0.5 per cent and continues to fall by more than 1 per cent up to

Chart 1: Impact of One-Period Adverse Climate Shock to Capital

Note: Red line in each chart represents the steady state whereas the blue line indicates the short run impact of a one period adverse shock to capital.

(Contd...)

5 quarters. This instantaneous fall in output translates into lower incomes, thereby resulting in a fall in consumption. The impact on consumption is more pronounced than output as the household is highly risk averse.

These developments are likely to get translated into an increase in the financial sector vulnerability. A deterioration of capital, due to an adverse climate shock, results in a lagged increase in the price of capital and a contraction in output. To recover from the damage to the capital stock due to the climate shock, investment demand expands significantly. On the whole, this pushes up the aggregate demand, which, along with the increase in the price of capital, pushes up inflation. Moreover, given the inflation targeting framework and resultant higher weight to inflation in the Taylor rule, the policy authority tightens the interest rates, increasing losses for firms. A contraction in capital stock due to the climate shock also deteriorates the value of borrowers' collateral (Gertler and Karadi, 2011). Consequently, delinquencies may increase, and this may affect bank profitability. Increase in interest rates and pressures on market and funding liquidity may exacerbate the financial stability risks.

Reference:

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of political Economy*, *113*(1), 1-45.

Gertler, M., and P. Karadi (2011). A model of unconventional monetary policy. *Journal of monetary Economics*, *58*(1), 17-34.

Ghosh, S., S. Nath, and P. Gopalakrishnan (2022). Distributional Impact of Cyclones on Indian Households' Income and Consumption. *Forthcoming, RBI Working Paper*.

Smets, F., and R. Wouters (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American economic review*, *97*(3), 586-606.

Measurement of Climate Risk

III.17 Measurement of financial risks associated with climate change invariably involves strong assumptions, given the high uncertainty about physical and transition risk drivers, data gaps, and model uncertainty. The unique features of climate-related financial risks necessitate granular and forward-looking measurement methodologies to account for these uncertainties. While the need for such methodologies and multiple scenarios for stress testing is increasingly recognised by banks and supervisors, frameworks to systematically translate climate change scenarios into standard financial risk analysis are still a work in progress (NGFS, 2019). Due to sectoral, jurisdictional and geographical heterogeneities, granular data on exposure to climate change are needed to incorporate these risks in analysis spanning three areas: translating climate risk drivers into economic risk factors; linking climate-adjusted economic risk factors to exposures; and measuring financial risk from climate-adjusted economic risk (BCBS, 2021).

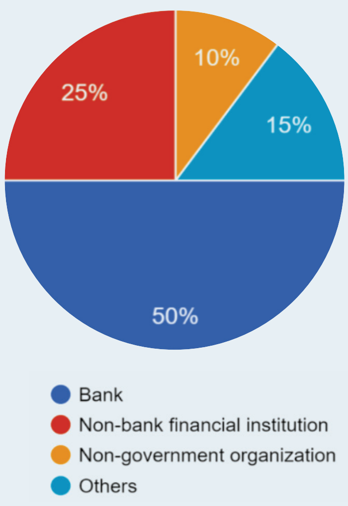
III.18 By their very nature, forward-looking climate risk estimation methods are required to span a longer time frame as compared with traditional macroeconomic exercises. This requires conditioning assumptions about balance sheet adjustment options. As a result, banks and supervisors often base their scenario analyses, or stress tests, on scenarios developed by third parties.

III.19 To date, progress in capturing banks' exposures to physical risks empirically has been less tangible, and the focus has been on mapping the near-term transition risk drivers to counterparty and portfolio exposures. Further, supervisors and banks have laid more emphasis on credit risk modelling, with relatively lesser focus on market risk, and very limited attention to operational and liquidity risk, while reputational risk assessment has remained predominantly qualitative (BCBS, 2021). Although work related to translating climate risks into robustly quantifiable financial risk is currently at a nascent stage, it is gathering momentum.

4. Stakeholders' Survey on Climate Risks

III.20 A major factor that influences the effectiveness of policies and their transmission is market perception. An anonymous survey of various financial institutions in India was undertaken in December 2022 to assess the market perception of climate risks, their awareness about the same and policies implemented/ being contemplated by these institutions to hedge against them. The informal survey was conducted among major banks, NBFCs, brokerage institutions and other financial firms. The analysis in this section pertains to twenty responses received and is, thus, indicative in nature (Chart III.5).

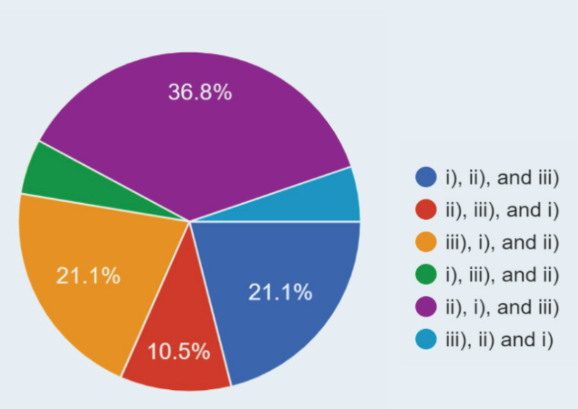
Chart III.5: Respondents' Affiliation



Source: Authors' calculations based on survey responses.

Chart III.6: Source of Climate Threat

What is/are the sources of climate related risks? Rank between – i) Physical Risk ii) Transition Risk and iii) Liability Risk



Source: Authors' calculations based on survey responses.

Perception of Exposures

III.21 Almost 90 per cent of the respondents considered climate risk as a material threat to the institution's business. When asked to rank the climate risks, about half of them identified transition risk as the prime concern for their business. Another 26 per cent respondents identified it as the second biggest risk (Chart III.6).

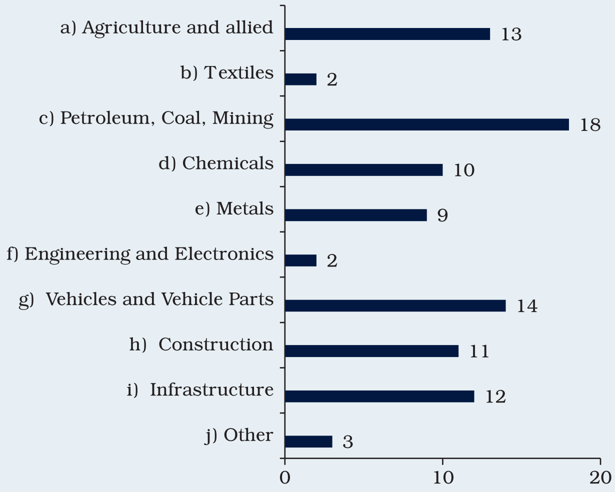
III.22 According to the respondents, energy and mining sector was identified as the most exposed to climate risk, followed by automobiles, agriculture, infrastructure, and construction. Sectors like textiles and engineering were not expected to have significant exposure (Chart III.7).

Interconnected exposures and risks

III.23 Sixty per cent of the institutions surveyed claimed to have incorporated climate risk in their risk management framework and 80 per cent respondents confirmed that their board has discussed climate related risks in the recent financial year. However, most of these institutions

Chart III.7: Sectoral Exposure to Climate Risk

What are the main economic sectors on which a significant impact is expected? Multiple options may be selected



Source: Authors' calculations based on survey responses.

are yet to develop specific mechanisms to identify and deal with such risks. Among those surveyed, 65 per cent responded that there is no existing division which specifically deals with climate related assessment. In the absence of an official taxonomy, only 45 per cent respondents had developed their own norms to explicitly classify counterparties into 'green' and 'brown' and a similar percentage of respondents considered climate sustainability while selecting projects for financing. The deficiency in the assessment of climate risks is also reflected in the lack of hedging against such risks. Only 40 per cent of those surveyed had mobilised new capital for scaling up green lending or have set any target for such lending. Forty-five per cent have introduced new financial products which can take advantage of the new opportunities arising out of green finance.

III.24 Some of the respondents confirmed having developed certain mechanisms to assess and hedge against risks pertaining to climate change. Two respondents said that they categorise climate risk under the ICAAP Pillar –II risk category. One of them further elaborated that it has allocated additional capital under Pillar-II category for loans made to high emission sectors.

Challenges

III.25 The lack of capacity and data seem to be the biggest impediments to assess climate risk and implementing policies to mitigate them. Almost 95 per cent of the respondents said that they lack appropriate data to robustly assess climate risks. Consequently, only 25 per cent of respondents use scenario analysis to assess climate change risks.

III.26 Regarding expectation of policy support, many respondents suggested implementing mandatory disclosures from borrowers under Scopes 1, 2, and 3 emission categories. Some respondents also asked for a national database on climate scenarios at a disaggregated geographic level to assess physical risks from climate events. Respondents also opined that a well-defined taxonomy will help in clearly assessing and preparing for transition risks.

5. Climate Stress Test for Indian Banks

III.27 While it is important to quantify the impact of climate change risks on financial system and its constituents, it is difficult to rely on traditional risk quantification techniques. This is because these methods rely on past data, but extant data may no longer be sufficiently representative of extreme climate events that may occur in the future. Climate stress tests are scenario-based exercises that assess the loss to the financial system/entities due to climate related risks by adapting the methodology of traditional stress tests to climate-related exigencies.

Chart III.8: Comparison of Climate and Non-Climate Stress Test Methodologies

	Traditional Stress Tests	Climate Stress Tests: Physical Risks	Climate Stress Tests: Transition Risks
Definition	Analyse financial risks under stressed economic and financial conditions	Analyse financial risks caused by materialisation of physical climate risks	Analyse financial risks caused by transition to a low carbon economy
Framework	Both top-down/bottom-up approaches coexist	Both top-down/bottom-up approaches coexist	Both top-down/bottom-up approaches coexist
Baseline *vs*. Adverse Scenarios	Baseline is usually "business-as-usual" (BAU) scenario	Short-term baseline is BAU scenario, long-term baseline is orderly transition scenario	Short-term baseline is BAU scenario, long-term baseline is orderly transition scenario
Horizon	Mostly 2-3 years, maximum 5 years	From 30 to 80 years	Overnight to 30 years
Risk Transmission Channels	Credit, market and liquidity risk	Underwriting risk and market risk	Credit and market risk

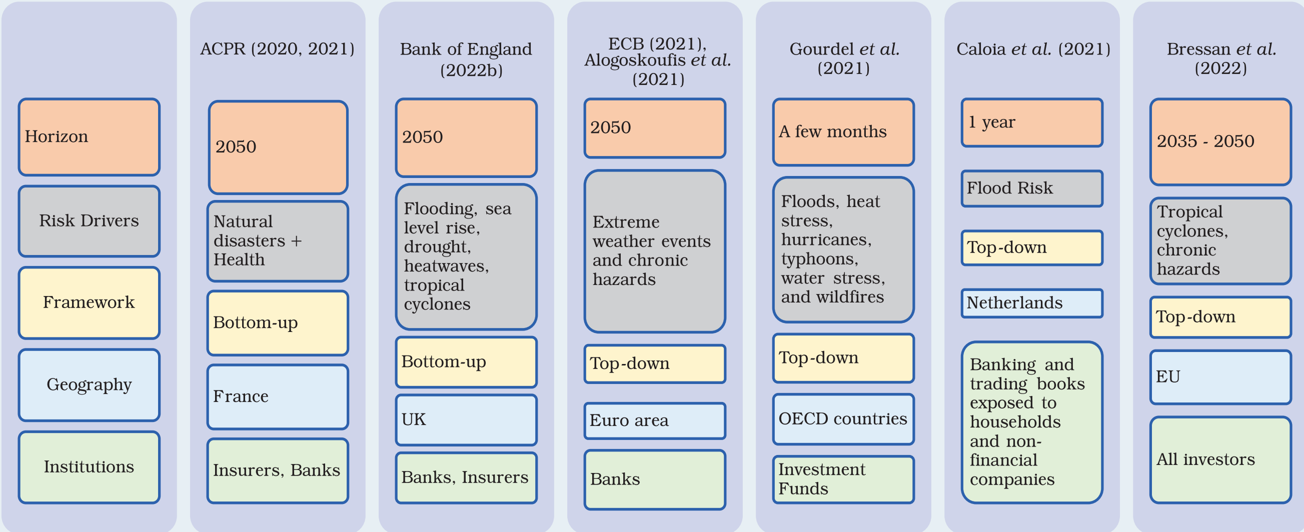
Source: Cartellier (2022) and edits by authors.

III.28 The key differences between climate and non-climate stress tests lie in scenario horizons, as the former are usually for longer periods (30 to 80 years) (Chart III.8).

III.29 Climate stress tests have been implemented by central banks and regulators for testing system-wide and entity-specific resilience to climate-related risks. A significant amount of recent academic research has also been devoted to developing climate stress testing methodologies. Exercises have been carried out by the French supervisor (ACPR) in conjunction with Banque de France (ACPR, 2020) and Bank of England (BOE) using a bottom-up framework with a direct participation of banks and insurance companies. Other top-down exercises have been undertaken by the European Central Bank (ECB) (Alogoskoufis *et al.*, 2021) among others. So far, these methodologies are applied to measure physical risks (Chart III.9) and transition risks (Chart III.10) and significant differences exist across them. Macro stress tests and banks' internal assessment of climate related risks have not resulted in additional capital requirements, so far.

III.30 Transition risk associated with climate change remains a major concern of most financial market stakeholders, all over the world. One approach to measure the risk involves estimating a climate risk factor based on 'stranded' assets portfolio returns (Jung *et al.*, 2021). The approach relies on the idea that a transition to a less carbon-intensive environment may result in underutilisation of existing fossil fuel reserves, which could be viewed as stranded assets. A lower return on a stranded asset portfolio as compared to market-wide benchmark indices, thus, could be indicative of a higher transition risk. A stranded assets portfolio similar to the one in Jung *et al.* (2021) is constructed for India, with 30 per cent weight to NIFTY Energy Index and 70 per cent weight to Coal India Limited. In other words, the returns on the stranded assets portfolio calculated below are used as a climate risk factor; it rises when fossil

Chart III.9: Studies on Climate Stress Tests for Physical Risks



Source: Cartellier (2022) and edits by authors.

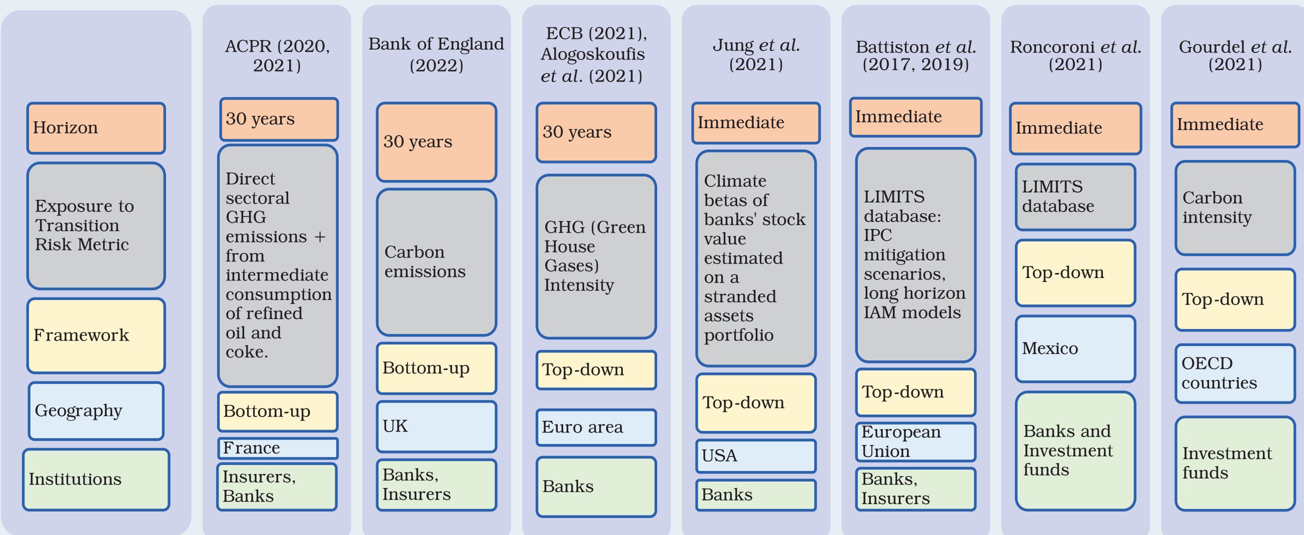
fuel stock prices rise relative to the market and *vice versa*.

$$\begin{aligned} Climate\ Risk\ Portfolio\ (CRP)\ Return \\ = 0.3 * NIFTY\ ENERGY\ Index\ Return \\ + 0.7 * COAL\ India\ Limited\ Return \\ - NIFTY\ Index\ Return \end{aligned}$$

III.31 The second step involves estimating time-varying climate betas of financial institutions by regressing financial institutions' stock returns (r_{it}) on the climate risk factor:

$$r_{it} = \beta_{it}^{Mkt} NIFTY_t + \beta_{it}^{Climate} CRP_t + \varepsilon_{it}$$

Chart III.10: Studies on Climate Stress Tests for Transition Risks



Source: Cartellier (2022) and edits by authors.

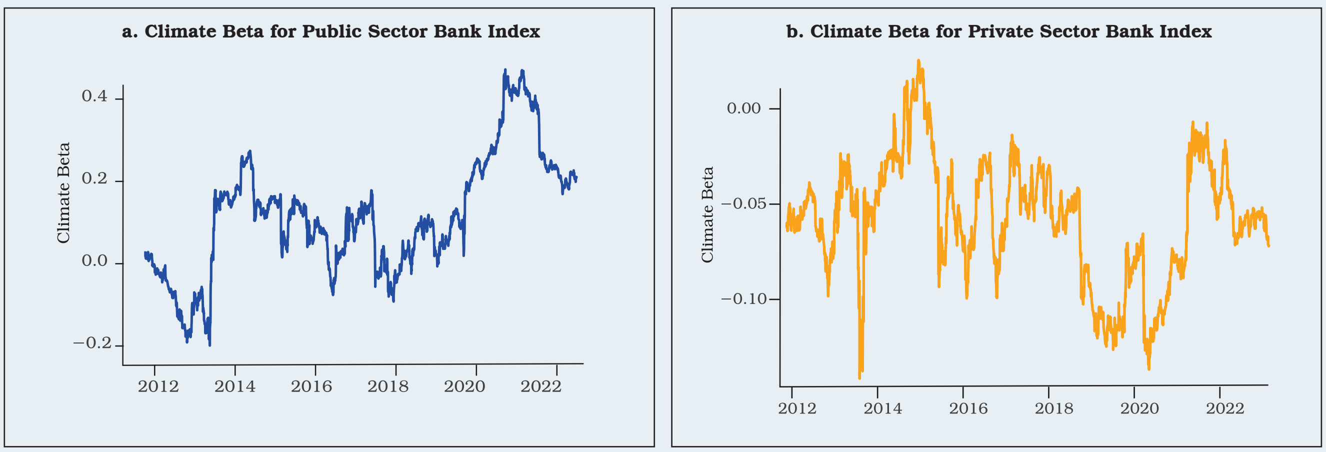
The climate betas for the Indian banking institutions were estimated on a daily frequency by running 252-day rolling regressions to capture the dynamic time-varying nature of the exposure. Daily climate betas were estimated separately for NIFTY Public Sector Banks Index and NIFTY Private Banks Index starting from November 2011 up to February 2023. Climate betas for public sector banks are mostly positive and have been rising consistently since 2018, with a slight moderation beginning 2022 (Chart III.11.a). Climate betas for private banks largely remained in the negative territory and were much lower than those for public sector banks (Chart III.11.b). This alludes to the greater sensitivity, and therefore higher risk of public sector banks to climate related risks as compared to private sector banks.

III.32 The third step involves estimation of expected capital shortfall on account of aggregate climate related stress using a CRISK framework following Jung *et. al.* (2021) which defines the bank's capital shortfall as the amount of capital reserves a bank needs to hold minus its equity as estimated by

$$CRISK_{it} = k\,(D_{it}) - (1-k)\,E_{it}\exp(\beta_{it}^{Climate}\log(1-\theta))$$

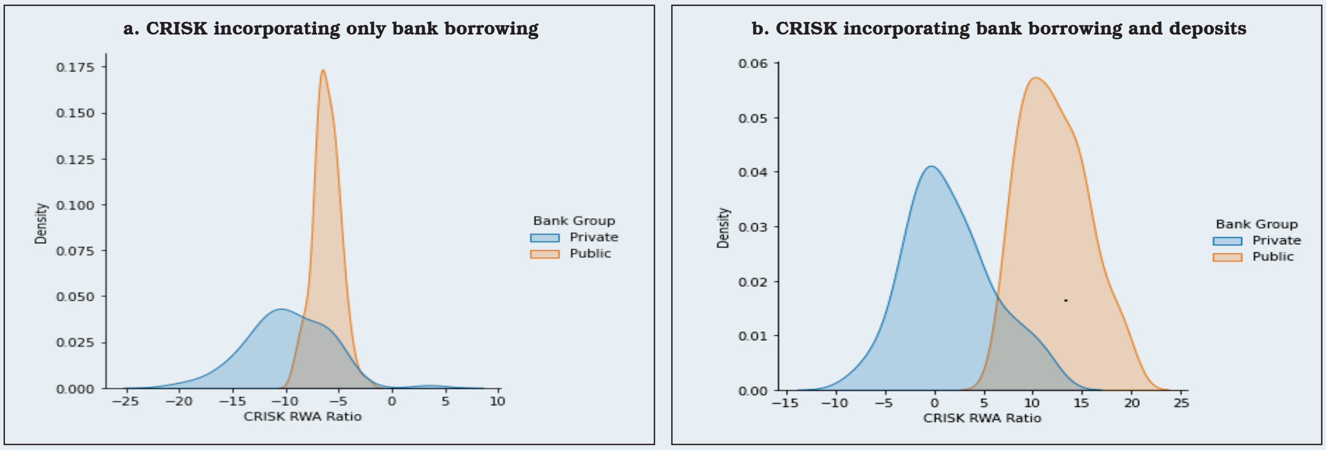
Where $CRISK_{it}$ represents the capital shortfall of bank *i* at time *t*, k represents the prudential ratio of equity to assets, D_{it} represents the book value of debt and E_{it} represents the market value of equity and θ is the climate stress level. In terms of the above equation, a negative capital shortfall (CRISK) represents no stress, while a positive CRISK represents stress in the bank's balance sheet, as it may not be able to meet its regulatory obligations. Several alternatives were evaluated for the above equation. For instance, when only borrowings of the bank were included in '*D*', there was no shortfall for any bank (Chart III.12.a). However, when total deposits and borrowings were used, many banks were found to face shortfalls (Chart III.12.b). Thus, when the repayment obligations of the bank cover only its borrowings, banks remain solvent and can meet regulatory capital requirements even in the face of sudden adverse climate shock. However, if the banks are obliged to repay their borrowings as well as deposits, larger capital shortfalls may be expected. In the second case, the amount of capital shortfall as well as their density is higher for PSBs than PVBs, highlighting greater risks faced by the former.

Chart III.11: Climate Beta



Sources: Bloomberg and authors' calculations.

Chart III.12: Climate Stress Test: PSBs *vis-à-vis* PVBs



Source: Authors' calculations.

III.33 The stress test results depend crucially on the assumptions relating to the severity of climate events and banks' short-term credit and deposit compositions and as such, are indicative in nature. Further, the CRISK framework projections are not baseline forecasts but shed light on low probability extreme climate events and serve as a useful tool for monitoring risks to financial stability.

6. Green Financing Requirement

III.34 Apart from the requirements of higher banking capital, a successful green transition plan would also entail a large new investment in an array of socio-economic infrastructures. A large number of estimates by various institutions suggest that the total financing requirements by India could be approximately 5 to 6 per cent of the annual GDP at the lower end[6] (Table III.1).

Table III.1: Projected Estimates of Green Finance Requirements

Organisation	Target	India
Climate Policy Initiative, 2022	Till 2030 for NDC	USD 170 billion per year till 2030
International Energy Agency, 2022	To reach net zero emissions by 2070 on average between now and 2030	USD 160 billion per year
Council on Energy, Environment, and Water-Center for Energy Finance, 2021	To achieve net-zero carbon emission by 2070	USD 202 billion per year
McCollum et al., 2018	Below 1.5 degree Celsius from 2016-2050	USD 288 billion per year
McKinsey, 2022	Net zero emissions by 2070	USD 44 billion per year increased by 3.5 times by 2030 and by 10 times by 2040

Note: Most of the reports mentioned above do not specify the methodology used in their estimation. Given the possibility of differences in their underlying assumptions, scenarios and coverage, estimates may not be strictly comparable across the board.
Source: Reports of respective organisations/ authors as specified in the reference list.

6 Based on World Bank, India's annual GDP for 2021 was USD 3.18 lakh crores.

The required investment amount would rise if the horizon to achieve the net zero target is shortened.

III.35 An innovative estimate of climate finance requirement is developed following Hughes *et al., 2010*. This framework estimates a gap between available infrastructure and what would have been achieved in the absence of climate change. Under this framework, regressions are estimated for more than 10 indicators separately using cross-country data since early 1960's. Details of the model and underlying assumptions for India are presented in Annex III.1.

III.36 The estimates suggest that, in India, the gap between current infrastructure and the level of infrastructure which could have been achieved in the absence of climate events would be about 5.2 per cent. This, in turn, suggests that an additional annual investment of about 2.5 per cent of GDP would be required to replenish this infrastructure gap by 2030. As these estimates do not explicitly take into account any investment required for mitigation and adaptation due to climate change, the actual funding requirements are likely to be higher.

7. Mitigation of Financial Risks

III.37 To mitigate climate change risks and their macro-financial consequences, it is necessary to have a financial system in place that can support sustainable initiatives and ringfence the financial sector from climate risks. The options for mitigation are plenty but each has its own pros and cons. The debate about best strategies remains complex, multi-layered, and not yet settled.

Ringfencing Financial Sector from Climate Risks under Basel Norms

III.38 Basel III, the third set of international banking regulations defined by BCBS operates under three pillars: 1) capital adequacy requirements; 2) supervisory review; and 3) market discipline (including rules on public disclosures). Which of these three pillars is most suitable to ensure that banks have adequate capital to manage climate risk and uses better risk management techniques in monitoring and managing these risks, is a subject of intense policy debate. Advocates of Pillar 1 suggest that it cannot be completely ignored as many of the Pillar 2 measures that are already available to supervisors are not being utilised optimally. Also, Pillar 3 measures on disclosures and reporting are necessary but insufficient to drive the policy and behavioural changes required (Climate Safe Lending Network, 2022).

III.39 On the other hand, the focus of supervisors world over, has increasingly shifted to Pillar 2 measures as the time horizon of climate-related financial risks is usually considered long, with a high degree of uncertainty. Standard Pillar 1 instruments of regulating minimum capital requirements might be suboptimal in addressing such risks as these measures are not developed for longer time periods. For climate-related financial risks, the historical loss data is not available, and a more forward-looking approach is required (FSB, 2022). As uncertainty increases with accumulated assumptions and longer time span, it is difficult to do capital planning for 20-30 years (EBF Staff, 2022). Moreover, as climate risks become evident, banks may change their lending strategies proactively. Requiring banks to set aside capital today to cover losses for risks that may only materialise long after the maturity of most of their current exposures may be inconsistent with the construction of the prudential framework in a scenario where the investment strategy changes substantially (FSB, 2022).

III.40 In contrast, the intrinsic flexibility of the supervisory review is a better fit for ensuring that banks effectively manage such risks and have sufficient loss-absorbing capacity. For instance, supervisors may require banks to submit a timeline to mitigate their exposures to climate risk and improve their risk management framework. In case of persistent and unjustified deviations, the findings may be factored into regular Pillar 2 assessments for capital. Additionally, improved Pillar 3 disclosures may aid in attaining the transparency required for market incentives to operate effectively (Coelho and Restoy, 2022).

Green Credit and Priority Sector Norms in India

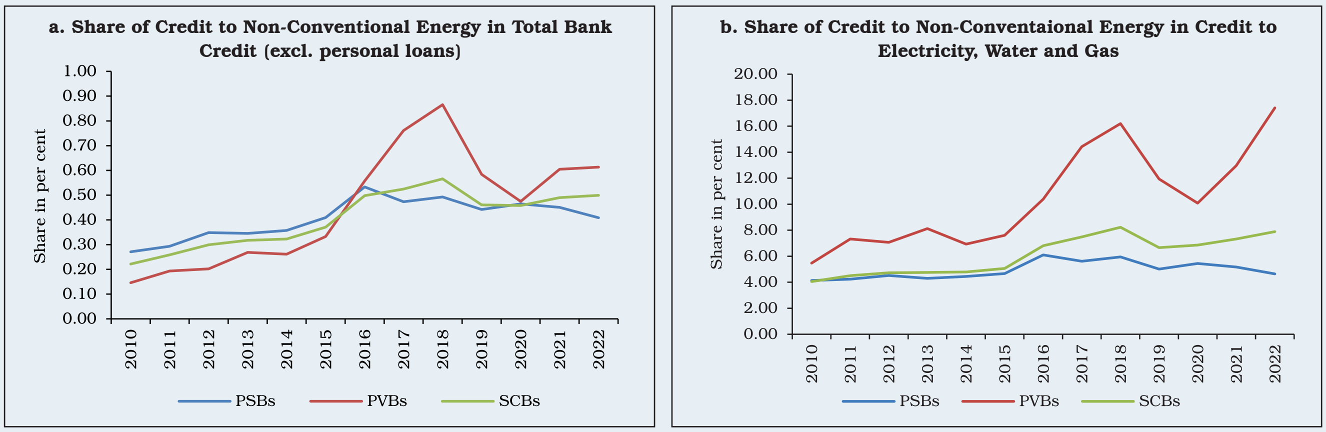
III.41 The early efforts of the Reserve Bank—for example its December 2007 notification—were directed at creating awareness and nudging the banks towards climate sensitive policies. In the recent decade, however, the Reserve Bank has initiated a more direct approach. The inclusion of renewable energy sector under priority sector lending (PSL) scheme in 2015 was one such direct measure. Under this scheme, firms in renewable energy sector are eligible for loans upto ₹ 30 crore (increased from ₹15 crore since September 4, 2020) while the households are eligible for loans upto ₹10 lakh for investing in renewable energy. A preliminary data analysis suggests that this approach was successful in channelising more resources to the renewable energy sector. As a result of the first policy intervention in 2015, share of non-conventional energy sector in credit, especially by PVBs, increased during 2015-2018. The subsequent decline in share was arrested by the second policy intervention in 2020 (Chart III.13.a and b).

III.42 There is a significant regional and bank-group wise variation in the deployment of credit to the non-conventional energy sector. Both PSBs and PVBs extended higher than national average credit to the sector in Goa, Telangana, Tamil Nadu and Gujarat. On the other hand, states like Kerala, Haryana, Chhattisgarh and West Bengal received lower than national average credit to the sector, by both PSBs and PVBs (Chart III.14).

Green Taxonomy and Disclosures

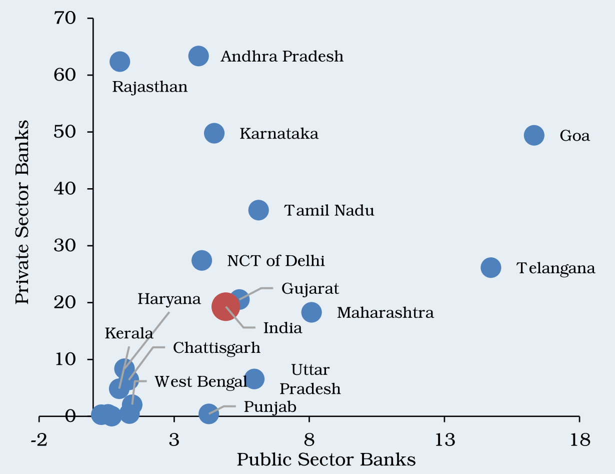
III.43 Reliable and standardised information dissemination and disclosure is the backbone of efficient financial intermediation. A uniformly

Chart III.13: Bank Credit to Non-Conventional Energy Sector
(at end-March)



Source: Basic Statistical Return-I, RBI.

Chart III.14: Spatial Distribution of Bank Credit to Non-Conventional Energy

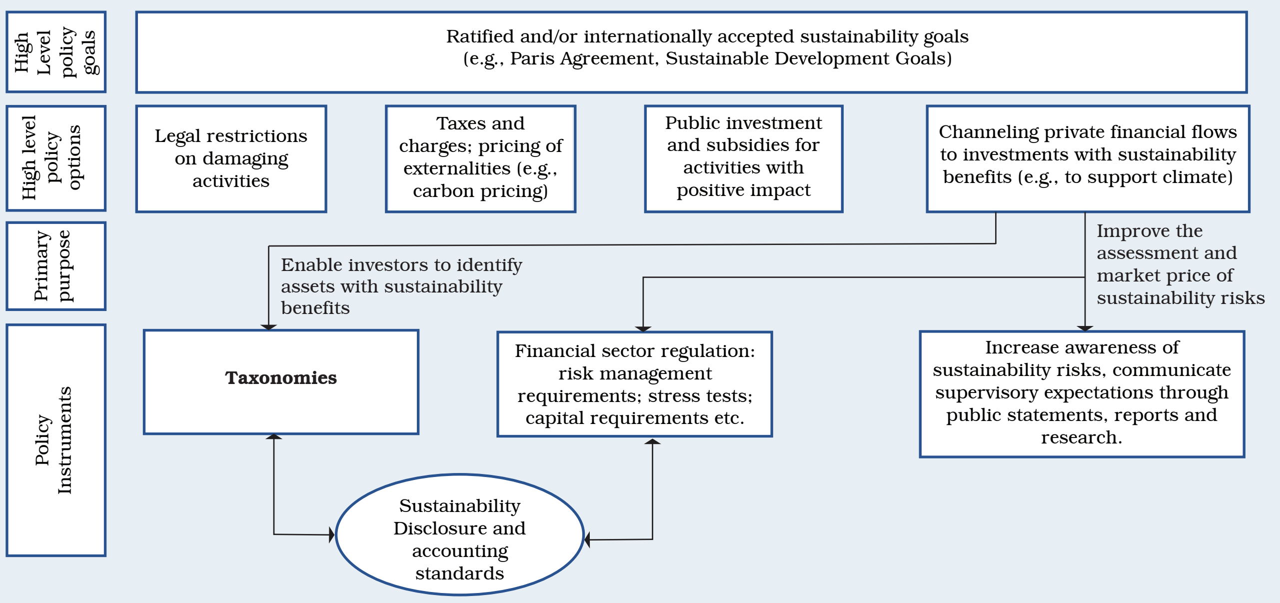


Note: Bank credit to non-conventional energy as a per cent of total power sector credit at end-March 2022.
Source: Basic Statistical Return, RBI.

accepted 'green taxonomy', therefore, plays a major role in the identification, standardisation, disclosure and awareness regarding climate change (Chart III.15). While available definitions include general statements, market-led standards, and broad criteria for policy, regulatory, or statistical purposes, a globally accepted single definition for green or sustainable finance is largely missing.

III.44 As a principle, any financial instrument whose proceeds are used for environmentally sustainable projects, initiatives, and policies under the single goal of promoting a green economic transformation could be referred to as green finance. A good taxonomy provides a strong signal to investors and other stakeholders and assists in their decision-making by identifying the non-financial benefits of a given asset. Taxonomies can be classified depending on four key characteristics: a) objective: which sustainability goals are supported? b) scope: which activities/ industries/entities are included? c) target: how is the purpose translated into a measurable target? d) output: what type of information is provided? (Ehler *et al*., 2021). While countries like China, Russia, Japan, South Africa, Sri Lanka, Indonesia and Bangladesh already have their taxonomies

Chart III.15: Taxonomy as a policy instrument to achieve high-level sustainability goals



Source: Ehler *et. al* (2021).

approved or in use, most of the countries are still developing their taxonomies (IPSF, 2022).

III.45 India is yet to publish a formal taxonomy, although SEBI and the Central Government have issued some guidelines which are covered in detail in Chapter IV of the Report. ESG stock indices, which were adopted across the globe as part of the Sustainable Stock Exchange initiative, are effective instruments for quantification of exposure and management of sustainability risks. Available cross-country data suggest that companies which adopted ESG related disclosures reported excess market adjusted stock returns during the pandemic period for many countries (Ghosh and Nath *et al.*, 2023). A similar trend was observed in the case of India as well during the COVID-19 period (Box III.4). The findings may also hint that companies that reported to have undertaken ESG initiatives are possibly among the financially stronger companies, that weathered the pandemic crisis better than other players.

Blended Finance

III.46 The term 'blended finance' refers to the strategic use of public and philanthropic resources to mobilise private capital for development purposes. In addition to facilitating the flow of new capital into high-impact sectors, blended finance can be used to effectively leverage the expertise of the private sector in identifying and executing developmental investment opportunities and strategies. Typically, grant funding is blended with other sources of capital such as debt or equity to maximise funding and social impact capacity.

III.47 Blended finance initiatives are usually oriented towards developing economies through different forms of intervention. These include, *inter alia*, concessional debt or equity, guarantees for credit enhancement to particular initiatives, and technical assistance funds (TAFs). A report that captured around 600 blended finance transactions till 2020, representing an aggregate financing of

Box III.4

Performance of ESG Indices *vis-à-vis* Broad Market Indices

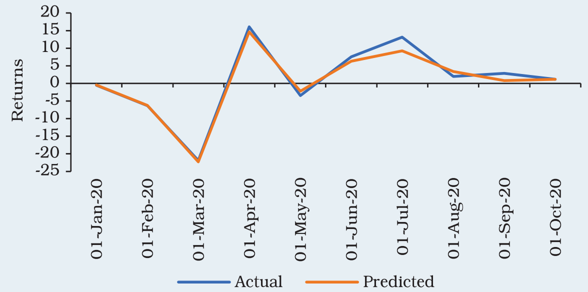
ESG Leaders' index, published by Morgar Stanley Capital International (MSCI), consists of market capitalisation weighted stock prices of corporates that make greater environment, social and governance related disclosures as compared to their peers.

Using a methodology suggested by MacKinlay (1997), the monthly returns in MSCI ESG leaders' price index (ESG_t) is regressed on MSCI broad market index ($Broad_t$) between September 2010 and December 2019. The estimation equation is as follows:

$$\Delta \log(ESG_t) = \alpha + \beta_1 \Delta \log(Broad_t) + u_t$$

Where u_t represents the error term of the regression. The estimated coefficient β_1 captures the sensitivity of ESG returns to the broad market movements. The difference between actual and estimated returns on ESG Leader's index is an indicator of their excess returns. Out-of-sample estimates for India suggest that average excess returns were positive during the COVID-shock (Ghosh and Nath, 2023) (Chart 1).

Chart 1: Estimated and Actual Returns on ESG Leaders' Index for India (COVID Period)



Source: Authors' calculations based on MSCI.

Reference

Ghosh, S., and S. Nath (2023). ESG Disclosures and Performances: Cross-Country Evidence. *Reserve Bank of India Bulletin*, February.

MacKinlay, A. C. (1997). Event Studies in Economics and Finance. *Journal of Economic Literature*, 35(1), 13–39.

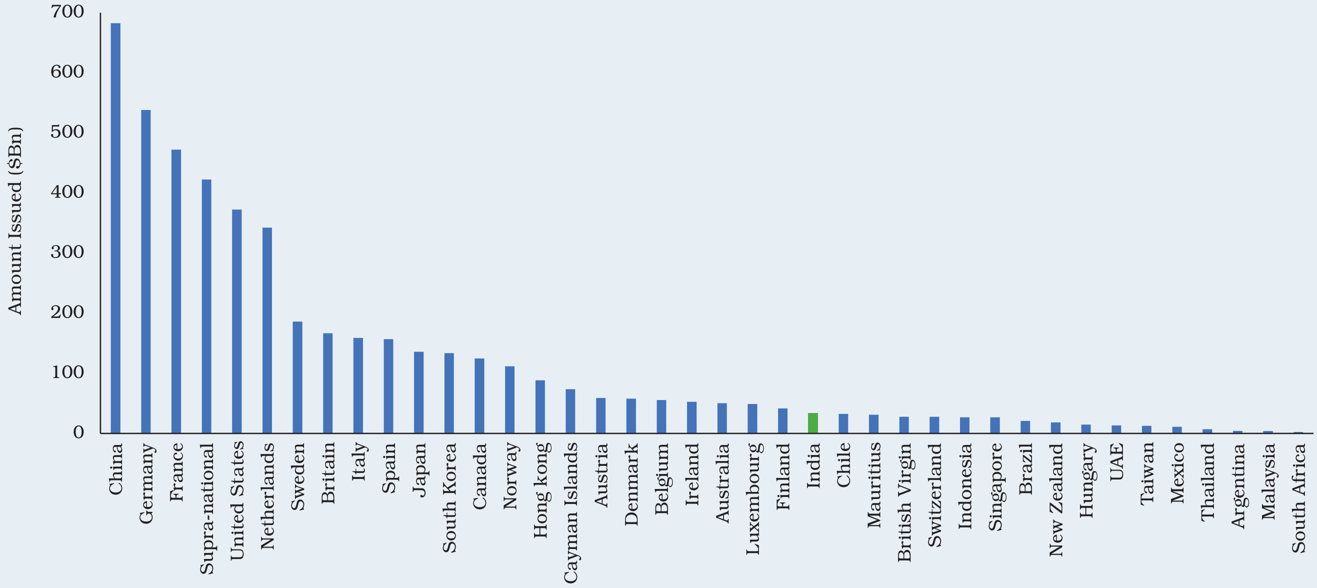
nearly USD 144 billion, found that funds such as TAFs have consistently accounted for the largest share of blended finance transactions, while there was a notable uptick in the prevalence of bonds from 2017-2019 (Convergence, 2020). Further, there has been a decrease in the concurrent use of multiple blending approaches indicating less complexity as structures become streamlined. Sub-Saharan Africa remains the most targeted region for blended finance with a gradual shift towards Asia.

III.48 Due to the potentially higher impact of climate change and lesser per-capita consumption of energy in Sub-Saharan Africa and South Asia, investment in renewable energy through blended finance has a greater opportunity in these regions. Within these, India represents 80 per cent of total renewable energy investment potential, followed by Kenya and South Africa (Tonkonogy *et al.*, 2018). There have been several successful examples of blended finance being used in India to enable additional investment in social and developmental sectors. The recently launched healthcare blended finance facility, for instance, was supported by USAID and addressed the COVID-19 pandemic response in India (Chakraborty and Rao, 2022). The case study of a climate-smart agriculture project, the Integrated Fish Farming in Odisha, however, demonstrated that actors have some reservations regarding blended finance implementation. While local banks were hesitant to embrace blended finance due to procedural restrictions, the implementing agency found the incentive structure unappealing and overloaded due to frequent monitoring (Dey and Mishra, 2022).

Green Bonds

III.49 Green bonds are instruments that can help finance long-term investments into projects which can mitigate climate change. China has the highest amount of green bond issuances till date (since 2007) (Chart III.16).

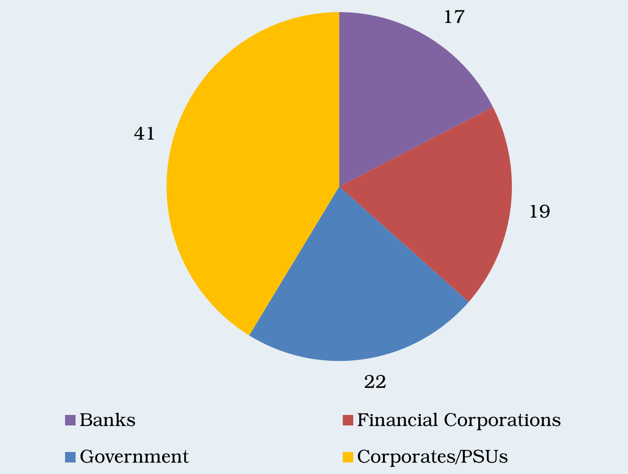
Chart III.16: Corporate and Government Green Bonds by Country



Notes: 1. Government green bonds do not include municipal green bonds.
2. A Supra-national organisation relates to more than one country.
Source: Bloomberg data as on April 28, 2023.

III.50 As on April 28, 2023, 63 green bonds were issued in India. Issuer-wise break up shows that corporates and PSUs have issued the highest number of these bonds (Chart III.17). (A detailed discussion on green bonds is covered in Chapter IV).

Chart III.17: Issuer-wise Breakup of Green Bonds Issued in India (Per cent)



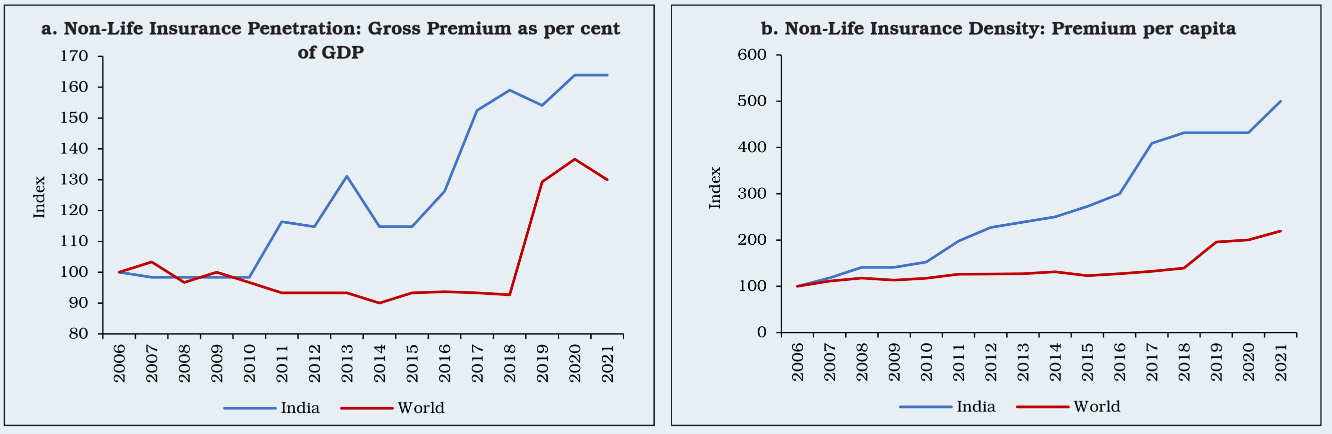
Note: Government green bonds include municipal green bonds.
Source: Bloomberg data as on April 28, 2023.

Non-Life Insurance

III.51 Insurance can help households and firms hedge against climate risks and consequently, can reduce risks for banks which are lenders to such households and firms. However, non-life insurance penetration remains low in India with total premium being just around 1 per cent of GDP in 2021 while the global average was about 4 per cent. Non-life insurance density measured as per-capita insurance premium was just USD 22 in India in 2021 while global average was USD 492 (IRDA, 2021). IMF ranked India at 131st place in a list of 168 countries in terms of non-life insurance coverage. On the positive side, both insurance penetration and insurance density have been rising fast in India and their growth trajectories have been much higher than global growth rate for the past 15 years (Chart III.18.a and b).

III.52 One of the challenges to increasing insurance penetration, especially as a climate risk management tool, may be the low claim-settlement ratio in case of climate catastrophes. The ratio for climate events in 2019-20 and 2020-21 was 28 per cent and 29 per cent, respectively. Even though IRDA has issued guidelines to ensure that claims related to natural disasters are attended promptly,

Chart III.18: Non-life Insurance in India *vis-à-vis* World



Note: The charts show growth trajectories of insurance premium and insurance density. The values are indexed at 100 at the starting year (2006).
Source: IRDA.

many claims remained unresolved several months after the incidents (IRDA, 2021 and 2022). This can potentially discourage households and businesses from buying insurance protection against climate risks.

Insurance underwriting risk

III.53 In the case of large and concentrated insured losses, insurance companies face the risk of insolvency. More frequent and severe weather events have resulted, and could continue to result, in underwriting risks: that is, higher-than-expected claims against insurance for physical risks. Claims faced by non-life insurers with respect to certain weather-related catastrophes have increased in recent decades. While part of this increase may be due to increases in exposure (*i.e.* increasing value of property insured in areas prone to physical risks), it may also be due to increase in severity of weather events. In the USA, destruction caused by hurricane Andrew resulted in some insurance companies going insolvent in 1992 (McChristian, 2012). Failure and distress in the insurance sector can potentially destabilise the financial system.

III.54 One of the ways to mitigate underwriting risks is diversification. Insurance companies which operate over varied geographical locations will have lower exposure to any particular severe weather event as each such event will affect only a small portion of its counterparties. With global cooperation, an innovative financial risk transfer solution called Index Based Flood Insurance (IBFI) has been developed, particularly suitable for states with many small holding farming communities, against flood losses. Re-insurance is another tool which can help diversify risk by allowing insurance companies to share some of the physical risks with financial institutions that are not directly exposed to them.

Commodity Futures

III.55 Environmental futures are the latest innovation in the financial market for commodities. Beginning 1995, a programme in the United States established tradable allowances for the emission of sulphur dioxide. Efforts are on to develop comparable tradable permits for other air pollutants, particularly carbon dioxide, in several other countries. In order to establish a carbon market, a nation must first set an upper limit on its emissions and then distribute an equivalent number of tradable permits or credits to emitters. A corporation has the option to increase its emissions by purchasing additional credits at the market rate, but it will also weigh the potential financial benefits of limiting or even reducing its emissions. The International Petroleum Exchange started trading futures on the price of carbon-dioxide emission rights in April 2005, following the European Union's imposition of limitations on companies' emissions of carbon dioxide and emission of greenhouse gases by others. The success of the policy can be gauged by the fact that within three months, it was conducting daily trades on more than 500 contracts (Levinson, 2005).

III.56 The Government of India has initiated actions to create a market for carbon credits which will help India achieve its NDC goals. Between 2010 and June 2022, India issued 35.94 million carbon credits (Yarlagadda, 2022). For details, please refer to Chapters II and IV.

Greening of Central Bank Balance Sheet

III.57 Sovereign debt issued by reserve currency countries generally forms part of a central bank's forex reserves. Given the differences in carbon footprints across countries, the 'greenness' of sovereign bonds issued by them varies drastically. The composition of sovereign debt held by a central bank in its reserve portfolio determines the carbon intensity of such portfolio. If countries with higher carbon footprints have more weightage in the portfolio, it leads to higher carbon intensity of the reserves. In some central banks, the asset portfolio may also consist of corporate bonds and other private securities. Greening of central bank balance sheet involves re-adjustment of these portfolios to increase the weightage of green bonds.

III.58 So far, the international experience in greening of central bank balance sheets is limited. BoE is the first central bank to issue climate related financial disclosures annually since 2020. The report consists of a review of carbon emission intensity of the BoE's assets. As part of the quantitative easing strategy during COVID-19, the BoE had bought over GBP 20 billion worth of corporate bonds (Milliken, 2022). The BoE declared in 2021 that it will try to reduce the carbon intensity of its corporate bond portfolio and their latest financial disclosure shows that the weighted average carbon intensity of the portfolio has declined by 18 per cent from 2020 (Bank of England, 2022a). The ECB had also undertaken quantitative easing during COVID-19 in which it bought corporate bonds. An assessment by the ECB in 2020 found that 8.4 per cent of its asset portfolio consisted of debt instruments of fossil fuel related companies, while only 1 per cent was ESG securities (Oil Change International, 2021). The ECB has since undertaken policy measures to green its balance sheet. In 2021, it announced that certain ESG bonds will be accepted by the ECB as collateral. The Swiss National Bank and Banque de France have also announced that they will not have corporate bonds of companies which use coal in their portfolios (Oil Change International).

III.59 In case of India, as the Reserve Bank does not hold corporate bonds in its portfolio, the above measures are not applicable. If the Reserve Bank keeps some of the recently issued sovereign green bonds in its portfolio, it may serve the objective of greening the balance sheet. However, greater greening of the central bank balance sheet will require development of a functional secondary market, so that green bonds, like other government securities, can be bought or sold in the secondary market.

8. Concluding Observations

III.60 Central banks and the financial sector regulators have increasingly recognised the rising risks to financial stability from climate change and have been exploring ways to support the net zero transition goals while preserving financial stability. Financial markets have already become aware and are driving capital reallocation to facilitate adaptation, risk pricing and mitigation. The non-linear and multidimensional assignment problem involving all key stakeholders has no easy solution. The success of any financial sector risk mitigation strategy will also depend on dynamic recalibration of policies, growth in the pro-green investors and their appetite for green financial investment.

III.61 An assessment based on energy intensity of borrowing sectors to gauge transition risks of Indian banks suggests that risks may emanate from banks' exposures to basic metals, and generation and distribution of energy. Hearteningly, in the recent years, bank credit to green industries has accelerated at a pace faster than that to other industries. This may be a sign of rising climate risk awareness driving credit allocation pattern in the economy.

III.62 Estimates suggest that annual green financing requirement could be about 2.5 per cent of GDP to address the infrastructure gap caused by climate events, which could increase if faster carbon emission reducing goal has to be pursued than what is committed under the NDC.

III.63 A stylised partial equilibrium model based on the interrelationship between banks and NBFCs suggests that any large-scale default by NBFCs arising on account of physical or transition risk may spill over and adversely affect the overall macro-financial stability.

III.64 To ascertain the transmission channels of climate shocks to the financial sector, a DSGE model calibrated for Indian parameters is employed. The simulation results highlight that climate events could lead to destruction of capital stock, impacting consumption and output. The adverse impact on inflation could also harden interest rates, amplifying the initial impact on capital stock. Loss of collateral value and higher pressure on market and funding liquidity in the banking sector can potentially become a source of financial vulnerability.

III.65 A climate stress test conducted for India suggests that PSBs are more prone to climate risks than their private sector counterparts and may face capital shortfalls in case of extreme adverse climate shocks, particularly in the rarest event of banks being necessitated to repay their borrowings and deposit liabilities simultaneously.

III.66 The proper functioning of a regulatory framework requires a robust statistical infrastructure to evaluate climate risks. India currently uses platforms such as PAT (perform, achieve, trade) and RPO (renewable purchase obligations) for tracking GHG emissions. The implementation of national MRV (measurement, reporting, and verification) to track both domestic and international climate finance is under consideration. In this vein, there is a need for a unified statistical framework, including a consistent and comparable taxonomy, regular disclosures, and monitoring. Though an expert committee has been set up, India is yet to publish its taxonomy, which would require a significant amount of work relating to standardisation and interoperability. An internationally harmonised taxonomy will be essential for the development of the green bond market and other mitigation tools.

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Annex III.1: Methodology and Underlying Assumptions for Measurement of Green Finance Requirements

Hughes *et al.* (2010) estimate the following model to estimate infrastructure funding gap due to climate shock:

$$log(infra_{it}) = f(Per\ capita\ GDP_{it}, Urbanisation_{it}, Temperature_{it}, Precipitation(mean)_{it}, precipitation(range)_{it}, \varphi_{it})$$

Using annual cross-country data for more than 100 countries, the above relationship is estimated for 10 infrastructure related indicators, *viz.*, electricity generating capacity, number of fixed telephone lines, road length, aircraft movement, container movement, municipal water use per person, industrial water use per person, number of hospital beds, number of teachers in schools and number of post offices. The subscripts i and t represent country and year, respectively. The explanatory variables related to temperature and precipitation measure the extent of climate change, per capita GDP indicates the impact of climate change on aggregate demand and urbanisation measures the demand for infrastructure. φ includes controls which are unrelated to climate change, such as country size and landscape pattern.

While the estimated regression coefficients for the explanatory variables in the above model represent the average global relationship, the models are calibrated for India using the following climate change scenarios applicable to India (Table 1).

Table 1: Assumptions on Indian Scenario of Climate Change

Variable	Impact of Climate Change (Per cent)
Per Capita GDP loss due to climate change#	-2.0
Temperature (Mean)-Population weighted	2.0
Temperature (Mean)-Inverse Population weighted	0.4
Precipitation (Mean)	-2.0
Precipitation (Range)	5.0
Urbanisation*	1.5

Note: Estimates for temperature and precipitation indicate deviation of the observed values between 2011-12 and 2019-20 from the long-term averages between 1950 and 2020.

Sources: #: Authors' assumptions. *: World Bank. Indicates annual growth rate in urban population to total population ratio. Other indicators are based on data from India Meteorological Department (IMD).

IV POLICY OPTIONS TO MITIGATE CLIMATE RISKS*

The enormous scale of the green transition challenge and the colossal cost of delayed policy actions warrant a comprehensive decarbonisation strategy, encompassing all carbon emitting sectors of the economy and all available policy levers – fiscal, technology, regulatory, trade and monetary. The policy mix needs to strike the right balance between a carbon tax, technology support for non-fossil fuel, green hydrogen, carbon capture and storage, standards for energy efficiency, regulatory tweaks incentivising flow of adequate resources for green projects and adoption of energy saving appliances at home and in business establishments. Estimates suggest that compared with a no policy action scenario that could increase India's carbon emissions to 3.9 gigatonnes by 2030 (from 2.7 gigatonnes in 2021), a balanced policy intervention can lower carbon emissions to 0.9 gigatonne by 2030.

1. Introduction

IV.1 A successful transition to a net zero economy would require a strategy of "deep decarbonisation" encompassing all carbon emitting sectors, ranging from power generation and transportation to industrial production processes, construction activity, agriculture, and above all, nudging the citizens to change their lifestyle habits and consumption preferences. India's emphasis on the Mission LiFE (Lifestyle for Environment) aims at making individuals adopt sustainable lifestyles to minimise carbon footprints. Even as firms and households have progressively been adopting greener business practices and lifestyle changes, the enormous scale of the transition challenge and the colossal cost of delayed actions warrant comprehensive policy interventions using all feasible options as an integral part of the country's decarbonisation strategy. India already has a long-term low-carbon development strategy in place (MoEFCC, 2022), which sets out clearly the country's envisaged multi-pronged climate action plans. International experience and emerging risk mitigating policy options, however, suggest that the strategy may have to be dynamic to be effective, and there must be an unwavering commitment displayed through timely actions to achieve the net zero target.

IV.2 An effective strategy would first need to recognise the dimension of the challenge. Of the current annual carbon emissions in India, about 40 per cent could be addressed by replacing fossil fuels with renewables, another 15 per cent by switching over to electric vehicles (EVs) and energy efficient electrical appliances in residences and business establishments. The remaining 45 per cent, however, relate to hard-to-abate sectors, *viz.*, heavy industries, animal husbandry and agriculture (Mony, 2022). They are hard to abate because either technology to support the green transition is not available or the cost is prohibitive. A business-as-usual scenario can only increase the annual absolute size of carbon emissions by about 2.6 times between 2020 and 2050 (Paltsev *et al.*, 2022). While use of more renewables and energy efficient practices can reduce emissions from the hard-to-abate sectors by 15-20 per cent by 2050, appropriate carbon pricing would be critical

* This chapter has been prepared by a team comprising Sitikantha Pattanaik, Dhirendra Gajbhiye, Abhilasha, Monika Sethi, Silu Muduli, Shobhit Goel, Saksham Sood, Soumya Suvra Bhadury, Rajas Saroy, Satyam Kumar, Prashant Kumar and Rashika Arora.

to reducing carbon emissions by 80 per cent by 2050. The Energy Conservation (Amendment) Act, 2022 recognises the importance of carbon pricing and aims at development of a carbon market or an emissions trading system (ETS), where the focus will be on reduction of carbon emissions rather than the current emphasis on energy efficiency under the Perform, Achieve and Trade (PAT) scheme. In the context of the forthcoming Carbon Border Adjustment Mechanism (CBAM) of the European Union (EU), an early attention to carbon tax/ETS in India has become necessary.

IV.3 The second key dimension of the challenge is the scale of resources required for mitigation, adaptation and disaster management. Financial resources have two key components – cost and availability – but much of the current policy focus has been on keeping the cost low through greenium. The real challenge for India will be in arranging new investment, estimated to be in the range of US$ 7.2 trillion (baseline scenario) to US$ 12.1 trillion (accelerated scenario) till 2050 (Ghosh, 2023). One of the related challenges in financial planning would be managing the costs of decarbonisation – as several carbon emitting industries, buildings and firms would have already made large fixed investments, while also deploying considerable labour force, which may have to be re-trained to facilitate re-deployment in greener ventures.

IV.4 The third dimension relates to access to technology and mineral resources at an affordable cost. Increasing dependence on new technologies used in batteries; solar panels and wind turbines; green hydrogen; carbon capture, utilisation and storage (CCUS); and e-waste management would require higher expenditure on research and development (R&D) and strategic collaboration. Currently, there is a high degree of concentration in the solar supply chain – polysilicon, silicon wafer, photovoltaic (PV) cells and PV modules – and access to strategic minerals such as lithium, rare earths, copper, zinc, chromium and graphite. Therefore, the goal of enhancing and securing the capacity for a successful green transition may have to contend with known and unknown impediments. Increasing geo-economic fragmentation of the world economy is amplifying uncertainty about access to technology, industrial raw materials and final products for individual countries, with a few major economies cornering disproportionately large shares of available global supplies.

IV.5 Each sector of the economy faces formidable challenges that could potentially slow down the pace of green transition. Globally, rice farming, cattle rearing and biomass burning are estimated to account for more than a fifth of total methane emissions. While India has a National Mission for Sustainable Agriculture (NMSA) to promote climate-smart agriculture and climate-smart villages aimed at avoiding excessive use of water and electricity, adopting climate resilient cropping practices, and reducing carbon emissions; wider adoption on a sustained basis would be required going ahead. In the power sector, despite laudable progress in generating renewable energy, the country's dependence on fossil fuels remains large, and the financial stress facing electricity distribution companies, though easing in recent years, continues. In the transportation sector, the state road transport companies have limited financial capacity to phase out old vehicles, and the cost of EVs needs to fall much more to enhance their attractiveness to the common man. While solar and wind energy generation costs are reducing, their uneven supply cycles pose a major challenge given the costs of storage technology. In the construction sector, despite known climate-smart building techniques and guidelines, most construction projects prefer extant low-cost techniques, in view of the large shortages of housing in urban areas and the rising cost of construction in the country. Despite sustained efforts of the Bureau of Energy Efficiency (BEE) and rising enforcement of efficiency norms, energy conservation practices are not widely adopted in businesses. The limited financial capacity of several municipal corporations has been a constraint for sewage and waste treatment in cities in sync with the national green transition plans. Therefore, a multi-pronged policy approach is necessary that recognises the trade-offs of each policy intervention and uses a mix of incentives and enforcement for optimal results that accelerate green transition.

IV.6 Set against this context, this chapter explores the policy choices available to India today for transitioning to a greener and cleaner India over the coming decades. The broad available policy levers include fiscal policy, technology-enabled solutions, regulatory measures, trade policy, and monetary policy, besides energy conservation norms for wider voluntary adoption by the households and more effective interventions by firms under corporate social responsibility recognising the rising preference of investors, shareholders and other key stakeholders in every business for pro-planet realignment of business strategies. Governments, the world over, have been leading the fight against climate change risks by setting national climate action plans, coordinating across borders with key stakeholders, identifying national-level challenges to sustainable development and nudging individuals and firms to embrace climate-friendly lifestyles and business practices. Section 2 discusses fiscal policy initiatives and options, such as the current tax-subsidy mix and budgetary allocations, carbon taxes, ETS, and sovereign green bonds. Section 3 explores evolving innovations and technology-based solutions across various sectors that are essential for securing desirable progress towards a greener and cleaner India. Section 4 examines the scope in trade policy for accelerating the pace of green transition. Section 5 reviews and proposes a gamut of regulatory measures to support the green transition, while Section 6 delves into market-based solutions. Section 7 discusses the complementary role that monetary policy could play in supporting green transition. Section 8 examines ways to nudge consumers/businesses to contribute to green transition embracing the virtue that "green begins at home/self" and as part of people's clean India movement (*Swachh Bharat Abhiyan*). Section 9 presents a scenario analysis to highlight the critical role of policy interventions in reducing carbon emissions compared with a business-as-usual scenario and recommends the need for concerted actions covering all spheres of policy making. The concluding section sets out specific policy recommendations, encompassing those that are already part of the animated debate at various stages of implementation, or are new and need greater attention.

2. Fiscal Policy Initiatives

IV.7 For a policy-induced structural shift in the economy to achieve the net zero target, large scale reallocation of resources would be required from carbon-intensive to green industries/sectors, besides sizeable additional investment within a pre-set time frame. Fiscal policy, therefore, must play a prominent role, backed by an actionable and time-bound policy framework. Green fiscal policy encompasses the use of fiscal instruments such as taxes, subsidies, grants, and expenditures to help align the fiscal policy with climate and other environmental goals (Petrie, 2021).

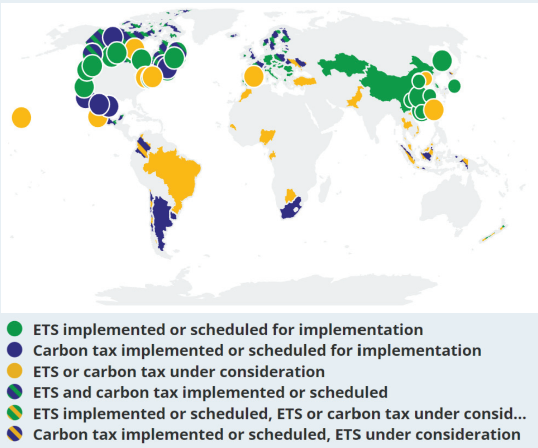
IV.8 The rationale for fiscal intervention is premised on the conflicting interface between public finances and the green transition goal. On the one hand, governments across the world subsidise fossil fuels – US$ 1 trillion in 2022 alone (IEA, 2023a) – on the other hand, they also spend large budgetary resources on protecting the environment, such as expenses on environmental R&D, incentivising adoption of greener technology, management of flora and fauna to protect natural habitats, and building disaster resilient infrastructure. Besides pro-active measures to mitigate climate change risks under a well-designed strategy, adapting to climate change would also entail large fiscal costs. Due to the potential effects of climate change on long-term economic growth, it has emerged as an important risk to public finance sustainability (Baur *et al*., 2021).

IV.9 The Union Budget 2023-24 has identified 'Green Growth' as one of its seven priorities, which will guide the economy through the *Amrit Kaal*. Accordingly, the Government announced several measures to facilitate the transition of the economy to lower carbon intensity and reduced dependence on fossil fuels, such as building infrastructure to evacuate renewable energy from Ladakh and allocation for Green Hydrogen Mission, which targets annual production of 5 million metric tonnes (MMT) by 2030. Additionally, the Budget has also introduced new schemes such as *GOBARdhan* (Galvanizing Organic Bio-Agro Resources Dhan) scheme to set up 500 new 'waste to wealth' plants; PM PRANAM (Programme for Restoration, Awareness, Nourishment and Amelioration of Mother Earth) to incentivise States and Union Territories (UTs) to promote alternative fertilisers and balanced use of chemical fertilisers, MISHTI (Mangrove Initiative for Shoreline Habitats & Tangible Incomes) scheme for mangrove plantation along the coastline and on salt pan lands through convergence between funds under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and the Compensatory Afforestation Fund Management and Planning Authority (CAMPA); and the *Amrit Dharohar* scheme to encourage optimal use of wetlands, and enhance biodiversity, carbon stock, eco-tourism opportunities and income generation for local communities.

IV.10 Climate change adaptation generally requires an increase in government spending to minimise the damage from climate-related disasters (Dabla-Norris *et al*., 2021). Climate change mitigation can be pursued through carbon pricing, as it helps generate revenues which can be invested in green projects and/or used in providing incentives to the private sector for reducing emissions, including through innovation in green technologies (Ferdinandusse *et al.*, 2022).

IV.11 As of April 2022, 70 carbon pricing initiatives, covering 23.2 per cent of global greenhouse gas (GHG) emissions, have been put in place (Chart IV.1). Its potential, however, is still untapped as most carbon prices are below the levels needed to deliver significant decarbonisation (World Bank, 2022a). The EU has the largest and most vibrant ETS – the EU ETS – where prices have moved close to €100 per tonne of carbon dioxide (CO_2) (Financial Times, 2023). This is higher than in several other countries but still lower than €120 per tonne of CO_2 that would be required by 2030 to decarbonise by 2050 (Ferdinandusse *et al.*, 2022).

Chart IV.1: Summary Map of Carbon Pricing Initiatives



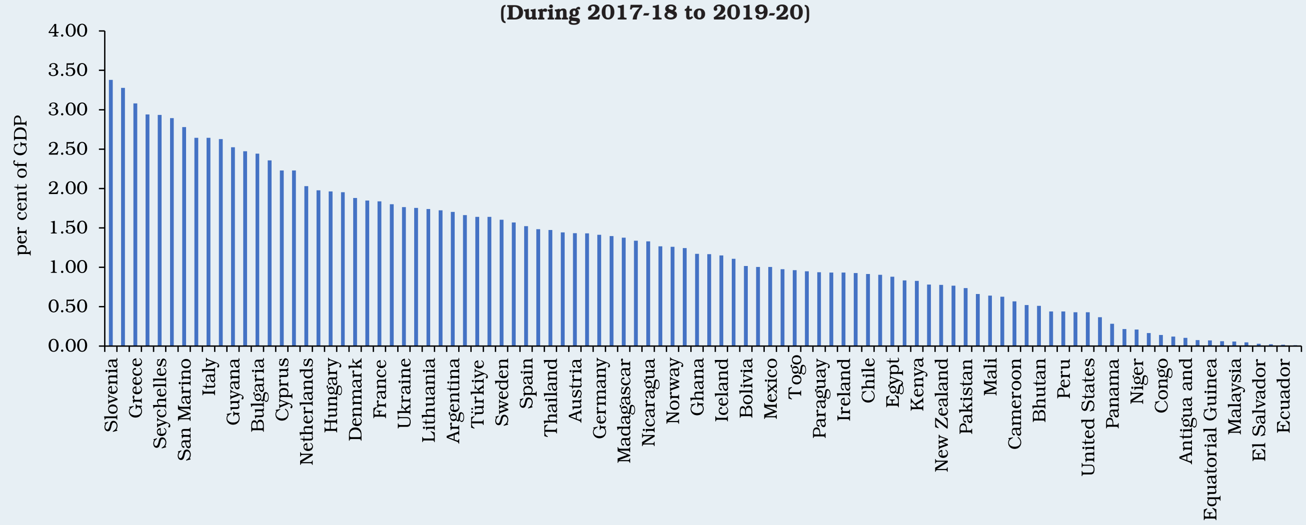
Notes: 1. 70 Carbon Pricing Initiatives implemented, which include 47 national jurisdictions and 36 subnational jurisdictions.
2. India's recently amended Energy Conservation Act, 2001 empowers the Government to specify a carbon credit trading scheme, which can aid carbon price discovery in India.

Source: Reproduced from Carbon Pricing Dashboard (World Bank); accessed on April 21, 2023

IV.12 The commonly used fiscal policy measures to mitigate and adapt to climate change are: (i) A carbon tax or a green tax; a compulsory, unrequited payment to the government on tax bases deemed to be harming the environment. When the green taxes are introduced along with a reduction in other taxes (such as labour tax or social security), it is viewed as an environmental tax reform (ETR). ETRs were first introduced in the Nordic countries in the 1990s followed by other European countries, Australia (2011), Japan (2012) and Chile (2014) (Gramkow, 2020); (ii) ETS; a market-based solution, which enables carbon emitters to trade emission units to meet their targets. There are two main types of emission systems: (a) cap-and-trade, where an upper limit on emissions is fixed and emission permits are either auctioned or distributed – those exceeding the limit must buy carbon credits and those operating within the limit earn carbon credits (*e.g.,* Kazakhstan, Switzerland, South Korea and Shanghai) and (b) baseline and credit system, in which baseline emission levels are defined but there is no fixed limit on emissions. Entities that reduce their emissions more than the mandated amount can earn carbon credits to sell to underachievers (*e.g.,* Alberta and Tokyo); (iii) Feebates and Regulation; which include a sliding scale of fees (or rebates) for carbon emissions above (or below) certain rates. Examples include emission standards for vehicles, fuel quality standards for petrol and diesel (*e.g.,* China, India, Japan, and Indonesia), tax rebates for EVs, and higher fees on high-emitting vehicles (*e.g.,* Singapore and India). The structure of fees and rebates is usually set to make the system revenue neutral. While feebates and regulations may have limited mitigation impact, they can play an important role in fostering investment in green energy (IMF, 2019); and (iv) Public green investment; even as the private sector is likely to take the lead in undertaking additional green investment, the public sector will need to act as a catalyst for the transition, through direct investment, co-financing, public-private partnership (PPP) or state guarantees (Ferdinandusse *et al.*, 2022). Governments may be incentivised to increase green investment by implementing a green golden rule, under which green investment expenditure is exempt from fiscal rules (Darvas and Wolff, 2022).

IV.13 Fiscal authorities in emerging market economies (EMEs) need to carefully consider the pros and cons of these policy options, as well as the methods used to implement them when determining carbon pricing. For arriving at a suitable carbon pricing policy framework for India, it is necessary to understand how carbon taxes and subsidies have been used in other countries.

Chart IV.2: Tax Revenues from Non-renewable Energy (During 2017-18 to 2019-20)



Note: Figures are averages for 2017-18 to 2019-20.
Source: OECD.

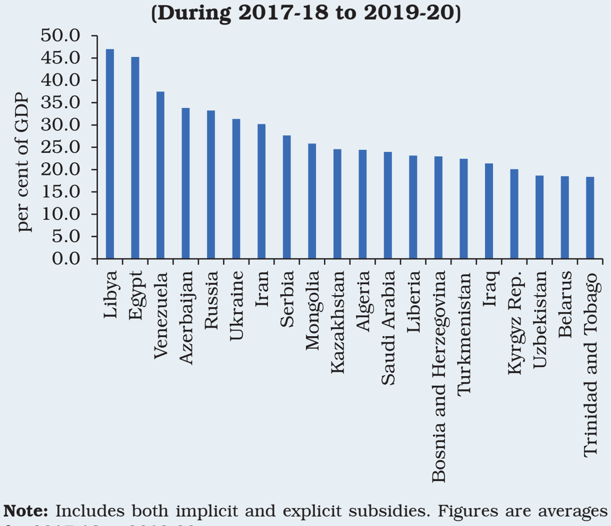
IV.14 Countries that tax non-renewable energy sources, including transportation fuel are shown in Chart IV.2. India is not included in this group of countries because there is no explicit carbon price specifically imposed on fuels like gasoline and diesel. These petroleum products are, however, subject to substantial excise duty and value-added tax (VAT). The total contribution of the petroleum sector to the exchequer in 2021-22 stood at 3.3 per cent of GDP[1].

IV.15 Several countries subsidise fossil fuels, with the total amount of subsidies (both explicit and implicit) as a share of GDP high enough to disincentivise and constrain green transition efforts (Chart IV.3). Keeping in perspective the international experience, we explore next the scope of carbon taxes and ETS in India.

Carbon Tax

IV.16 Governments impose carbon tax on CO_2 emitters to make them internalise the associated negative externalities and attain socially optimal

Chart IV.3: Countries with Highest Subsidies on Non-renewable Energy (During 2017-18 to 2019-20)

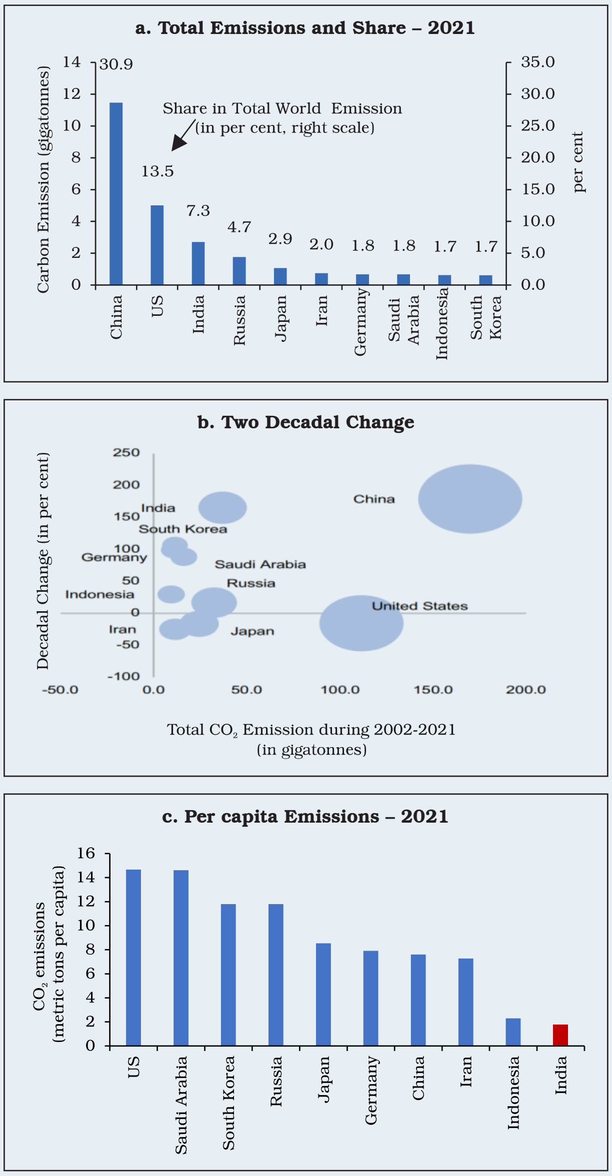


Note: Includes both implicit and explicit subsidies. Figures are averages for 2017-18 to 2019-20.
Source: Parry *et al.* (2021).

[1] Authors' calculations based on data from the Petroleum Planning and Analysis Cell, Ministry of Petroleum and Natural Gas, Government of India.

production levels. CO_2 emissions have increased between 2002 and 2022, particularly in Asian countries *vis-à-vis* the advanced economies (AEs) (Charts IV.4a and IV.4b). India is the third largest emitter of CO_2 after China and the US, though, on a per capita basis, it is one of the lowest (Chart IV.4c). To date, very few Asian economies have incorporated carbon taxes into their climate risk-mitigation strategies.

Chart IV.4: CO_2 Emissions and Carbon Tax



Note: The size of the bubble in Chart 4b represents the share of CO_2 emissions in global CO_2 emissions.
Source: Our World in Data and World Bank (2022a).

IV.17 Carbon taxes have been introduced by 36 jurisdictions as of April 2022 (World Bank, 2022b). These are levied per unit of metric tonne of carbon dioxide equivalent (tCO_2e). Finland was the first country to adopt a carbon tax, followed by Sweden and Norway. As of April 2022, the carbon tax rate of Finland stood at US$ 85 per tCO_2e. Uruguay has the highest tax rate of US$ 137 per tCO_2e, followed by Switzerland and Sweden at US$ 130 per tCO_2e each. The adoption of carbon taxes significantly reduced GHG emissions in Finland, Sweden, and Norway (Andersson, 2019; Bruvoll and Larsen, 2004; Khastar *et al*., 2020).

IV.18 Estimates based on data for the Asia and Pacific region suggest that a carbon tax of US$ 25 per tonne could reduce emissions by 21 per cent by 2030, with these nations outperforming their Paris Agreement targets and generating additional revenues of 0.8 per cent of GDP (Dabla-Norris *et al*., 2021). For India, a US$ 25 per tonne of carbon tax is estimated to reduce emissions by about 25 per cent by 2030 (IMF, 2019)[2]. Limiting global warming to 2 degree celsius, however, would require a carbon tax that may have to rise rapidly to US$ 75 per tonne of carbon dioxide by 2030. Carbon taxes are found to be more effective, but comparatively less used, whereas non-tax risk mitigation measures such as the ETS, feebates and regulations are less effective and therefore should be used as a complement to carbon taxes (Dabla-Norris *et al*., 2021). The proposed implementation of border carbon adjustments

[2] The scenario analysis in Section 9 of this Chapter uses same estimates.

(BCAs)[3] by some of the AEs to prevent their mitigation efforts from being undermined also strengthens the case for other nations to implement a carbon tax[4].

IV.19 India introduced a clean energy cess on coal at a rate of ₹50 per tonne in 2010[5]. The tax proceeds were earmarked for the newly created National Clean Energy Fund (NCEF) to fund research and innovative clean energy technology projects. The utilisation of funds from NCEF was, however, low and disbursements were aligned more with ongoing programmes/missions of various ministries/departments than with the fund's stated objectives (Pandey, 2013). In July 2017, the clean energy cess was replaced by the Goods and Services Tax (GST) compensation cess of ₹400 per tonne on coal production, which was meant to bridge the revenue shortfall of States due to the implementation of GST. Furthermore, with an excise tax of ₹19.9 per litre on petrol and ₹15.8 per litre on diesel by the Central Government and a VAT by the State Governments, the consumption of petrol and diesel is heavily taxed in India. It is estimated that 54.7 per cent of GHG emissions in India are subject to a positive net effective carbon rate (NECR).[6] The NECR in India is the highest in the road transport sector and zero or negative in other sectors such as agriculture, industry and buildings (OECD, 2021a).

IV.20 Carbon taxes on fossil fuels entail distributional consequences as they are generally regressive. The imposition of carbon taxes can reduce social welfare and is more likely to increase income inequality (Khastar *et al*., 2020). Revenue recycling, *i.e.,* earmarking revenues from carbon taxes for spending on citizen welfare schemes can help enhance public support for carbon taxation. It is estimated that the introduction of carbon pricing without revenue recycling could increase the Gini coefficient by 0.59 per cent over the baseline scenario of business as usual in 2030 (Zhao *et al*., 2022). With a progressive recycling scheme (*i.e.,* lower income groups receiving higher benefits), however, the Gini coefficient in 2030 would be 0.34 per cent lower than the baseline.

IV.21 The impact of carbon taxes also depends on the utilisation of tax proceeds. There are three possible ways to utilise tax proceeds to reduce tax burdens and improve economic outcomes: (a) providing a lumpsum dividend to households, as in the United Kingdom and France, which can improve progressivity but may reduce employment and income by disincentivising work/search for work among the unemployed; (b) a corporate tax rate cut, which may increase output, productivity, and innovation but at the cost of likely reduction of progressivity; and (c) a reduction in income tax, as in Finland, which can improve progressivity, income, and employment (Pomerleau and Asen, 2019). Hence, the third strategy may be the preferred policy tool to reduce the adverse impact of a carbon tax.

3 A border carbon adjustment is an environmental trade policy that consists of levying import fees by carbon-taxing countries on goods manufactured by non-carbon taxing countries.

4 In December 2022, the EU Member States and the European Parliament agreed to the world's first Carbon Border Adjustment Mechanism, which will be effective in its transitional phase from October 1, 2023 and in its permanent phase from January 1, 2026.

5 The cess was subsequently increased to ₹200 per tonne in March 2015 and to ₹400 per tonne in March 2016. In terms of carbon tax equivalent, the latest increase translated into a carbon price of US$ 4 per tonne of carbon dioxide.

6 NECR is the Effective Carbon Rate (ECR) adjusted for fossil fuel subsidies. ECR is the total price that applies to CO_2 emissions from energy use because of market-based instruments such as fuel excise taxes, carbon taxes and carbon emission permit prices (OECD, 2021a).

Table IV.1: Step-wise Considerations for Implementing a Carbon Tax

Determination of tax base	Determination of tax rate	Implementation	Utilisation of tax revenue
All fuels that produce carbon should be considered as the universal tax base.	There are two approaches to determining the tax rate: 1) Social cost of carbon - tax rates are estimated based on the social cost due to emissions of CO_2. 2) Abatement approach - carbon tax is imposed to meet specific emissions reduction targets committed at international fora.	• Phased yet timely implementation is crucial, with institutional amendments. The tax base and rate may be gradually increased over time. • Inclusion of carbon taxes in GST, Central Excise and State VAT, may help implementation in India.	• Revenues may be utilised for the promotion of clean technology and R&D spending on low-carbon technology. • Since a carbon tax may increase the burden on low-income households as they may not be able to switch to low-carbon technology quickly, appropriate offsets may be required. • Small industries using less carbon-efficient production technology may increase their final prices which may degrade their competitiveness. Hence identifying and subsidising these industries using the tax proceeds may be required.

Source: EY (2018).

IV.22 At present, India does not have an explicit carbon tax system but it imposes taxes on the use of fossil fuels, as noted earlier. As and when a carbon tax is introduced, it is important to recognise that several considerations must predate its implementation (Table IV.1). Moreover, the World Bank recommends that countries imposing carbon taxes should target higher economic growth, spend more on clean technology, provide direct benefit transfers to low-income households and effectively regulate and monitor environmental objectives of carbon pricing.

Feebates and Subsidies

IV.23 Fiscal measures should also support investment in clean technologies through greater budgetary outlay on R&D for developing low-carbon technologies and by compensating losses arising from the transition to clean technologies to incentivise firms to adopt these technologies. Investment in climate resilient infrastructure and specifically earmarked resources for managing post-disaster losses must also be an integral part of the medium-term fiscal policy strategy. After decades of congressional stalemate, the Inflation Reduction Act (IRA) in the US was passed on account of two major strategic shifts. First, carrots score higher over sticks to build political support and hence the law subsidises clean energy rather than taxing carbon pollution. Second, the law explicitly favours US-made products (such as EVs) and clean energy, as part of a broader shift toward strategic intervention to promote and protect firms in targeted sectors such as production of semiconductors (Joselaw and Montalbano, 2022).

Emissions Trading Systems (ETS)

IV.24 Like a carbon tax, an ETS has its own challenges and benefits (Table IV.2). Adopting a new carbon pricing mechanism such as the ETS may necessitate overhauling the current carbon tax/subsidy framework.

IV.25 India's Energy Conservation (Amendment) Act, 2022 has drawn attention to the importance

Table IV.2: Carbon Tax and ETS: Advantages and Disadvantages

	Carbon Tax	ETS
Advantage	Provides certainty about the price of carbon	Increases certainty about emission reductions and environmental benefits.
Disadvantage	The outcome of emission reductions is unknown.	The costs of achieving the desired level of abatement are unknown.

Source: Observer Research Foundation (2022).

of carbon markets and green financing *via* green bonds for meeting the country's decarbonisation targets. Its scope is substantial, and it gives the Government the authority to create a system for trading carbon credits, laying the foundation for a legitimate carbon market. Several EMEs (accounting for around half of the global GHG emissions) have so far implemented or are contemplating carbon pricing using ETS or carbon taxes (Table IV.3).

IV.26 Mexico conducted several pilots involving specific enterprises before its three-year trial operational phase in 2020. China implemented its national ETS market in 2021 after trials in eight provinces. The federal structure of India could help in implementing ETS pilot programmes

Table IV.3: Carbon Pricing Mechanism in Emerging Market Economies

Name	GHG Emissions (as per cent of World emission)	Status	Description	Scope (Share of GHG emissions covered)
Argentina	0.80	Carbon Tax (Implemented)	Implemented a Carbon tax in 2018, replacing the fuel tax	20 per cent
Brazil	2.92	ETS (TBC)	National Climate Policy aims to promote ETS. Since 2013, a group of leading companies have participated in a voluntary ETS simulation	Not decided
China	24.23	ETS (Implemented)	The world's largest ETS, in terms of covered emissions, was implemented in 2021.	33 per cent.
Indonesia	3.94	Carbon Tax (Implemented) / ETS (TBC)	Passed a law to implement carbon tax in October 2021, Working towards a mandatory ETS in the power sector	26 per cent using Carbon tax
South Korea	1.31	ETS (Implemented)	Launched a cap-and-trade based ETS at a national level in 2015	73 per cent.
Malaysia	0.80	ETS (TBC)	Considering between Domestic ETS and Carbon tax	Not decided
Mexico	1.35	Carbon Tax (Implemented) / ETS (TBC)	Carbon tax is an excise tax under the special tax on production and services that was implemented in 2014	44 per cent.
Poland	0.64	Carbon Tax (Implemented)	Part of the Environmental Protection Act that covers CO_2 emission, dust, sewage, and waste.	3.75 per cent.
South Africa	1.13	Carbon Tax (Implemented)	Places a price on CO_2 emissions from large businesses in the industry, power, and transport sectors.	80 per cent.
Thailand	1.13	ETS (TBC)	Following COP 26, the government is developing guidelines for ETS, expected to be released in 2022	Not decided
Türkiye	1.31	ETS (TBC)	Laws governing monitoring, reporting, and verification (MRV) were implemented in Türkiye in 2012, and monitoring of GHG emissions from large installations began in 2015.	Not decided
India	6.75	Carbon Tax (TBC)	NA	NA

Note: TBC: To be confirmed.
Source: Our World in Data.

Table IV.4: Emissions Trading Model in Surat

Key Areas	Details
Background	▪ Pollution reached a high level in Surat in 2018. ▪ Surat was selected as the location for the pilot programme.
ETS model in Surat	▪ ETS is a regulatory mechanism that aims to reduce pollution load in a region while simultaneously minimising the business compliance cost. ▪ Different types of businesses can buy and sell the rights to release particulate matter into the atmosphere by exchanging licences, measured in kilograms (kgs) that fall within this cap.
Trading	▪ At the beginning of every month (during which the emission permit is valid), 80 per cent of the total cap of 280 tonnes for that period is distributed free to all participating units. ▪ GPCB will offer the remaining 20 per cent during the first auction of the compliance period at a floor price of ₹ 5/kg.
Auctions	▪ Transactions like these take place on the trading platform known as ETS-PM, which is hosted by the National Commodities and Derivatives Exchange e-Market Limited (NeML), where all participants must register a trading account. ▪ There are two types of auctions: (i) Uniform price auction and (ii) Continuous market. To satisfy compliance responsibilities, units may acquire and sell leftover permits at the final auction price 2-7 days before the compliance period ends.
Punitive Actions	▪ Environmental damage compensation to the amount of ₹ 200/kg will be assessed for emissions over a unit's permit holdings when the compliance term ends. ▪ An upper limit has been established so players cannot stockpile permits to gain an unfair advantage.

Source: Gujarat Polltuion Control Board (GPCB): Emissions Trading Scheme (Pilot Project, 2019).

across states. The gradual enlargement of its scope into a more practical nation-wide ETS would require simulations and pilots. On July 15, 2019, the Gujarat Pollution Control Board (GPCB) introduced India's first ETS and the world's first cap-and-trade market in particulate pollution (Table IV.4).

IV.27 An ETS provides a transformational alternative to command-and-control policies that are expensive, inflexible and could be enforced by imposing costly and time-consuming penalties. The ETS is anticipated to provide emissions reduction certainty without significantly altering the existing carbon tax or subsidies, and may be adopted in India for accelerating decarbonisation in industries like transportation. ETS may be politically more acceptable and relatively easier to implement (IMF, 2022a).

IV.28 Public spending on climate change and related issues remains underreported in India, and hence, a consistent reporting template needs to be put in place to record climate-related expenditures and report them in a Climate Budget Report as a supplement to the annual budget. Even before that, an effective green taxonomy to limit the potential risk of greenwashing is needed. Starting with the first climate budget published by Nepal in 2013, several countries have followed suit, including Bangladesh, Indonesia, Moldova, Kenya, Norway, Sweden and France (Petrie, 2021). In India, Odisha became the first state to publish a climate budget report in 2020.

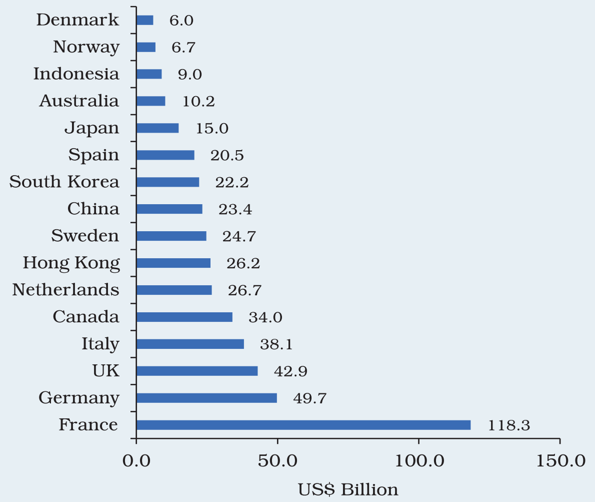
IV.29 To meet its climate goals, India needs to introduce a broad-based carbon pricing system in line with the global best practices highlighted above. Furthermore, a variant of the NCEF may be instituted, to which all receipts from carbon taxes and proceeds from the recently introduced green bonds may be credited. Expenditure tagging must be undertaken to highlight separately expenditures that benefit the environment, and those that are harmful, to produce full-fledged climate budget reports, which may be instrumental in better identifying the green financing needs and attracting international financing (Petrie, 2021).

Sovereign Green Bonds

IV.30 Sovereign green bonds (SGBs) are similar to traditional Government securities except that they contain a "use of proceeds" clause which states that the funds will be utilized solely for green investments (Ando *et al.*, 2022). The first ever SGBs were issued by Poland in 2016, followed by France, Fiji and Nigeria in 2017. While several EMEs have started issuing SGBs, advanced economies are the frontrunners in SGB issuances so far (Chart IV.5). India issued its first SGBs amounting to ₹16,000 crore in 2022-23. While SGBs are gaining popularity, their market remains shallow as they account for only 0.2 per cent of all Government debt securities issued in the OECD area and 12 per cent of total green bond issuances in EMEs (OECD, 2021b).

IV.31 Some of the benefits of SGBs include lower refinancing risk as these bonds are generally issued with a long maturity (Doronzo *et al.*, 2021); and a green premium (or greenium) which occurs when the SGB exhibits a lower yield compared to the traditional Government bond, due to strong demand from investors following greater transparency on the use of bond proceeds, despite lower liquidity of SGBs (Ando *et al.*, 2022). SGBs can be a stable source of financing for Government expenditure on climate related infrastructure and can facilitate the transition to a low-carbon economy which would, however, depend on how they perform relative to conventional bonds (Box IV.1).

Chart IV.5: Sovereign Green Bond Issuances



Note: The chart represents the total SGB issuances of each country as of mid-April 2023.
Source: Bloomberg, accessed on April 19, 2023.

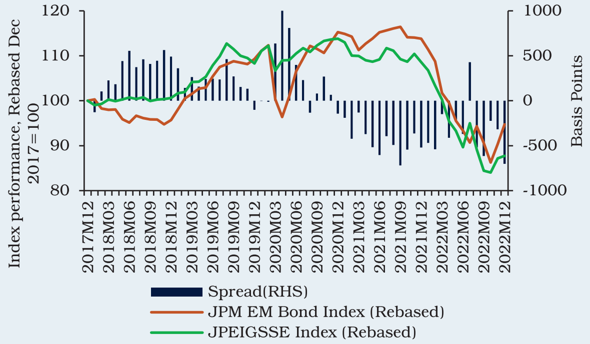
Box IV.1
Emerging Market (EM) Green Bonds: The Significance of Greenium

'Greenium'- a premium over vanilla bonds, is an integral feature of a successful green bond issuance strategy. JP Morgan's EM Green Bond Index outperformed the comparable JP Morgan EM Bond Index in 2022, extending the cumulative over-performance since December 2017 to 790 basis points (bps) (IFC, 2021; Bloomberg, 2022). When the green bond index outperforms the conventional bond performance, the greenium widens (Chart 1).

Global financial conditions have influenced the evolution of the spread between the return on EM green bonds and their non-green counterparts. A tighter global financial condition (proxied by the US financial conditions) is associated with an increase in the spread, and the association almost doubled from the pre-COVID to post-Covid period. For example, the correlation was 0.31 in the pre-COVID period (2018 M01- 2020 M02) and rose

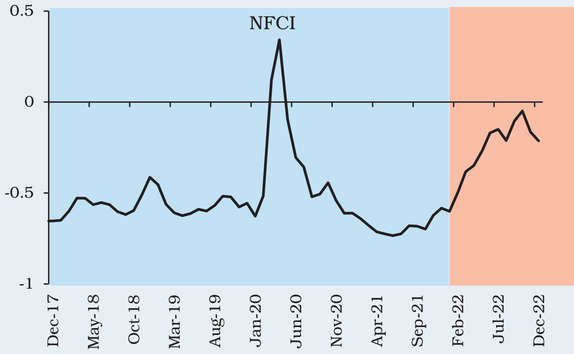
(Contd...)

Chart 1: Total Return Performance (JP Morgan EM Green Index versus JP Morgan EM Aggregate)



Note: Spread represents the difference in the returns of these indices. J.P. Morgan ESG Green Social & Sustainability IG EUR Bond Total Return (JPEIGSSE) Index.
Source: Bloomberg and Authors' calculation.

Chart 2: National Financial Conditions Index



Source: Federal Reserve Bank of Chicago.

Table 1: Granger Causality Test Results

Null-Hypotheses	NFCI does not Granger Cause Spread	Spread does not Granger Cause NFCI
Lags = 2	13.13*** (0.00)	2.15 (0.13)
Lags = 3	9.42*** (0.00)	1.49 (0.23)
Lags = 4	10.18*** (0.00)	1.24 (0.31)
Lags = 5	9.72*** (0.00)	1.07 (0.39)

Note: All coefficients are F-Statistics; Terms in bracket are p-values. Sample: December 2017 to December 2022; Blue shaded region shows easy global financial conditions, whereas red shaded part represents tight financial conditions (post October 2021 tightening of global financial conditions is the outcome of high inflation and expected rise in the US fed funds rate).
Source: Authors' calculations.

to 0.61 (2020 M03 – 2022 M12). Granger causality results between spread and financial conditions strongly support causality from the National Financial Conditions Index (NFCI) to spread at 1 per cent level of statistical significance (Chart 2 and Table 1).

While assessing the pricing of SGBs, it would be important to recognise the significance of global financial conditions in shifting investor appetite, besides the role of a pool of savers, both domestic and foreign, who may accept lower returns on such bonds if the proceeds are clearly earmarked and used for green projects.

References:

IFC (2021). Emerging market green bonds report: On the road to green recovery.

3. Innovation and Technology Adoption

IV.32 Technical progress can be a key enabler to achieving a successful green transition. Besides increasing the productivity of resources, it can reduce the degradation of natural resources and curtail pollution. In most traditional economic models and growth theories, technology is modelled as an exogenous variable that appears as 'manna from heaven'. Endogenous growth theories acknowledge that technological change occurs as a result of identifiable and deliberate processes, including R&D; investment, economies of scale and public policy changes. As per this view, public institutions have an important role in allowing efficient price discovery for desirable resource allocation and providing a conducive environment for environment-related innovation. Therefore, Governments have a more direct role in developing and diffusing technology for sustainable development and financing basic research for green innovation. In this context, this section explores alternative technology choices available to the policymakers today while pursuing the path to a clean, green and sustainable energy transition.

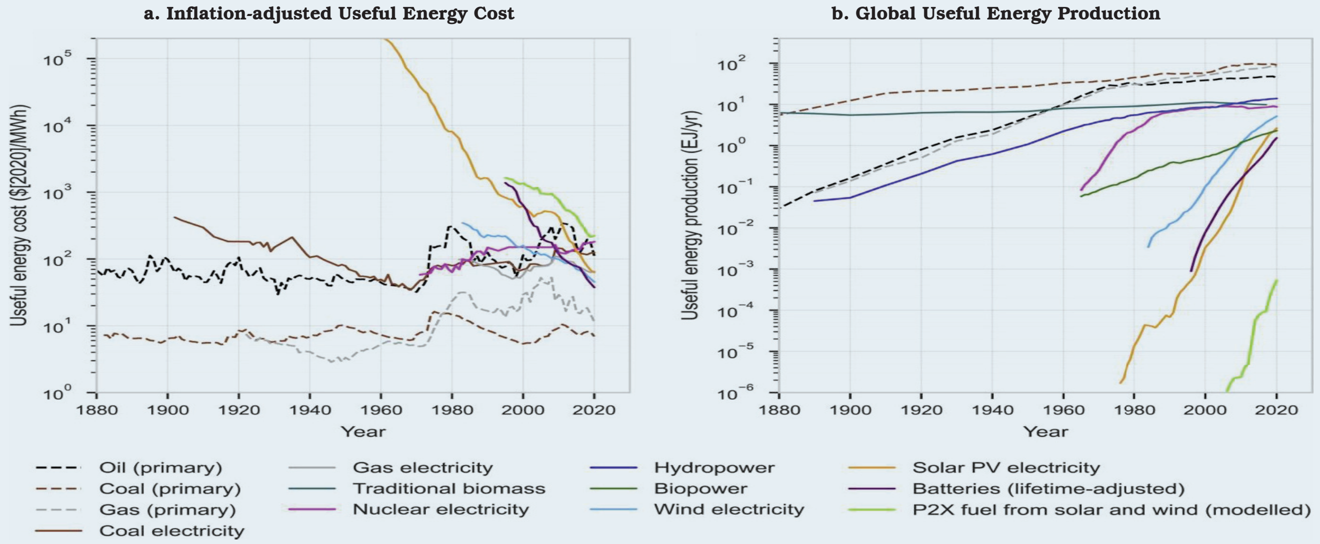
Renewable Energy

IV.33 Technology solutions have helped discover and exploit alternative energy sources, enhance energy efficiency of current and new systems, reduce risks arising from climate change, and lower renewable energy costs.

IV.34 Most energy-economy models, in fact, historically underestimated the pace of deployment of renewable energy technologies and overestimated their costs (Way *et al.,* 2022) (Chart IV.6). Compared to continuing with a fossil fuel-based system, a rapid green energy transition may result in significant savings. The price of electricity from utility-scale solar PVs has reduced by 89 per cent from 2009 to 2019, while prices of lithium-ion batteries have fallen by 97 per cent since their commercial introduction in 1991 (UNDP, 2022).

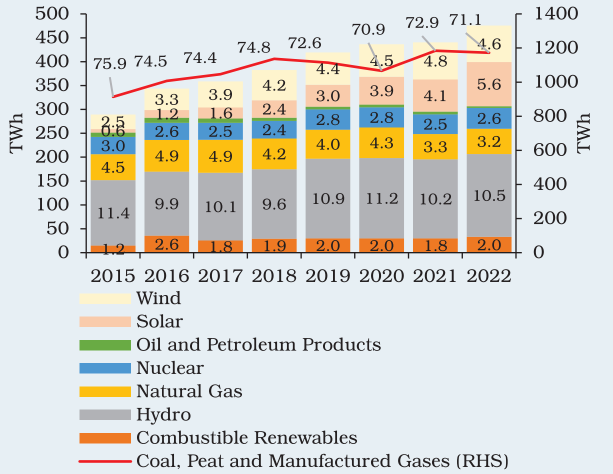
IV.35 Renewables' growth in 2022 was much faster than initially expected, driven by strong policy support in China, the EU and Latin America (IEA, 2022a). India has made significant strides towards a sustainable energy mix over the past few years, with an installed capacity from renewable sources of energy of more than 157 GW (PIB, 2022a), and the share of renewables in electricity generation increasing from around 16 per cent in CY2015 to 23 per cent in CY2022. This is in pursuance of India's vision of achieving the Net Zero Emission target by 2070 and increasing renewables capacity to 500 GW by 2030. A granular analysis of India's electricity generation mix shows that the share of solar energy has increased from 0.6 per cent in 2015 to 5.6 per cent in 2022 (Chart IV.7). Hydro-power share remains steady at approximately 10 per cent, while the share of wind energy has nearly doubled. The share of coal and natural gas in the electricity mix has reduced over the years. The key challenge in raising the share of renewable energy is not only incentivising domestic production of solar panels, wind turbines, batteries and EVs, but also facilitating research and technology extension for dealing with the fluctuating energy output from

Chart IV.6: Cost and Use Trends of Various Energy Sources



Source: Reproduced from Way *et al.* (2022).

Chart IV.7: Net Electricity Production by Source (TWh)



Note: Data labels show percentage shares, calculated as a per cent of total net electricity generation; they may not add to 100.
Source: IEA Monthly Energy Statistics, and Authors' calculations.

renewable energy sources like solar and wind, and securing the entire supply chain.

IV.36 Various policy steps have been taken by the Government towards a sustainable energy mix, including the new solar-powered toll plazas, development of Mass Rapid Transit Systems (MRTS) across cities, the National Smart Grid Mission and the Green Energy Corridor Project for an efficient transmission and distribution network for renewable energy and the Faster Adoption and Manufacturing of Hybrid Electric vehicles (FAME India) scheme. More recently, India submitted its long-term low greenhouse gas emission development strategies (LT-LEDS) at the 27th Conference of Parties (COP 27) of the United Nations Framework Convention on Climate Change (UNFCCC) at Sharm El Sheikh (MoEFCC, 2022). The LT-LEDS is a crucial policy tool that can help a country to place short-term climate actions in the context of the long-term structural changes required to transition to a low-carbon and climate-resilient economy.

IV.37 As part of its LT-LEDS, India aims at carrying out a just, smooth and sustainable transition away from fossil fuels by making India a green hydrogen hub, increasing electrolyser-manufacturing capacity in the country, and undertaking a three-fold increase in nuclear power generation capacity by 2032. Additionally, the LT-LEDS focuses on low-carbon transportation, by increasing the use of biofuels through ethanol blending in petrol (which is envisaged to rise to 20 per cent by 2025 from 10 per cent under the Ethanol Blended Petrol programme), increase in EV penetration and promotion of green hydrogen fuel.

Solar Power, Batteries and EVs

IV.38 In line with international trends, the cost of solar power generation has come down in India in recent years, with the lowest auction winning tariffs hovering in the range of ₹2-3 per kilowatt-hour (kWh). Installed capacity is increasing in a mission mode, but the focus now needs to shift to addressing viability of solar power for use by all. Important sources of non-conventional energy, wind and solar, face two major challenges - high fluctuation in supply due to their dependence on environmental factors such as sunlight and wind speed, and inflexibility in scaling up or down in line with the demand. Hence, a grid with high solar and wind capacity needs stabilising mechanisms to manage fluctuations in demand. One solution could be supplementing the grid with readily variable sources like run-off-the-river hydro or geothermal energy. Another could be to manage demand through the use of smart grids that can monitor power flows from points of generation to points of consumption and control the power flow or curtail the load to match generation in real-time or near real-time. The National Smart Grid Mission is a step in this direction and is expected to inculcate dynamic pricing mechanisms to incentivise consumers to shift their usage over different times of the day in response to price signals.

IV.39 The smart grid will also facilitate distributed generation, especially rooftop solar generation, by allowing movement and measurement of energy in both directions using control systems and net metering, which could help "prosumers" *i.e.*, the consumers that both produce and consume electricity, to safely connect to the grid. Yet another option is developing Energy Storage Systems, which involve converting excess solar and wind power to potential energy in batteries, supercapacitors, compressed air energy storage systems, flywheels, and gravity storage or pumped hydro storage plants. Rapid technological progress and cost competitiveness have made batteries the mode of choice for most applications (ISGF, 2019). The research priorities for electrical batteries in India include new cell chemistries emerging from the lithium-ion family, such as lithium-air, lithium-sulphur or other metals, such as sodium and magnesium. The recent discovery of 5.9 million tonnes of lithium reserves should enhance the indigenous impetus for green transition and help India in reducing its import dependence for this crucial mineral. Nevertheless, research and innovation for exploring other battery technologies is a strategic requirement.

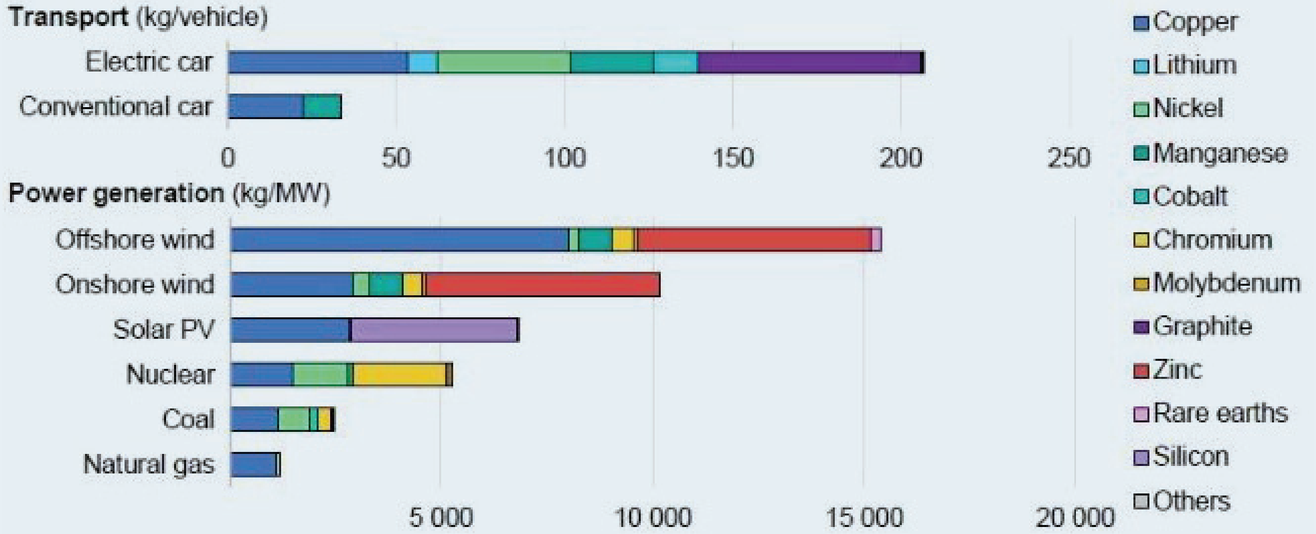
IV.40 EVs have emerged as the next frontier in mobility, with global electric car sales exceeding 10 million units in 2022. Cumulatively, the number of electric cars on road exceeded 26 million in 2022 - more than five times the stock in 2018 (IEA, 2023c). According to the *Vahan* dashboard[7], India achieved the milestone of one million EV registrations in 2022 – a substantial jump from 3,31,365 registrations a year ago. Globally, the success of EVs has largely been driven by sustained policy support through subsidies aimed at increasing EV sales and crowding–in charging infrastructure and manufacturing capacity.

IV.41 In India, the FAME scheme has been extended to FAME-II till the end of 2024, which now includes a 50 per cent increase in purchase incentives for electric two-wheelers to ₹15,000 per kWh of battery capacity. This is important, given that India is the largest two-wheeler market in the world. The FAME-II scheme has provided subsidies to the tune of ₹1,000 crore to develop almost 2,900 charging stations across 25 states. Additionally, the National Highways Authority of India has set an objective to install EV charging stations every 40-60 km along national highways, covering 35,000-40,000 km of highways by 2023. Nineteen states in India offer some form of policy support for EVs, such as purchase incentives, exemptions from road taxes, and subsidies for investment in battery manufacturing and related components (IEA, 2022c).

IV.42 The switch to EVs is bound to exert pressure on mines for supply of minerals such as copper, lithium, nickel, manganese and graphite and for rare earth elements that are used in EV manufacturing (Chart IV.8). This is true even for wind power. It is important that the environmental costs of mining and extraction are accurately factored in, and appropriate compensation mechanisms are devised. The prices of these metals surged in the aftermath of the war in Ukraine, and their supply chain remains highly concentrated.

7 Ministry of Road Transport and Highways, Government of India (accessed on April 17, 2023).

Chart IV.8: Mineral Intensity of Selected Clean and Fossil Energy Technologies

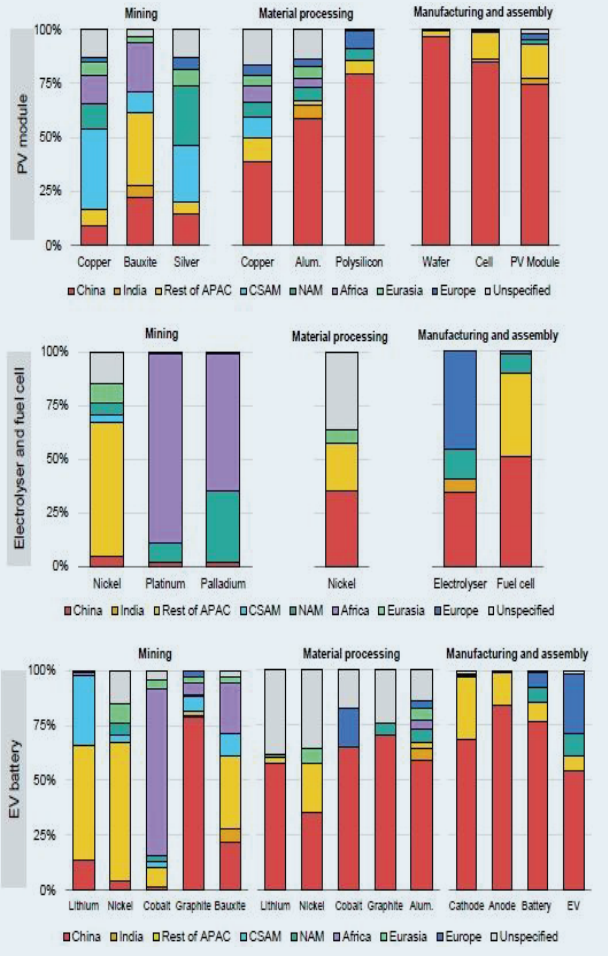


Source: Reproduced from IEA (2022d).

IV.43 Three-fourths of worldwide lithium-ion battery production is centred in China, and over half of lithium, cobalt and graphite processing and refining capacity is located there. Central and South America and Africa hold a large share of reserves of minerals used in the renewable power supply chain (Chart IV.9). China currently dominates the processing, manufacturing and assembly phases of the supply chains of key renewable energy technologies. India needs to secure its supply chain, including through indigenous production and outward foreign direct investment (FDI), as being pursued by the European nations and the US. India neither has substantial reserves of such minerals (other than the recently discovered lithium), nor is it globally competitive in processing capacity. Hence, there is an urgent need to secure a steady supply of these minerals through diplomatic efforts recognising the benefits of South-South cooperation and at the same time, incentivising investment for creating large capacity for material processing, manufacturing and assembly of solar PVCs, wind turbines, EV batteries and related components.

IV.44 The electrification of the road transport sector will have to be supported by subsidies, especially in the case of charging stations, until EV density is sufficient to sustain the charging infrastructure without any support. Incentivising the installation of home chargers in existing parking spaces, mandating EV readiness for new buildings and installation of chargers in existing buildings are the way forward. Recycling of metals involved in battery and EV production or moving to newer technologies such as lithium iron phosphate cathodes and manganese-rich cathodes may be necessary to combat metal shortages and encourage local battery production. Battery standardisation and developing a common set of standards for testing and evaluating second-hand batteries may be necessary for the effective recycling of old batteries.

Chart IV.9: Geographic Concentration of Selected Clean Energy Technologies by Supply Chain Stage and Country/Region, 2021



Notes: NAM: North America; Rest of APAC: Asia-Pacific excluding China and India; CSAM: Central and South America. Alum: Aluminum.
Source: Reproduced from IEA (2022d).

Green Hydrogen

IV.45 Green hydrogen is the hydrogen produced by the electrolysis of water molecules using energy from renewables. India currently consumes about 6.17 MT of hydrogen annually, and this is expected to grow to 28 MT per annum by 2050 (TERI, 2022). Presently, most consumption is of grey hydrogen[8] and its use is largely confined to the fertilizer and refinery sectors. Hard-to-abate sectors such as cement, steel and transport can be potential future hydrogen-consuming sectors. Green hydrogen can be an effective way of storing excess energy during times of low demand to be fed back into the grid when demand rises. The cost of green hydrogen is expected to be reduced by more than 50 per cent by 2030, largely driven by the decrease in the cost of renewables and electrolysers in India (TERI, 2022). The National Green Hydrogen Mission aims to make India a global hub for production, utilisation and export of green hydrogen and its derivatives. Moreover, it would reduce fossil fuel imports by more than ₹1 lakh crore by 2030, thereby bringing down the overall import bill. Various public sector enterprises and conglomerates have announced long-term investment commitments in the green hydrogen space.

IV.46 Furthermore, the Green Hydrogen Mission could be a major catalyst for India's decarbonisation, built on the government's proactive policy focus, ambitious private sector partnership and advantageous production environment. With abundant renewable resources availability coupled with comparatively lower construction costs than competing regions, India is well positioned to take the lead in green hydrogen production. Indigenisation of technological processes and industry-led R&D for breakthrough technology would be the key to enhancing electrolysis capacity for green hydrogen production.

8 Hydrogen is classified as grey, blue, and green based on the method of production. Grey Hydrogen is the most widely produced, and is generated from methane through steam reforming, which generates a significant amount of carbon dioxide. Hydrogen is labelled blue whenever the carbon generated from steam reforming is captured and stored underground through industrial carbon capture and storage. Green hydrogen is produced by using clean energy from surplus renewable energy sources to split water into two hydrogen atoms and one oxygen atom through electrolysis.

Carbon Capture Utilisation and Storage (CCUS)

IV.47 Leading US tech companies[9] have pledged US$ 925 million to remove CO_2 from the atmosphere (known as carbon capture) to arrest global warming. Globally about six gigatonnes of CO_2 a year is required to be removed from the atmosphere by 2050 to avert any disastrous effects of climate change (McKinsey & Company, 2022). The inclusion of Carbon Capture Utilisation and Storage (CCUS) as one of the 13 activities that qualify for carbon trading in India's upcoming carbon trading market may provide a more diversified toolkit for India to tackle CO_2 emissions (PIB, 2023). Moreover, the Ministry of Petroleum and Natural Gas (MoPNG) received ₹35,000 crore grant in the 2022-23 budget, which is expected to be deployed in carbon sequestration technologies such as CCUS. Thus, CCUS can play a crucial role in achieving India's goal of reducing CO_2 emissions by 50 per cent by 2050 by decarbonising hard-to-abate industries such as steel, cement, and petrochemicals (NITI Aayog, 2022a). However, its expensive cost structure and unproven technology pose certain downside risks.

Nuclear Energy

IV.48 According to the World Nuclear Industry Status Report 2022, the share of nuclear energy in global commercial gross electricity generation in 2021 dropped to 9.8 per cent – the lowest in four decades – and 40 per cent below the peak of 17.5 per cent attained in 1996. Nuclear energy generation in India accounted for 2.6 per cent of total electricity generation in 2022. India has 19 of the world's total 411 functioning nuclear reactors with eight of them under construction as of October 2022. The declining trends are largely in response to the Fukushima disaster in 2011, after which even firm believers in nuclear power as the viable path to sustainable energy security, such as France, decided to scale down. Post-pandemic energy shortages and the energy crisis in Europe on account of the war in Ukraine, however, have led to a revival of interest in nuclear power.

IV.49 New technologies, such as very small reactors, are emerging, which are sealed and do not require regular refueling, making them well-suited for applications in which the entire reactor can be plugged into a grid or dropped into a remote location where they can operate for many years till refueling is required. In a bid to reduce its dependence on imported Uranium, India is tilting towards thorium based nuclear reactors in the long run, since this fuel is available in the monazite sands of the eastern and western coasts of the country.

Artificial Intelligence (AI) and Machine Learning (ML) for Sustainable Energy Transition

IV.50 In recent years, a large volume of data has been unlocked through the Internet of Things (IoT) enabled sensors, satellite data and drones, with scope for using AI, ML, and blockchain to identify and propagate climate solutions. These technologies can help measure, understand and evaluate challenges and make forecasts, enable informed policy choices, permit the automation of responses, optimise resource use, and provide smart infrastructure. Moreover, AI can also help integrate renewables of fluctuating supply by enabling smart grids that partially match electricity

9 Four big tech companies – Alphabet, Meta, Shopify, and Stripe.

demand to times of high sunshine and wind speed. AI is estimated to have the potential to enable the fulfilment of 93 per cent of the environmental Sustainable Development Goals (Rolnick *et al*., 2023). Various ML technologies have immense potential to provide green solutions in domains such as electricity systems, transportation and climate prediction (Table IV.5).

IV.51 With technology expected to shape the progress on green transition, it is important to prioritise an innovation-supportive policy regime

Table IV.5: Machine Learning and its Deployment for Climate Change Solutions

Solution Domain	Causal Inference	Computer Vision	Interpret-able Models	Natural Language Process-ing	Reinforce-ment Learning and Control	Time-Series Analysis	Transfer Learning	Uncer-tainty Quantifi-cation	Unsu-pervised Learning
Electricity systems									
Enabling low-carbon electricity		✓	✓		✓	✓		✓	✓
Reducing current-system impacts		✓				✓		✓	✓
Ensuring global impact		✓					✓		✓
Transportation									
Reducing transport activity		✓				✓		✓	✓
Improving vehicle efficiency		✓			✓				
Alternative fuels & electrification					✓				✓
Buildings and cities									
Optimising buildings	✓				✓	✓	✓		
Urban planning		✓				✓	✓		✓
The future of cities				✓			✓	✓	✓
Industry									
Optimising supply chains		✓			✓	✓			
Improving materials									✓
Production & energy		✓	✓		✓				
Farms & forests									
Remote sensing of emissions		✓							
Precision agriculture		✓			✓	✓			
Monitoring peatlands		✓							
Carbon dioxide removal									
Direct air capture									✓
Sequestering CO_2		✓						✓	✓
Climate prediction									
Uniting data, ML & climate science		✓	✓			✓		✓	
Forecasting extreme events		✓	✓			✓		✓	

Source: Rolnick *et al.* (2023).

accompanied by a large and sustained increase in R&D expenditure (Box IV.2).

Digitalisation and Energy Efficiency

IV.52 Digitalisation could prove to be a potent means to enhance energy efficiency, saving energy in the major energy-intensive sectors such as transportation, buildings and industry (Chart IV.10). At the policy design stage, digital tools can provide access to more granular and real-time data, and advanced analytics and modelling capabilities can help predict the impact and cost-effectiveness of programmes. Digitalisation can be an effective communication tool to enable more user-centred policies during programme implementation (Table IV.6).

Transportation Sector

IV.53 The transportation sector accounts for about 28 per cent of global final energy demand

Box IV.2
Innovation for Sustainable Energy Transition

Innovation is central to putting the world on a sustainable energy path. It creates value by improving existing processes and generating new ways of doing business. Innovation augments the portfolio of policy options available and the potential strategies to meet goals. Over time, it brings down the costs of achieving set goals (Kobos *et al.*, 2006).

Using a panel dataset of 12 AEs and EMEs (including India) with annual frequency between 1996 and 2020, the factors influencing the share of renewable energy in total energy consumption is assessed (Table 1). The analysis incorporates per-capita CO_2 equivalent emissions and per capita GDP to control for common but differentiated responsibilities in climate change mitigation, and the levels of oil and natural gas reserves – since availability of such reserves domestically may influence the preferred local energy mix. Gross domestic expenditure on R&D consists of the total expenditure (current and capital) on R&D by all resident companies, research institutes, universities, and Government laboratories. It is found that higher the R&D related expenditure as a per cent of GDP, greater is the shift to renewable energy. This effect may be experienced with a lag (of about two years, as in Models 2 and 3). Hence, the fruits of innovation may take time to yield results, extend to the commercial space and finally percolate into the actual energy mix. Technology innovation does not evolve in a vacuum: the market structure, public support for entrepreneurship, and direct government investment all influence how rapidly new technologies emerge and are adopted. This is true for energy as for other sectors of the economy. These findings suggest that enhancing and incentivising the flow of resources for innovation is essential to achieve a greener energy mix in the future.

Table 1: Panel Data Analysis Results

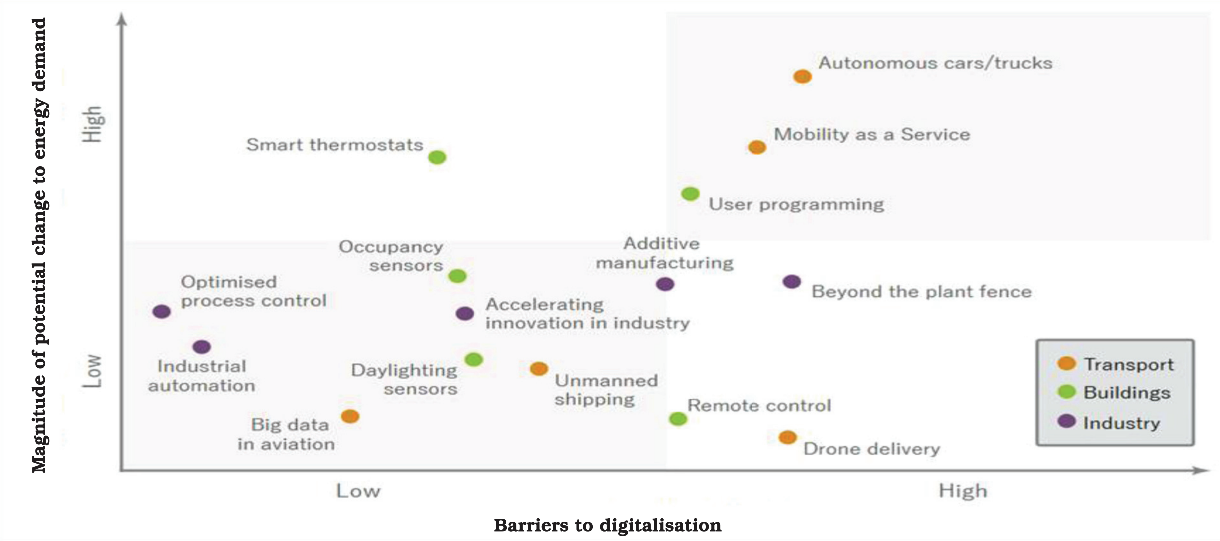
Variable	Model (1) Share of Renewable Energy	Model (2) Share of Renewable Energy	Model (3) Share of Renewable Energy
Per Capita CO_2 Emissions	0.004 (0.005)	-0.001 (0.009)	-0.002** (0.001)
Coal Dependence for Electricity	-0.001*** (0.000)	-0.001** (0.000)	-0.001*** (0.000)
R&D Expenditure Share in GDP	0.042** (0.018)	-0.095*** (0.021)	-0.075** (0.034)
2-year lag of R&D Expenditure Share in GDP		0.141*** (0.039)	0.105*** (0.037)
Log GDP per capita		0.005 (0.014)	0.003** (0.002)
Log Oil Reserves			0.016*** (0.002)
Log Gas Reserves			0.010 (0.007)
Intercept	-0.041 (0.055)	-0.053 (0.175)	-0.027 (0.019)
R^2	0.62	0.74	0.96
Observations	129	75	73
Countries	12	7	5

Notes: ***: *p<0.01, **: p<0.05, *: p<0.1; Robust standard errors in parenthesis.*
All models use the random effects specification (as supported by the Hausman test) and incorporate year fixed effects.
Notes on variables: Renewable energy consumption (exajoules); Per Capita CO_2 emissions (million tonnes of CO_2 equivalent per 1 billion population); Coal Dependence for electricity (coal share in total electricity generation); R&D Expenditure as a share of GDP (per cent); GDP per capita (2017 US$ PPP); Proven Oil Reserves (thousand million barrels); Proven Gas Reserves (trillion cubic metres). Data from BP Statistical Review and World Bank.

References:

Kobos, P.H., Erickson, J.D. and Drennen, T.E. (2006). Technological learning and renewable energy costs: implications for US renewable energy policy. *Energy Policy.* Volume 34, Issue 13. Pages 1645-1658.

Chart IV.10: Digitalisation's Potential Impact on Energy Demand Sectors



Source: Reproduced from IEA (2017).

and 23 per cent of global CO_2 emissions from fuel combustion (IEA, 2017). The dynamics and net effects of Automated, Connected, Electric and Shared (ACES) mobility will play a key role

Table IV.6: Digital Tools Used for Promoting Energy Efficiency

Tool	Country	Project	Description
Geographic Information System (GIS) mapping and remote sensing	Europe	Hot Maps Project	Open-source tool allowing city planners to visualise geographical areas with potentially high heating or cooling loads, which could then be prioritised for energy efficiency upgrades as part of heating or cooling action plans.
Virtual buildings and digital twin cities	Singapore	Virtual Singapore	3D digital replicas of every building in the city providing the capability to accurately simulate how new developments and planning changes in the city might affect a range of energy-related indicators, road and foot traffic flows, heating and cooling needs, *etc.*
Digital certification and compliance	EU, China	QR codes coupled with smartphones and apps	With QR codes attached on appliances and linked to a database, consumers can easily check and compare the energy efficiency of appliances
Digital communication and networking	US	Building Performance Database	Online tool created to help people access and browse data on building energy performance, from governments, utilities, energy efficiency programmes, building owners and private companies.
Natural language processing	US	US Department of Energy	Scan through texts and numerical data on energy investments and company information to track innovation and clean energy progress.
Web search analytics	Sweden, Denmark, Finland, Iceland	NordCrawl Project	Web scraping provides an alternative method for regulators to assess whether models are being sold that do not meet Minimum Energy Performance Standards. Using automated tools, regulators can quickly scan online shopping websites to assess which models are being offered for sale in their country.

Source: IEA (2021b).

in shaping the overall transport sector's future energy and emissions trajectory. In cities with high population density and good public transport networks, digitalisation could contribute to a shift away from the traditional paradigm of vehicle ownership towards the provision of Mobility as a Service (MaaS), which could simplify shared mobility services by offering a unified routing and payment platform.

Green Buildings

IV.54 In 2021, buildings accounted for nearly 30 per cent of global final energy consumption and 27 per cent of total energy sector emissions (IEA 2022e). Digitalisation has significant potential to enhance user comfort in buildings while reducing overall energy use. The energy load of a building can be managed using active control systems that use real-time data from sensors. Wherever feasible, active controls should also integrate intelligently with building energy services sharing information to and from the grid, facilitating better electricity supply and demand management. Similarly, smart lighting in public places, notably street lighting, may also cut down energy use beyond the direct energy savings from the use of light emitting diode (LED) lamps, and by connecting streetlights to traffic lights and other traffic management tools. Policymakers and companies need to ensure that devices are able to provide and receive information using open-source or compatible software to allow for interoperability across technologies. Supportive policy frameworks, such as bulk procurement of energy-efficient technologies and white certificates[10] can help by driving down product costs and ensuring that those technologies deliver energy savings.

Industries

IV.55 Industry accounts for 38 per cent of global final energy consumption and around one-fourth of total CO_2 emissions (IEA, 2022f). Proactive Government policies in this regard may help small and medium-sized enterprises, that may not have had so far sufficient exposure to these technologies. The adoption of energy management systems such as ISO 50001 – the global standard for energy management – is driven by Government policies or incentives in many countries.

Climate-resistant Agriculture/Infrastructure

IV.56 Agriculture globally accounts for 25 per cent of GHG emissions, with four per cent contribution to global GDP. Adapting suitable technologies for climate change mitigation measures in agriculture is important as it still accounts for a large share of income in many low-income countries, absorbing a sizeable proportion of the labour force. Climate Smart Agriculture (CSA) practices have been recognised globally for developing sustainable agri-food systems, in line with the Food and Agriculture Organisation (FAO) Strategic Framework 2022-2031.

IV.57 Technological advancements in agriculture at various phases of the crop life cycle through Integrated Pest Management (IPM), Conservation Tillage and Enhanced Nutrient Management are crucial and should be promoted through public investment for long-term sustainability. Furthermore, awareness about the role of precision agriculture techniques for mass agricultural production should be further enhanced as empirical studies show that it can reduce the amount of chemicals required for optimum

[10] A tradeable instrument issued by an authorised body guaranteeing that a specified amount of energy savings has been achieved, usually combined with an obligation on a utility to achieve a certain overall amount of energy savings.

cultivation and reduce the level of nitrogen residue (Bongiovanni *et al.*, 2004).

IV.58 The relevance of these new agricultural technologies has increased in India due to growing climatic events like erratic rainfall, cloudbursts and heat waves. Many start-ups in the agri-tech space are providing sustainable solutions for improving farm productivity, reducing crop losses, better crop storage and lowering dependence on water and weedicides. The advancements in methods of agricultural practices may bring about substantial environmental benefits such as increased water retention capacity and accumulation of organic carbon.

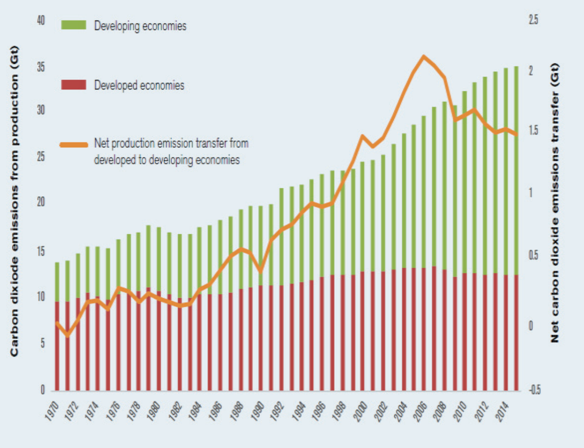
IV.59 Enhanced usage of technologies such as mapping and surveying, airborne laser scanning, satellite remote sensing, tide gauges, satellite altimetry and GPS could help develop robust climate change adaptation mechanisms to minimise the impact of these shocks. Building a climate-resistant infrastructure network is also important given its spillovers to other sectors of the economy. A study on the potential impact of a major flood in Paris found that the infrastructure sector could bear 30 to 55 per cent of the direct cost of flood damage (OECD, 2018). Resilient infrastructure networks are key for reducing direct losses and negating the challenges posed by climate vulnerabilities. India's aspirations to build a strong infrastructure network are reflected in recent initiatives such as the National Infrastructure Pipeline, the National Logistics Policy and GATI Shakti. India has spearheaded the global initiative for robust regional disaster management systems by launching the Coalition for Disaster Resilient Infrastructure (CDRI) (Das, 2023).

4. Trade Policy

IV.60 Since the mid-1980s, with the rise of globalisation, EMEs have seen a rapid increase in production-related carbon emissions, in part due to production for exports (Chart IV.11). International carbon emission transfers (from AEs to EMEs) increased much faster than growth in international trade and GDP in the 1990s and early 2000s; however, they have been declining since 2006 (Peters *et al.*, 2011). Notwithstanding the distinct deglobalisation since 2018 driven by geo-economic forces, emission transfers through trade remain a major challenge.

IV.61 International trade leads to GHG emissions in multiple ways and measuring the overall impact of trade on carbon emissions is a complex task. Over the past decades, GHG emissions from production and transport of traded goods and services have increased. There has been growing

Chart IV.11: Trade Imbalances in GHG Emissions



Note: Net emission transfer refer to the international carbon emission transfer, defined as the difference between the carbon emission embodied in production (including exports) and the carbon emission embodied in consumption (including imports).
Source: Reproduced from WTO (2021).

evidence suggesting that increasing global trade may lead to environmental degradation (Abman and Lundberg, 2020). It is estimated that 20-30 per cent of GHG emissions have been due to international trade (WTO, 2021). Economic growth and productivity increases have been regarded as the potential gains from trade liberalisation, but the impact of such liberalisation on the environment is debatable (Grossman and Krueger, 1995).

IV.62 While AEs tend to be net importers of GHG emissions, EMEs and commodity-dependent economies tend to be net exporters (WTO, 2021). Policy initiatives and advancements in environmental and energy efficiency technologies can reduce GHG emissions associated with production for exports and their transportation. In this context, international trade can play a crucial role in diffusing green technologies and improving carbon efficiency by (i) focusing on green and clean energy products in regional trade agreements; (ii) reducing the carbon content of international trade and (iii) promoting environmental quality standards and eco-labelling.

Climate change focus in regional trade agreements

IV.63 Regional trade agreements (RTAs) have generally proliferated with the recent geo-economic shifts and the preference for friend-shoring. Currently, 355 RTAs are in force worldwide, covering more than half of total international trade (WTO, 2022). Traditionally, the primary focus of RTAs has been on lowering tariff and non-tariff barriers to trade; however, there has been an increasing tendency towards the inclusion of environment-related provisions. RTAs, by including environmental provisions, can serve twin objectives – avoid adverse impact of trade liberalisation on the environment and promote trade of green goods.

IV.64 Broadly, the following areas have been identified for inclusion of necessary environmental provisions in trade agreements – removal of tariff and non-tariff barriers on green goods and services; clauses regarding environmentally harmful/beneficial subsidies; border adjustment carbon taxes; green procurement; international cooperation on climate change goals; and regulatory coherence (The Economist, 2019; J Ferrante, 2016). Almost 97 per cent of all RTAs notified to the WTO include at least one environmental provision (WTO, 2022a).

IV.65 India has so far signed 14 Free Trade Agreements (FTAs) with its trading partners. In addition, it has signed 6 limited coverage Preferential Trade Agreements (PTAs). The TREND database covers PTAs signed up to 2021 and includes information on 16 agreements signed by India. On average, each PTA in India contains around 12 environmental provisions. An examination of the environmental provisions in India's PTAs reveals that around 70 per cent of these provisions are only in 3 PTAs, with Singapore, Japan and South Korea. Most of the Indian PTAs include provisions on the conservation of natural resources, general exceptions for trade in goods if they are related to the life (health) of animals and/or plants, *etc*. Many relevant environmental provisions, such as commitments to enforce domestic environmental measures, promote production of renewable energy and energy efficiency and dispute settlement mechanisms which are present in most of the other countries' PTAs are either missing or are present only in one or two of India's PTAs (Table IV.7).

IV.66 India's recently signed PTAs are more comprehensive and include provisions relating to the environment. For instance, a reference

Table IV.7: Environmental Provisions in Most of the Global PTAs

	Description of Provision	Presence in India's PTAs
1	Conservation of natural resources	√
2	General exceptions for trade in goods if relate to the life (health) of animal/plant	√
3	Norms relating to technical barriers to trade	√
4	Sanitary and phytosanitary measures and environment	√
5	Implementation of obligations found in other environmental agreements (such as commitments at the Rio Summit, Millennium Development Goals, *etc.*)	√
6	Environment reference in preamble	√
7	Coherence with domestic trade or investment policies	√
8	Level of environmental protection such as not relaxing environmental measures to encourage trade	×
9	Sovereignty in determining own environmental policies	×
10	Conservation of forests	×
11	Promote production of renewable energy and energy efficiency	×
12	Interaction between energy policies/agriculture/transport and environment	×
13	Binding obligations such as commitment to enforce domestic environmental measures	×
14	Pesticides, fertilisers, toxic or hazardous products and chemicals	×
15	Contact point on environmental matters	×
16	Establishment of an inter-Governmental committee	×
17	Dispute settlement mechanisms	×
18	Education or public awareness for environmental protection	×
19	Joint scientific cooperation on environment protection including monitoring/assessment	×
20	General obligation to exchange information related to the environment including provision of information when taking measures to protect the environment	×
21	Exclusion of environmentally harmful inventions from patentability	×
22	Technical assistance, training or capacity-building provided to another party for environmental protection	×

Source: TRade and ENvironment Database (TREND). Morin, JF, A. Dür and L. Lechner (2018), "Mapping the trade and environment nexus: Insights from a new dataset", Global Environmental Politics, vol. 18(1).

to environmental protection is included in the preamble to India's agreements with the UAE and Mauritius. Going forward, India's future agreements are expected to cover more detailed climate and sustainable development provisions, given the emphasis being put by potential FTA countries/regions such as the UK, Canada, and the EU on climate change. Environmental provisions in trade agreements can be effective in improving environmental welfare, but they need to be specific and legally binding (Brenton and Chemutai, 2021).

IV.67 India needs to use its RTAs to facilitate and promote export of goods and services required in the clean energy sector, where it has a comparative advantage. India is the highest ranked G20 country according to the Climate Change Performance Index 2023 and is also the fifth best performing country globally (RBI, 2023). Many Indian companies have aggressively expanded their investment in green sectors such as solar equipment manufacturing, green hydrogen production and energy storage, thereby increasing India's export potential in a world that is increasingly becoming averse to importing carbon-intensive products. The Government's Production Linked Incentive (PLI) scheme also promotes green investment by incentivising manufacturing of electric vehicles, solar photovoltaics, and automotive cell company (ACC) batteries. There is a need to link such incentive schemes with environment-related performance parameters (Box IV.3). Additional policy support through trade agreements would foster these efforts to increase green exports of the country.

IV.68 EMEs face the challenge of identifying and avoiding the incorporation of protectionist measures under the pretext of environmental policy by their AE trade partners (The Economist, 2019). Therefore, EMEs, including India, need to develop and employ expertise while finalising future trade agreements so that effective provisions can be incorporated in the areas where synergies between trade and environmental objectives can be established while retaining autonomy on domestic environmental policy. Another daunting challenge for EMEs may emerge from the proposal to introduce a carbon border tax (CBT) by some of the AEs to restrict imports from countries having less stringent environment protection laws. Besides progressively reducing the carbon content of India's export basket, FTAs should emphasise

Box IV.3
Green PLI: Exploring India's Export Potential in Climate Friendly Goods (CFGs)

On April 7, 2021, the government approved the Production Linked Incentive (PLI) scheme for high-efficiency solar PV modules. This is an important step towards gradually replacing fossil-fuel-derived energy with renewable energy. To explore India's trade opportunities in 64 climate-friendly goods (CFGs) with India's major trade partners, the CFGs are identified under 6-digit HS code following the Dinda (2013) approach. The sub-groups under CFGs are classified under various categories related to (i) clean coal technologies, (ii) wind energy; (iii) solar PV systems and (iv) energy-efficient lighting.

The optimal mix of trade partners and product categories in CFGs is identified for boosting India's export potential. India's major trading partners since 2007 are examined using centroid clusters that best fit the data, applying the K-means clustering algorithm. By minimising within-cluster variation, the clustering method attempts to determine the centroid position from a cluster of data points.

In other words, K-means clustering minimizes within-cluster variation *i.e.,* $c_1,\ldots,c_k\{\sum_{k=1} W(C_k)\}$. One common choice involves minimising Euclidean squared distance;

$$W(C_k)=\frac{1}{|C_k|}\sum_{i,i'\in C_k}\sum_{j=1}^{p}(x_{ij}-x_{i'j})^2$$

The centroid coordinates are identified as (2.69, 0.07) and (-0.30, -0.01). In the case of cluster 1, it is observed that India's exports share of CFGs is relatively high for those importing countries with whom India has a relatively lower overall export share. Whereas cluster 2 analysis reveals that, India exports share of CFGs is low with importing countries with whom India has a high overall exports share

Chart 1: K-means clustering based Centroid Cluster: Export Share & Climate Friendly Goods (CFG) share

Cluster	Export Share	CFG Share
1	2.69	0.07
2	-0.30	-0.01

Source: WITS and authors' calculations.

(Chart 1). The trade cluster analysis can provide insights on developing effective trade engagements to enhance India's export prospects in a world that is increasingly differentiating imports based on their carbon content.

References:

Dinda, Soumyananda (2013): Climate Change Creates Trade Opportunity in India. Working Paper at A.K.Dasgupta Centre, Visva Bharati

transfer of technologies that could facilitate green transition.

Reducing carbon content of international trade

IV.69 The amount of GHG emissions embedded in an economy's international trade is determined by a broad range of factors, including the size of the economy, the sectoral composition of its foreign trade, its level of participation in global value chains (GVCs), the modes of transportation used for its imports and exports, and the energy efficiency of its production system, which depends in part on environmental and energy policies.

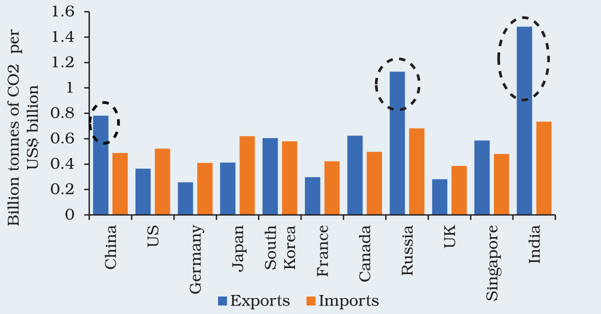
IV.70 Carbon emissions embedded in production differ considerably across economies. EMEs tend to emit more emissions per unit of output than AEs (Box IV.4). With a few exceptions, indirect emissions embedded in production tend to be greater than direct emissions embedded in production. The amount of indirect emissions embedded in production tends to be higher in such economies that are particularly active in downstream supply chains. Conversely, economies active in upstream supply chains tend to have lower indirect emissions embedded in production.

Box IV.4
Carbon Emissions Embedded in International Trade – India's Perspective

Total carbon emissions embedded in gross exports (around 9.7 gigatonnes of CO_2) accounted for around 29 per cent of global emissions in 2018 (Source: $TECO_2$ database, 2021 edition, OECD). While global carbon emissions have increased by approximately 57.3 per cent between 1995 and 2018, global emissions embedded in exports have risen by about 90 per cent over that period. Considering the carbon content of global trade, corrected for the size of trade flows, it is observed that CO_2 emissions per unit of exports are considerably higher for the EMEs, while their imports emit comparatively less CO_2 (Chart 1).

An in-depth analysis of the sources of trade-related emissions and their evolution can help in devising efficacious emission-abatement policies. Net CO_2 emission of exports are calculated as the difference between domestic CO_2 emissions embedded in a country's exports (EEE) and foreign CO_2 emissions embedded in its imports (EEI) (Kim and Tromp, 2021). Further, a comparison between CO_2 emissions and value-added in India's trade can indicate the environmental costs and economic benefits of trade (Table 1). Net value-added is the difference between domestic value-added in the country's exports (VAX) and foreign value-added in the country's imports (VAM).

Chart 1: Carbon Emissions Embedded in Trade – 2018 (corrected for size of trade flows)



Source: Trade in embodied CO_2 database ($TECO_2$), OECD 2021 edition, Authors' calculations.

$$NE^I = EEE^I - EEI^I;\ NV^I = VAX^I - VAM^I$$

Table 1: Implications of Net Emissions of Exports and Net Value Added

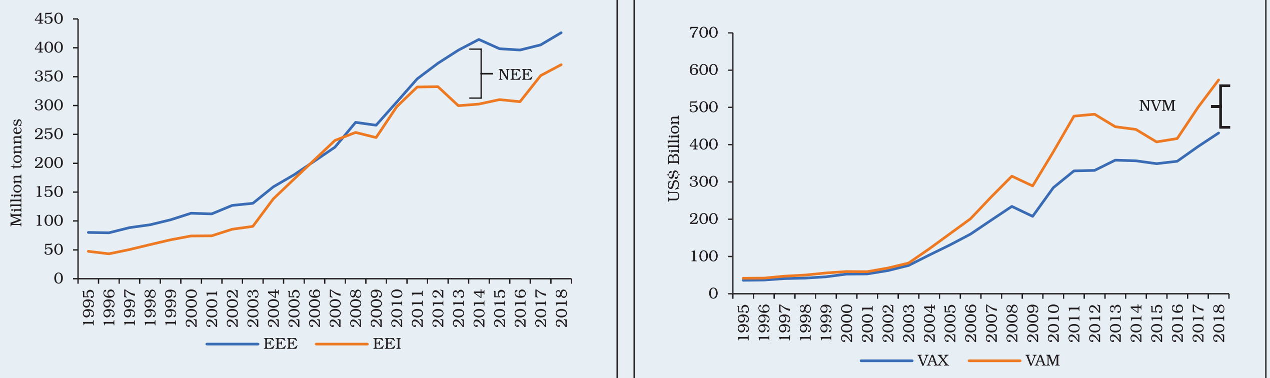
Net emissions exports	Net value-added	Exporter/Importer	Implication
$NE > 0$	$NV > 0$	Net emissions exporter, net value-added exporter	Incurring environmental costs but earning economic benefits from trade
$NE > 0$	$NV < 0$	Net emissions exporter, net value-added importer	Incurring environmental as well as economic costs
$NE < 0$	$NV > 0$	Net emissions importer, net value-added exporter	Earning environmental and economic benefits
$NE < 0$	$NV < 0$	Net emissions importer, net value-added importer	Earning environmental benefits but incurring economic costs

Source: Kim and Tromp (2021).

(Contd...)

Chart 2: Comparison of CO_2 Emissions and Value-added in India's Trade

a. Net Carbon Dioxide Emissions Exports for India | **b. Net Value Added Imports for India**



Source: Trade in embodied CO_2 database ($TECO_2$), OECD 2021 edition, Authors' calculations.

Source: Trade in Value Added (TiVA), OECD 2021 edition, Authors' calculations.

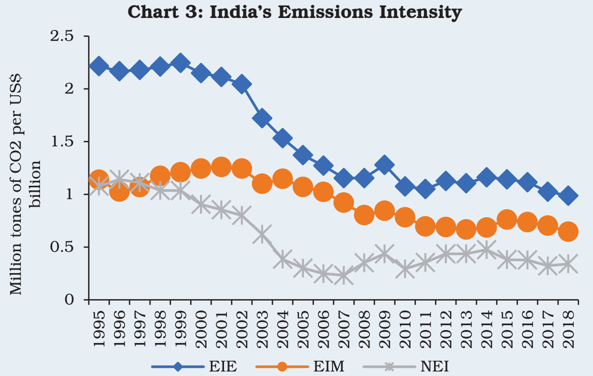
For most periods, $EEE^I > EEI^I$ implying $NE^I > 0$, *i.e.*, India's net exports add to carbon emissions. On the other hand, $VAX^I < VAM^I$ implying $NV^I < 0$, *i.e.*, India's net value-added through trade is negative. Thus, India incurs both environmental and economic costs in its trade (Chart 2).

Following Kim and Tromp (2021), emission intensity of value-added on exports (EIE) is assessed as a ratio of domestic emissions embodied in exports to domestic value-added of exports, and the emission intensity of value-added on imports (EIM) as a ratio of foreign emissions embedded in imports to foreign value-added of imports. $EIE^I = EEE^I/VAX^I$ $EIM^I = EEI^I/VAM^I$. Net emissions intensity $NEI^I = EIE^I - EIM^I$

If $NEI^I > 0$, India's CO_2 emissions generated by one unit of value-added on exports are more than the foreign CO_2 emissions generated by one unit of India's value-added on imports and vice versa. Both EIE and EIM have witnessed a downward trend, suggesting improvements in carbon emissions through net exports, but NEI still remains positive, indicating scope for further improvement (Chart 3).

Trade policies in India, therefore, should consider encouraging exports in sectors with scope for improvement in domestic value addition and relatively lower embedded carbon emissions.

Chart 3: India's Emissions Intensity



Source: Trade in embodied CO_2 database ($TECO_2$), OECD 2021 edition, Authors' calculations.

References:

Kim, T.-J., & Tromp, N. (2021). Analysis of carbon emissions embodied in South Korea's international trade: Production-based and consumption-based perspectives. Journal of Cleaner Production, 320, 128839. https://doi.org/10.1016/j.jclepro.2021.128839

IV.71 The current global tariff and non-tariff barriers are skewed in favour of dirty industries, thereby implicitly subsidising carbon emissions (Shapiro, 2021). Greening of trade would require focused attention on factors such as a review of country tariffs, removing biases favouring dirty sectors, reducing restrictions on access to environmental goods and services and environmentally preferable products; collective efforts for developing standards on carbon emissions embedded in products; promoting access to low-carbon technologies; international cooperation to ensure a coherent and predictable policy environment; and, mobilising adequate financial and technical assistance (WTO, 2022b).

Environmental Quality / Eco-labelling

IV.72 Environmental quality/eco-labelling is a market-based tool to encourage demand for and supply of products and services, which in turn could have a lower harmful impact on the environment over a product's life cycle (WTO, 2003). Eco-labels can change consumer behaviour by guiding them towards more environment-friendly purchase decisions (Marrucci *et al.*, 2019). For producers, labelling schemes can provide incentives to improve the environmental performance of products (Harris *et al*, 2021). They influence R&D activities for cleaner production methods and thereby promote innovation.

IV.73 A large number of environmental labelling and information schemes (ELIS) have been introduced globally over the past few decades. For instance, the Ecolabel Index is the largest global directory of ecolabels that currently tracks 456 ecolabels in 199 countries across 25 sectors. In India, to increase the acceptance of environment friendly and sustainable products and services, the Bureau of Energy Efficiency (BEE) has been tasked with enhancing the energy efficiency of appliances, and the Bureau of Indian Standards (BIS) for setting safety, quality and performance parameters of products.

IV.74 A growing number of such schemes globally tends to increase compliance costs for producers and thus affects their competitiveness (OECD, 2021c). Multiple schemes may also create confusion and loss of credibility for consumers. Such measures sometimes create a hindrance to free trade by effectively acting as a non-tariff barrier. Therefore, there is a need for promoting an internationally harmonised ecolabelling system to promote sustainable development without putting an unnecessary burden on producers and consumers.

IV.75 The available literature also suggests that multiplicity of standards, complexity of the certification process and its costs, regulatory compliance costs, and the lack of certainty about financial benefits exclude small-scale producers in EMEs from accessing standards-compliant markets (UNCTAD 2022). Therefore, small or medium scale producers should be provided with sufficient handholding while pursuing the sustainable growth objective through the instrument of eco-labelling.

5. Regulatory Measures

IV.76 Even as fiscal resources are expected to be at the forefront for meeting the financing requirements of the national green transition strategies, with the growing investor appetite for contributing to the private sector green initiatives/ projects, financial sector regulatory realignments have become essential to provide a congenial environment to facilitate higher flow of resources for a greener economy. In this vein, eight institutions from four continents started the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) in December 2017. The NGFS has 125 members as of March 2023.

IV.77 Addressing climate-related risks entails four main building blocks – disclosures, data, vulnerability analysis and regulatory/supervisory practices and tools (RBI, 2022a). The fourth block is where the regulators and supervisors have a role, transcending the work of the prior three blocks. Regulations and supervision aim at making the industry future-ready to: (i) bear the climate events resiliently without upending financial stability; and (ii) become the main purveyor of financing for adoption of technologies that can lead to a low carbon economy and help meet the national commitments. A major aspect of the regulatory realignment is sensitisation and cognisance of climate-related risks in the organisational strategy, governance, risk management and assurance functions of the financial services firms and integrating those risks into the existing prudential frameworks.

IV.78 The Reserve Bank had in December 2007 advised banks to put in place a Board-approved plan of action towards helping the cause of sustainable development. It brought out a discussion paper on climate risk and sustainable finance in July 2022, which was preceded by a survey of banks in January 2022. The feedback received on the discussion paper has been examined. On April 11, 2023, the Reserve Bank announced a framework for acceptance of green deposits[11] to foster and develop the green finance ecosystem in the country. Guidelines on: (a) disclosure framework on climate-related financial risks; and (b) guidance on climate scenario analysis and stress testing, are expected in due course. The Reserve Bank is setting up a dedicated webpage on its website to host all instructions, press releases, publications, speeches and communication on climate risk and sustainable finance.

IV.79 Corporate social responsibility (CSR), which had its genesis in the voluntary approach of "doing good" is also a part of the regulatory toolkit since the Government has legislated it as a mandatory compliance. The CSR legislation is a tool to hasten the green transition as it guides the corporate sector to undertake activities that generate positive externalities.

Green Finance

IV.80 Green finance comprises financing of green investments and policies that promote mitigation or adaptation (Lindenberg, 2014). The cumulative total expenditure for adapting to climate change in India is estimated to be ₹85.6 lakh crore (at 2011-12 prices) by the year 2030 (MoEFCC, 2022).

IV.81 Central banks as financial regulators have several policy instruments at their disposal to influence investment decisions and the allocation of resources and credit to achieve the sustainability targets (Dikau and Volz, 2018). Central banks can mandate banks and other financial institutions to consider climate and environmental risks through regulation which could be in the form of: (i) disclosure requirements – as mandatory disclosure requirements pertaining to climate-related risks of banks may prevent misallocation and mispricing of assets and sharp price corrections in the future; (ii) environment risk management – mandating financial institutions to incorporate environment risk factors in their risk management process; and (iii) green asset ratio (GAR), *i.e.,* the proportion of total assets invested in sustainable projects or economic activities – prescribing financial institutions to maintain a minimum threshold level. These may help divert the flow of finance from carbon-intensive sectors to green projects. A study

[11] A green deposit is an interest-bearing fixed deposit in the Indian rupee whose proceeds are earmarked for allocation to green finance – financing of projects entailing climate risk mitigation, climate adaptation/resilience and other related objectives. Guidelines have been laid out for impact assessment and reporting and disclosure.

finds significant reduction in fossil fuel holdings of financial institutions in France following the imposition of detailed reporting requirements of climate-related risk exposure and efforts to mitigate climate change (Nguyen and Mésonnier, 2021).

IV.82 A taxonomy of green finance can help the funding institutions in analysing better the climate risk in their loan portfolios, enhancing green financing while lowering the risk of greenwashing[12]. A more robust network of third-party verification, impact assessment and rating the green credentials of businesses, projects and instruments could mitigate greenwashing concerns, while also facilating increased funding at lower cost.

IV.83 In this regard, recent regulatory measures related to green bonds in India assume significance. The Securities and Exchange Board of India (SEBI) has issued guidelines that objectively define the purposes for which funds can be raised through 'green debt security' and the scope has been enhanced to include pollution prevention and control; circular economy; and eco-efficient products (SEBI, 2023a). Within the ambit of green debt security, sub-categories have been introduced: (a) blue bonds, related to water management and the marine sector; (b) yellow bonds, related to solar energy; and (c) transition bonds, related to transitioning to a more sustainable form of operations, in line with India's Nationally Determined Contribution (NDC). The SEBI has also outlined dos and don'ts to address concerns related to greenwashing (SEBI, 2023b).

IV.84 The regulations governing issuance of green debt securities have been tightened. An issuer desirous of issuing green debt security is required to make additional disclosures in the offer document, such as details about the decision-making process followed to determine the eligibility of projects/assets for which funds are being raised; systems/procedures to be employed for tracking the deployment of the proceeds of the issue; intended types of temporary placement of the unallocated and unutilised net proceeds from the issue of green debt securities; details on alignment of the objective with India's NDC in case of the proceeds raised through the issuance of transition bonds, among several others. Further, an issuer with listed green debt securities is required to make additional disclosures related to the utilisation of the proceeds of the issue, details of unutilised proceeds, qualitative performance indicators and, where feasible, quantitative performance measures of the environmental impact of the projects/assets (SEBI, 2023c). These additional disclosures are expected to improve the sustainable finance landscape in the country by enhancing public trust in the utilisation of funds for their intended uses.

Macroprudential Norms

IV.85 Macroprudential regulation aims at mitigating systemic risks in the financial system. One method to achieve this is through expanding the stress testing framework of banks to include the potential impact of climate-related events on their balance sheets.

[12] Activities or claims by a company/organisation that are intended to make people think that it is concerned about the environment, even if its real business harms the environment.

IV.86 The main objective of bank capital regulation is to safeguard a bank's balance sheet in scenarios of unforeseen adverse shocks and reduce the overall risks to financial stability[13]. As a regulatory policy instrument, several regulatory institutions have advocated relaxing risk weights for sectors with low carbon footprints to incentivise banks to extend more credit to those sectors (Gelzinis, 2021). A few studies have also suggested introducing an 'environment coefficient' which would help to internalise the pollution risk of the borrower. Therein, a bank's asset is weighted by the extant prudential regulation weight and then multiplied by an environment coefficient, thus determining an environment-risk weighted asset (Esposito *et al*., 2019). A coefficient value of 1 is considered the benchmark between the green and brown sectors – the green sector takes a value between 0.5 and 1 and the brown sector takes a value between 1 and 1.5. This can incentivise banks, particularly those facing a higher cost of regulatory capital, to allocate more loans to green sectors. This loan adjustment towards the green sector can help in accelerating the pace of transition to a low-carbon economy.

IV.87 There are, however, certain issues with capital regulations. A few studies argue that these are short-term risk management tools to absorb unforeseen losses. These losses are based on the Value-at-Risk approach that uses high-frequency historical data whereas climate events are not as frequent to estimate the Value-at-Risk associated with adverse climatic situations (Coelho and Restoy, 2022). Moreover, it has not been fully established that low-carbon projects are less risky. Reducing weights for these projects might deteriorate the asset quality of banks' loan portfolios and increase their fragility. Therefore, Pillar I capital regulation may not be appropriate to manage both financial stability and financing green sectors.

IV.88 Another possible policy instrument could be the green supporting factor (GSF). The GSF relaxes the capital requirement for investments in the green sector. It, however, suffers from the same limitation that green investments may not be less risky. Another risk that banks face is downgrade of ratings due to investment in environmentally risky assets. That could raise the external risk-premium of both equity and debt. As a result, it may reduce the profitability of banks. Since retained earnings form a part of reserves, which, in turn, constitute tier-1 capital of banks, GSF may alter the adequacy of capital base to mitigate short-term credit losses. As an example of this policy design, the European Commission introduced a 'Small to Medium Enterprise (SME) supporting factor' tool to increase lending to SMEs, but there is little evidence that it fulfilled the objective. The same argument also holds for GSF, whose design is based on unproven previous policy tools and limits its appeal as an instrument to incentivise banks to lend to the green sectors.

IV.89 Less capitalised banks that face a relatively higher cost of raising external regulatory capital could get an incentive to invest in green projects to abide by the capital requirement. Although these banks could help the economy to transit to a low-carbon equilibrium, it may also amplify their fragility and increase systemic risk. Hence, environment-adjusted risk-weighted assets and GSF can only be implemented if the green projects are relatively less risky. Capital regulation and GSF can be complemented with close monitoring

[13] Banks keep a minimum amount of capital as a proportion of their total risk-weighted assets (RWAs) to absorb unforeseen losses. The RWAs are calculated by multiplying the book value of the loans with their respective risk weights assigned by the bank's regulator. The riskier the loan, the higher the risk weight.

and supervision to attenuate the financial risks that are generated in loan portfolio adjustment (Baranovi *et al.*, 2021). The Prudential Regulation Authority (PRA) of the Bank of England (BoE) recommends further work on the design and calibration of the regulatory capital to reduce the unintended consequences of green bank capital regulation (PRA, 2021). The PRA requires entities to provide details on their adapted stress testing calculations and methodologies to assess whether assumptions, judgements, and factoring of output in firms' decision-making are appropriate.

IV.90 Prior to the implementation of the green capital regulation, the non-performing assets (NPAs) in the banking system need to be reduced to alleviate potential financial risk. If green capital regulation amplifies NPAs, it could impede monetary policy transmission (John *et al.*, 2016; Muduli and Behera, 2021). Hence, comprehensive disclosure of information related to climate risks and incorporating these risks in banks' Internal Capital Adequacy Assessment Process (ICAAP) under Pillar 2 are a few policy tools that may incentivise regulated entities to extend credit to sectors with lower climate risk.

IV.91 Another method is to prescribe exposure limits. Imposing a ceiling on the exposure of banks to carbon-intensive industries to limit the flow of resources to the polluting sectors could free up resources for the green sectors.

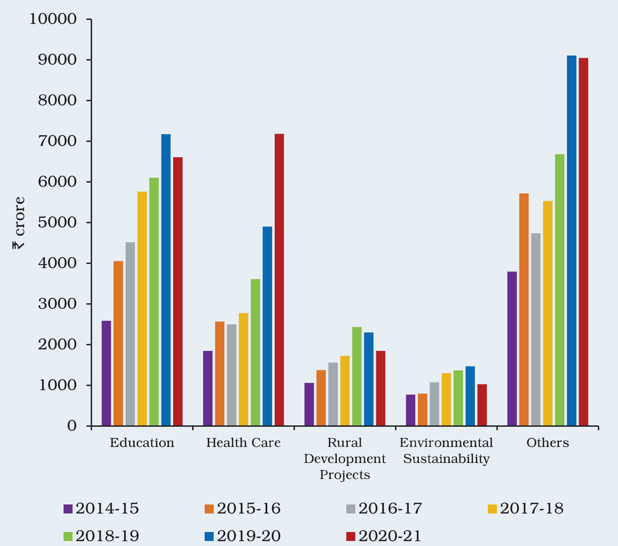
Corporate Social Responsibility (CSR) Norms

IV.92 The Ministry of Corporate Affairs had issued the 'Voluntary Guidelines on Corporate Social Responsibility' in 2009 which were further refined as 'National Voluntary Guidelines on Social, Environmental and Economic Responsibilities of Business', 2011. The voluntary guidelines were subsequently converted into mandatory CSR provisions in Section 135[14] of the Companies Act, 2013.

IV.93 The total CSR expenditure at ₹26,190 crore in 2020-21 was more than double the value in 2014-15, registering a compound annual growth rate of 17.3 per cent. While education and health care have attracted a significant share of the CSR expenditure, flow of funds towards environmental sustainability has also increased, *albeit* at a slower pace (Chart IV.12).

IV.94 A major chunk of the CSR expenditure is concentrated in a few states such as Maharashtra, Gujarat, Karnataka and Tamil Nadu. States like Bihar have received a minuscule amount in direct

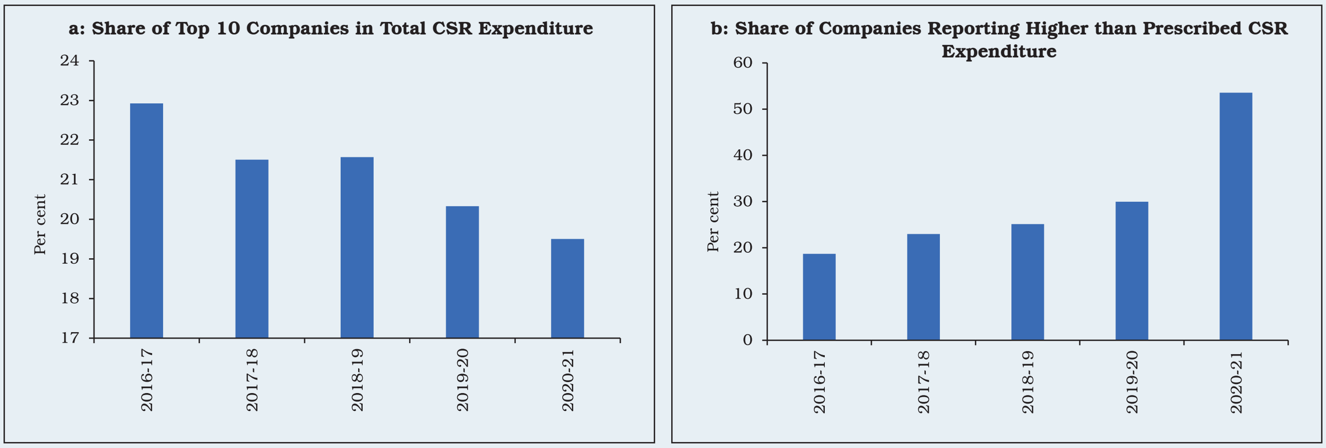
Chart IV.12: Sector-Wise CSR Expenditure



Source: National CSR Portal.

[14] Every company having a net worth of ₹500 crore or more, or turnover of ₹1000 crore or more or a net profit of ₹5 crore or more during the immediately preceding financial year shall constitute a CSR Committee of the Board.

Chart IV.13: CSR Expenditure by Companies



Source: National CSR Portal.

CSR expenditure. While the concentration of industries and corporate houses in a few States is the likely reason for the lopsided nature of CSR expenditure, a higher geographical diversification is desirable.

IV.95 The top ten companies, in terms of CSR expenditure incurred, account for around one-fifth of the total (Chart IV.13a). An encouraging trend is the rise in the share of companies reporting higher CSR expenditure than prescribed for statutory compliance (Chart IV.13b).

IV.96 While developments in the CSR space have been encouraging; there is scope for further improvement. First, since industries and corporate houses are concentrated in a few States, there is an inequitable geographical spread of CSR spending. Section 135 of the Companies Act recommends that “the company shall give preference to the local area and areas around it where it operates, for spending the amount earmarked for CSR activities”. It is proposed that geographical diversification in CSR spending for companies with large CSR budgets may be mandated by law. Second, the current CSR rules do not allow CSR in activities undertaken by companies in pursuance of their normal course of business, which restricts them from using their natural expertise in conducting socially responsible business. It is proposed that companies may be allowed to pursue CSR activities in their business operation domains. Third, while the entries in Schedule VII, Section 135 of the Companies Act (activities that companies may include in their CSR policies) are to be interpreted liberally, it is proposed that the list be rationalised to a few broad areas, as certain companies may find the current list prohibitive (Sinha, 2021). Fourth, CSR rules allow multi-year projects with timelines not exceeding three years, excluding the financial year in which the project commenced. This incentivises companies to avoid long-term projects (say afforestation), which may require a more extended period of regular funding. Fifth, firms/companies operating in relatively polluting sectors may be encouraged to use a part of their CSR obligations to adopt climate-friendly technologies/processes.

CSR – the First Mover Group

IV.97 A firm that invests in socially responsible activities ahead of its competitors can reap the benefits of the first-mover advantage. As per the available literature, firms in a duopoly with horizontally differentiated products can influence the willingness of the consumers to pay a higher price by investing in socially responsible activities. If the CSR investment spills over to the follower, the latter can benefit from the second-mover advantage through increase in sales (Kopel, 2021).

IV.98 Through CSR activities, a profit-maximising firm can achieve competitive advantage by focusing on customers with social preferences and a higher willingness to pay. Thus, the market itself offers incentives to make the economy green. The first-mover advantage, however, dissipates with every firm turning green, making winners out of companies that have the best execution (The Economist, 2008). Strict environmental regulations force companies to develop greener technologies, and thus promote innovations that may offset or even exceed the costs of regulatory compliance (Porter and Linde, 1995). Strict regulations lead to technological learning and trigger innovations that generate new areas of specialisation (Brandi *et al.*, 2020).

IV.99 India was the first country in the world to make CSR mandatory (Samantara and Dhawan, 2020). The inclusion of the CSR mandate in the Companies Act, 2013 was a major step in engaging the corporate sector in the equitable development of the country. CSR results in fulfilling the triple objectives of profits, protection of the environment and fight for social justice or what is known as the triple bottom line. To make CSR meaningful, there is a need to internalise such activities and make them part of a company's development strategy. In India, the primary challenge in assessing the success of CSR lies in the lack of reliable indicators of progress (Kumar and Ruhela, 2021). Further, there is a need to publicise the gains that can accrue to companies in terms of the first mover advantage.

Energy and Climate Ranking of States by NITI Aayog

IV.100 In 2022, the NITI Aayog released the State Energy and Climate Index (SECI) to track the efforts made by the States and UTs in the climate and energy domains. The index has been designed to assess and identify the scope for improving the performance of States and to help them efficiently manage their energy resources.

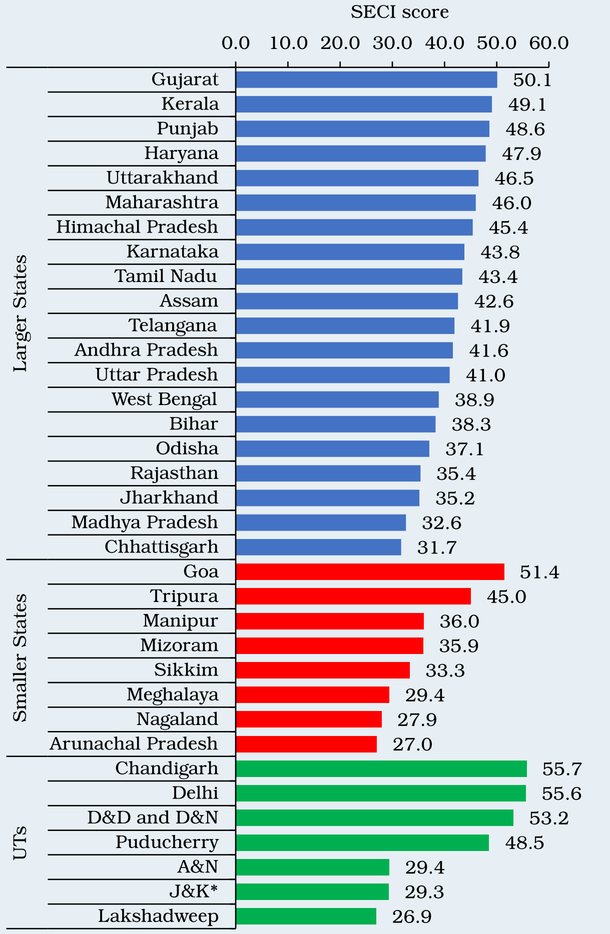
IV.101 Besides high dependence on imports, especially for crude oil, the energy sector accounts for a dominant share of the total GHG emissions of India. Therefore, a paradigm shift is required towards clean energy, with the twin objectives of ensuring affordable and reliable energy to all and reducing dependence on fossil-based energy by accelerating the clean energy transition. To achieve these two goals, the Government is focusing on downstream delivery to improve the transmission and distribution infrastructure and the financial position of the electricity distribution companies (DISCOMs); enhance access to clean and affordable cooking fuel; and ensure 24*7 supply of electricity. All these efforts require differential planning and execution. In the spirit of cooperative and competitive federalism, awarding ranks to measure a State's initiatives can play an important role in improving the country's performance in green transition. This

Table IV.8: Composition of State Energy and Climate Index (SECI)

Parameters	Weightage (Per cent)	Sub-indicators
DISCOMs' performance	40	9
Access, affordability, and reliability of energy	15	5
Clean energy initiatives	15	3
Energy efficiency	6	3
Environmental sustainability	12	4
New initiatives	12	3

Source: NITI Aayog, 2022b.

Chart IV.14: States Ranking and Score in SECI



Note: J&K includes Ladakh.
Source: NITI Aayog, 2022b.

will also be useful for the policymakers and the state authorities in identifying the leaders and the laggards in the energy sector and in fine-tuning policies by benchmarking against the best. The index consists of 6 parameters which are built from 27 indicators (Table IV.8).

IV.102 The scores and ranks are presented separately for large States, smaller States, and UTs (Chart IV.14). The top performers like Gujarat, Punjab and Goa have done well in DISCOMs' performance parameter by addressing the issues of reducing the debt-equity ratio, aggregate technical and commercial losses, and complexity of tariffs. In terms of clean energy initiatives, Chandigarh, Delhi and Goa have performed well as they have been able to pivot towards clean cooking fuel supply, renewable energy generation and CNG vehicles. Tamil Nadu and Maharashtra have done well in terms of energy efficiency by pushing for adoption of the Energy Conservation Building Code and nudging for industrial energy savings. Tripura and Delhi have higher scores in the new initiatives parameter on account of higher EV penetration and shifting consumers to smart meters.

6. Market-based Solutions

IV.103 With 'abatement' as the new catchphrase, there is a movement afoot to lower carbon footprints, even by the traditionally large emitters. The market is also actively adopting sustainability, guided not just by altruism but also in search of higher return. This has sparked a trend towards decarbonisation and digitalisation, nudging the market to come out with tools like environmental, social and governance (ESG) ratings for corporates and debt/equity funds guided by ESG principles. Moreover, in recent years, private equity (PE) firms – the bedrock of capitalism – have become sensitive to ESG factors in allocating their investment.

ESG Rating of Financial Instruments and Entities

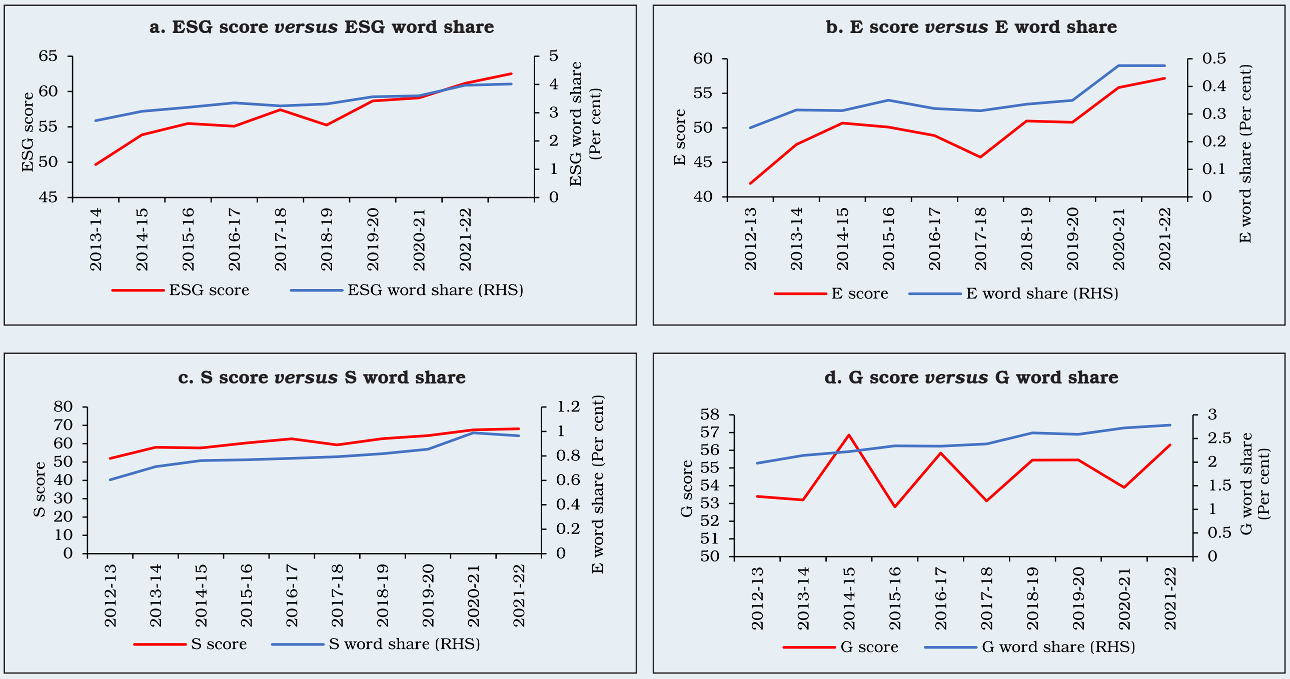
IV.104 There is a growing recognition that companies do not function in isolation; they are both affected by, and, in turn, affect environmental and societal factors. These factors impact firms' performance and sustainability. Therefore, there is a need to measure and evaluate a company's performance on ESG parameters, in addition to financial performance. A heartening development is that Indian companies are increasingly matching their growing ESG concerns with actions to support green transition (Box IV.5).

Box IV.5
Do Indian Companies Walk the Talk on ESG?

The importance of Environmental, Social and Governance (ESG) factors has grown rapidly over the last decade, becoming a prominent agenda item at company board meetings and in corporate communications. The rising focus on sustainability by customers and growing investor preference towards ESG-compliant investment products have ensured that companies are increasingly vocal about ESG-related aspects in their management commentary, as evident from several studies which have gauged this trend using text-mining techniques (Kiriu and Nozaki, 2020; Castellanos *et al.,* 2015; Ho *et al.,* 2021). Nevertheless, critics have pointed out the scope for divergence between the words of corporates and their actions. As corporates try to establish goodwill, their communication may emphasize ESG, without corresponding changes in their activities and performance, akin to greenwashing.

An exercise was carried out to assess whether the evolution of Indian companies' ESG communication over the years has been accompanied by an improvement in their ESG scores. The evolving ESG focus of Indian companies is examined by analysing the annual reports of 50 large-cap companies since 2012-13. These companies are mostly

Chart 1: Average ESG Scores and Word Shares in Annual Reports of Companies



Source: BSE; Refinitiv; and Authors' Calculations.

(Contd...)

part of the NIFTY-50 index[15]. The 491-word ESG dictionary compiled by Baier *et al.* (2020) is used to compute the share of such words in companies' annual reports. The historical ESG scores from Refinitiv[16] are used to proxy companies' actual performance on ESG parameters. The average ESG scores of Indian companies have improved over the last decade, especially for the Environmental and the Social pillars, while the score for the Governance pillar has fluctuated (Chart 1). The rise in the share of ESG-related words in the companies' annual reports has corresponded with the encouraging trend of improvement in performance-based metrics.

To examine whether companies that talk more about ESG show better ESG performance, the following panel data regression model (with time- and industry-fixed effects) is estimated covering data for the period 2012-13 to 2021-22:

$$ESG_{i,t} = \alpha + \beta_1 W_{i,t} + \beta_2 M_{i,t} + \sum_{t=2013}^{2022} \gamma_t D_t + \sum_{1}^{|S|} \gamma_s S_i \ ;$$

where, ESG is the ESG score, W is the ESG word share (in per cent) in the annual report, M is the market capitalisation (proxy for the firm's size) and D and S are indicators for the year and the industry of operation, respectively. It is found that with higher usage of ESG-related terms, the ESG scores also increase (Table 1). This result holds even after controlling for market capitalisation, industry-specific dummies, and different model specifications.

The empirical evidence shows that firms placing greater emphasis on ESG in their communication also tend to be better ESG performers. In this context, it would be interesting to see how the new reporting requirements introduced by SEBI, in conjunction with the law on CSR, would impact the companies' ESG performance.

Table 1: Regression Results Dependent Variable: ESG Score

	(1)	(2)	(3)	(4)	(5)	(6)
ESG Word Share	3.779** (1.598)	3.762** (1.602)	3.491** (1.619)	3.369*** (0.935)	3.737*** (1.166)	3.838** (1.916)
Log of Latest Market Capitalisation		3.677* (2.231)	3.390 (2.337)			
Log of Market Capitalisation					1.125 (1.174)	0.945 (1.830)
Intercept	37.751*** (5.971)	-50.065 (53.204)	-51.036 (57.166)	39.629*** (2.882)	21.809 (15.935)	19.194 (24.888)
Sample Size	431	431	431	431	306	306
No. of Firms	50	50	50	50	35	35
Individual-specific Effects	Random	Random	Random	Fixed	Fixed	Random
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sector Fixed Effects	No	No	Yes	No	No	Yes
Errors	Robust	Robust	Robust	Clustered	Clustered	Robust

Notes: 1. Hausman test lends support to random effects specification.
2. ***: significant at 1 per cent, **: significant at 5 per cent, *: significant at 1 per cent.
3. Standard errors in parentheses.

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Baier, Philipp, Marc Berninger, and Florian Kiesel (2020) "Environmental, Social and Governance Reporting in Annual Reports: A Textual Analysis", Financial Markets, Institutions & Instruments 29, No. 3.

Castellanos, Arturo; Parra, Carlos; and Tremblay, Monica, "Corporate Social Responsibility Reports: Understanding Topics via Text Mining" (2015). *AMCIS 2015 Proceedings.*

Ho, Jerry C., Ting-Hsuan Chen, and Jia-Jin Wu (2021) "Are Corporate Social Responsibility Reports Informative? Evidence from Textual Analysis of Banks in China" China Finance Review International 12, no. 1.

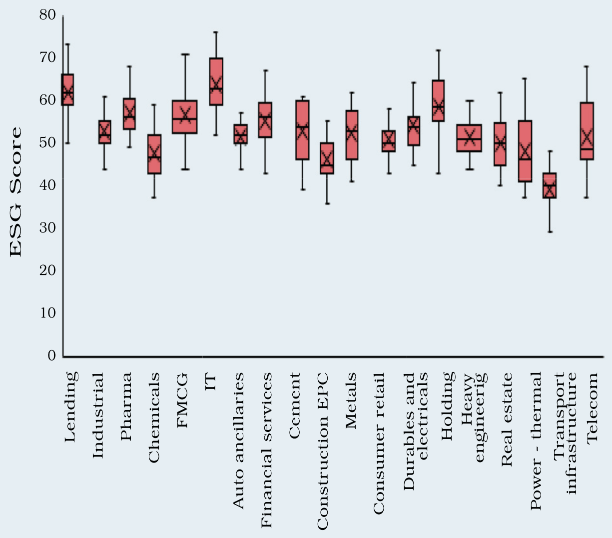
Kiriu, Takuya, and Masatoshi Nozaki (2020) "A Text Mining Model to Evaluate Firms' ESG Activities: An Application for Japanese Firms" Asia-Pacific Financial Markets 27, No. 4.

15 As of October 2022.

16 The ESG score measures a company's ESG performance based on verifiable reported data in the public domain. Refinitiv captures and calculates over 630 company-level ESG measures, of which a subset of 186 of the most comparable, are used in the scoring process. These are then grouped into 10 categories that are further rolled up into the three scores – environmental, social and corporate governance.

IV.105 The ESG rating agencies assess companies across geographies/industries on their custom-defined templates to evaluate a firm across the ESG pillars and assign a rating to it. The coverage of Indian companies by the major global ESG rating providers (ERPs) is limited. The India ESG leadership summit report, however, covered 586 companies (CRISIL, 2022). An analysis of the ESG scores for Indian companies in major sectors reveals that information technology (IT) companies expectedly have the highest average ESG scores, while transport infrastructure companies have the lowest scores (Chart IV.15). Component-wise analysis of ESG scores found the highest degree of variation in the environmental score, both within and across sectors.

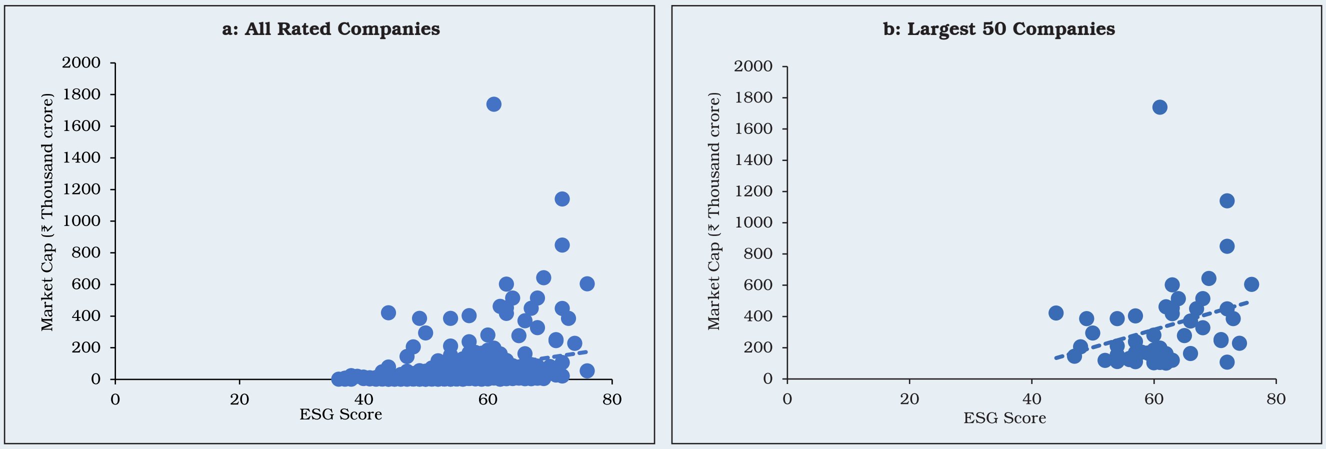
Chart IV.15: Sectoral Average ESG Score



Source: CRISIL; and Authors' Calculations.

IV.106 On the relationship between firm-specific characteristics and ESG performance, it is found that firms with higher market capitalisation have higher ESG scores (Chart IV.16a). When the sample is reduced to include only large firms, the relationship between market capitalisation and ESG score becomes even more prominent (Chart IV.16b). This shows that a firm's growth and perceived valuation by the investors is inherently correlated with its performance on the ESG parameters. A good performance on the ESG parameters is a reflection that the firm can minimise its risks on the ESG front, enabling it to grow and also get rewarded by the investors. Also, a large company has more resources at hand to improve its performance on the ESG front, and

Chart IV.16: Relationship between Market Capitalisation and ESG Score



Source: Bloomberg; CRISIL; and Authors' Calculations.

has greater stakes, driving it to make investment that mitigates risk from ESG-related events.

IV.107 As financial market participants become increasingly interested in ESG-related aspects, the role and influence of ESG ratings and data providers is growing. These entities have, however, come under increased scrutiny in recent times. The International Organization of Securities Commissions (IOSCO) in its report on ESG Ratings and Data Products Providers has highlighted issues such as: (a) lack of clarity/ alignment on definitions, including on what exactly the ratings measure; (b) lack of transparency about the methodologies behind the ratings/data products; (c) uneven coverage of rating products offered; and (d) concerns about the management of conflicts of interest when the ratings and data product providers, or their closely associated entities, perform consulting services[17] for the client companies (IOSCO, 2021).

IV.108 Two major concerns on the methodology employed for computation of the ESG scores are: (i) Most ESG ratings include too many parameters leading, at times, to a convoluted picture making it tough for the average investor to understand what the aggregate ESG score stands for; and (ii) The arithmetic average is mostly employed for aggregation of different parameters to compute the ESG rating. It corresponds to viewing E, S and G scores as perfect substitutes, allowing a company the flexibility to mask its poor performance in one parameter by focusing on good performance in others.

IV.109 With each ERP using its own proprietary system, algorithms, metrics, definitions, and sources of non-financial information, there is scope for wide variations in the ESG ratings of the same firm by different providers (Chatterji *et al.*, 2016). An analysis by Bloomberg found that an ESG rating upgrade for many companies was rarely accompanied by their record on sustainability (Simpson *et al.*, 2021).

IV.110 Further, research has shown that an ESG rating agency's underlying bias or the overall view of a firm has an influence on the ESG rating provided to the firm (Berg *et al.*, 2019). Also, the precision and efficiency of ESG ratings cannot be evaluated by commonly used procedures like back-testing, due to the absence of simple observable outcome variables such as default events (Erhart, 2022). These issues and the absence of an appropriate regulatory regime to oversee the methodology or data collection process, further undermine the credibility of ESG ratings.

IV.111 The ESG scores of firms located in EMEs are found to be systematically lower than those in AEs (IMF, 2022b). This is partly explained by the treatment of missing data on certain parameters. The absence of a globally agreed reporting format makes ERPs adopt parameters which are most widely reported and relevant for the AEs, thus putting the firms in the EMEs at a disadvantage.

IV.112 The IOSCO has recommended that regulators should focus their attention on ESG ratings and data products providers. Standardised definitions of the terminologies and written policies and procedures would enable the ESG ratings and data products providers to generate high quality data. Public disclosures of their methodologies and processes would help achieve transparency. The

[17] There may be instances where the ERP also has a consulting subsidiary which might be providing other services such as on improving ESG performance and even non-ESG related consultancy to the company it is rating.

entities being assessed should streamline their disclosure processes for sustainability-related information in accordance with the applicable regulatory and other legal requirements (IOSCO, 2021).

IV.113 Following the nudge from the IOSCO, several securities market regulators are updating their guidelines on ESG ratings and data products providers. An ESG rating/score is only as good as the data used to arrive at it. Standardised and regular company disclosures are, therefore, of utmost importance. SEBI took the first step towards making ESG reporting a part of regulatory reporting in 2012, when it mandated the top 100 listed entities by market capitalisation to file Business Responsibility Reports as part of their annual reports. This requirement was progressively extended to the top 500 listed entities in 2015 and to the top 1000 in 2019.

IV.114 SEBI has now introduced a revamped disclosure framework, titled the Business Responsibility and Sustainability Report (BRSR), which aims to put more emphasis on quantifiable metrics (SEBI, 2021). This, in turn, would allow easier measurement and comparability across companies, sectors and time. The BRSR seeks disclosures from listed entities on their performance against nine principles of the 'National Guidelines on Responsible Business Conduct'. Reporting under each principle is divided into essential and leadership indicators. The essential indicators are required to be reported on a mandatory basis, while the reporting of leadership indicators is voluntary. Filing of BRSR is compulsory for the top 1000 companies by market capitalisation from 2022-23. This should result in better data quality on ESG parameters.

IV.115 Further, SEBI has introduced a framework of BRSR core which consists of select key performance indicators under each of the E, S and G attributes aimed at enhancing credibility and investor confidence in the ESG-related disclosures. This is to be achieved by verification of the reported data by an assurance provider. The BRSR core will have to be filed by the top 150 listed entities from 2023-24 and will be progressively extended to the top 1000 by 2026-27. Further, based on disclosures in the BRSR core framework, the ERPs will publish a core ESG rating based on assured/verified data. To curb greenwashing at the scheme level by mutual funds (MFs), the regulator has mandated that an ESG scheme shall invest at least 65 per cent of its assets under management (AUM) in companies, where assurance on BRSR core is undertaken. Further, to get a complete picture and account for ESG footprints associated with the value chain of a company, SEBI has introduced ESG disclosures and assurance as per BRSR core, for the supply chain of top 250 companies on a "comply-or-explain" basis from 2024-25 and 2025-26, respectively (SEBI, 2023d).

IV.116 Regulators can identify the ESG leaders and standardise some of the practices and processes adopted by them as mandated regulations over time. This can allow the regulation formulation process in the ESG space to be well-tested and have wider acceptability.

IV.117 A framework after incorporating recommendations from all the stakeholders including relevant ministries, industry associations, environmental policy advocacy groups, and other regulators including the Reserve Bank will help address the major issues plaguing ESG ratings. SEBI is establishing a regulatory framework and a code of conduct for ERPs which covers a range of pertinent concerns related to business models, accountability and transparency in the rating process (SEBI 2023e; SEBI 2023f).

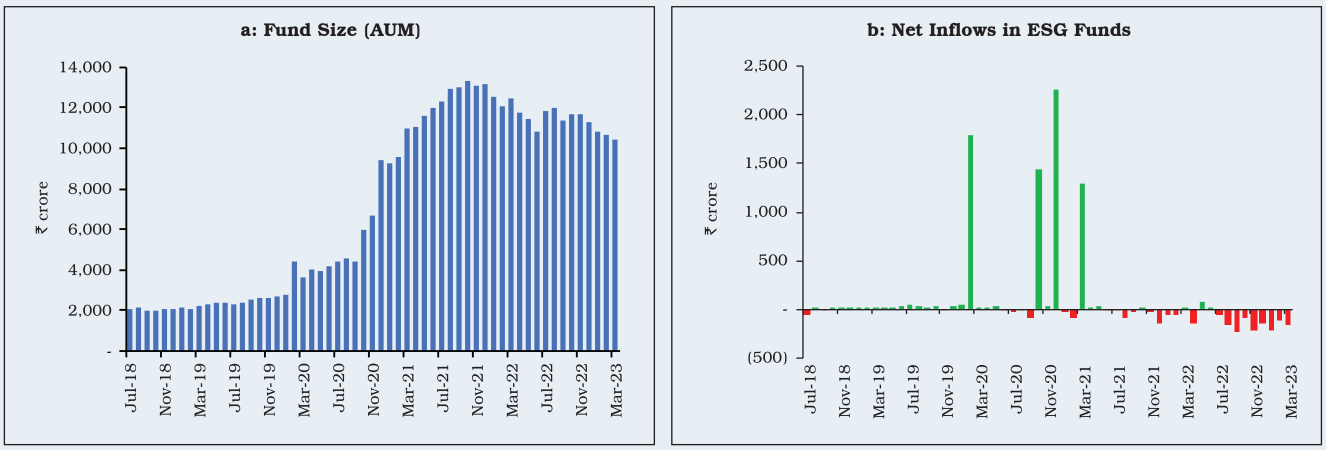
ESG Funds

IV.118 The first ESG Fund in India was launched by the SBI Mutual Fund in 2017[18]. The onset of the pandemic gave a major impetus to ESG funds across the world, including India. While it led to the launch of 8 new funds with the ESG theme, the AUM of ESG funds more than quadrupled in less than two years to ₹13,146 crore as on December 31, 2021. There was, however, stagnation in asset growth thereafter, driven not just by decline in valuation but also net outflow of ₹1,393 crore in 2022-23. As a result, the AUM of ESG funds declined to ₹10,427 crore as on March 31, 2023 (Chart IV.17a).

IV.119 An analysis of the net inflows data shows large inflows in some months followed by negligible inflows in subsequent months (Chart IV.17b). The large inflow months are typically those which had new funds launched. This pattern reflects that while investors lap up the new fund offers in the ESG domain, subsequent investment remains tepid. Post the delta wave of COVID-19 in India, not only have the new fund offers for ESG funds stopped, but there have also been outflows.

IV.120 ESG funds and indices have been criticised for various reasons. First, is their stock selection, with some questionable inclusions and exclusions. The 20 largest ESG funds globally have, on average, investment in 17 fossil fuel producers each, thereby undermining the environmental dimension of ESG investing (The Economist, 2021). Second, a considerable portion of funds labelled as ESG don't select stocks based on ESG ratings or performance on ESG parameters but use ESG ratings as one among many risk management tools for their usual portfolios. This is analogous to non-ESG themed funds being labelled as ESG.

Chart IV.17: ESG Funds in India



Source: Morningstar.

[18] SEBI had issued a circular on categorisation/rationalisation of mutual fund schemes to bring about uniformity in the functioning of asset management companies and to standardise attributes of mutual fund schemes across specific categories. One of the categories introduced was sectoral/thematic under equity mutual funds, which is used for the launch of ESG funds. Post re-categorisation of norms by the SEBI, the SBI Mutual Fund converted its erstwhile SBI Magnum Equity scheme into an ESG themed mutual fund and renamed it as SBI Magnum ESG Equity Fund.

IV.121 In order to provide better clarity on the ESG strategies of MFs, the regulator has proposed new sub-categories of ESG funds based on underlying strategies. A more active stewardship role for asset management companies has been envisioned mandating enhanced disclosures on voting decisions with specific focus on ESG factors. For ESG-related funds, a separate section on 'fund manager commentary' and case studies detailing issues like the application of the ESG strategy in the fund has also been introduced (SEBI, 2023d).

IV.122 The absence of dedicated ERPs of global repute for EMEs, including India, is a factor contributing to the limited inflow of ESG funds to them. Allocations to EMEs (equities and bonds) by ESG funds are lower than those by non-ESG funds. ESG is a new trend, and regulators worldwide are trying to understand the market before developing detailed guidelines. This is a prudent thing to do as over-regulation may stifle innovation.

The Role of Private Equity

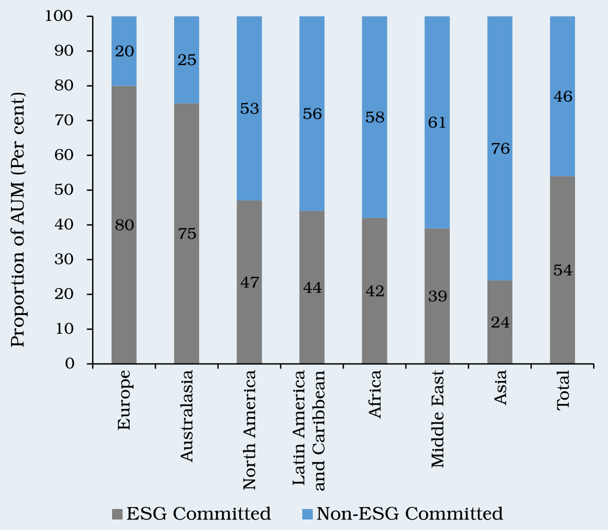
IV.123 The global climate finance currently stands at about US$ 630 billion annually, which is about one-fifth of the estimated requirement (Climate Policy Initiative, 2021). The share of private equity (PE) is less than 4 per cent (The City UK, 2022). With their high-risk appetite, PE and venture capital (VC) funds should increasingly fill the gap, guided by the returns that the investment generates.

IV.124 In 2021, PE had US$ 6.3 trillion in AUM, projected to exceed US$ 11 trillion by 2026 (Eccles *et al.*, 2022). The number of PE and VC signatories to Principles of Responsible Investment (PRI)[19] has quadrupled to 1090 by 2021. PE is uniquely positioned to support the green transformation as its longer investment horizon positions it to undertake investments in projects with long gestation periods. A major limitation of PE/VC funding, however, is that it is mainly restricted to small-sized private companies that potentially have large commercial value but not necessarily projects that have the most significant social and climate benefits.

IV.125 There is considerable opportunity to accelerate the deployment of PE/VC capital, especially in emerging markets. In Asia, just 24 per cent of private assets are committed to ESG, compared with Europe's 80 per cent (Chart IV.18).

IV.126 India too has seen the entry of private investment groups in the climate financing landscape. Eversource Capital, a joint venture between Everstone (one of India's leading private investment groups) and Lightsource BP (BP's renewable energy platform) started

Chart IV.18: Private Capital Assets Management



Source: Preqin (2020): The Rise of ESG in Alternative Assets, Impact Report.

19 PRI, a UN-supported organisation, is a leading proponent of responsible investment and supports its international network of investor signatories in incorporating ESG factors into their investment/ownership decisions.

India's first dedicated climate change fund – the Green Growth Equity Fund (GGEF) in 2018. The CGEF targets raising equity capital up to US$ 940 million for India's green infrastructure sectors such as renewable energy, transport, resource efficiency and energy services (Eversource Capital, 2021).

IV.127 With a deal value of US$ 7.9 billion, the share of ESG in total PE investment in India increased from 5 per cent in 2021 to 13 per cent in 2022 (Bain & Company, 2023). About 90 per cent of the cumulative investment of US$ 19.2 billion between 2018 and 2022 has been in clean energy and electric mobility. This is driven by increased cost competitiveness on the back of improved efficiency, growing climate awareness as also Government policies including regulatory policies that provide the tailwind.

7. Monetary Policy

IV.128 While several central banks remain cautious[20] on incorporating climate concerns directly in their monetary policy framework and operations to avoid potential dilution of accountability in relation to their principal mandate(s), the European Central Bank (ECB) and the BoE are the two major central banks that have adopted climate change considerations explicitly into their monetary policy operations. It is estimated that the emission reduction through a carbon tax is four times the maximum reduction possible through green quantitative easing (Abiry *et al.,* 2022). The latter can, however, serve as an effective complementary policy instrument.

Monetary Policy Transmission

IV.129 Climate change could alter the speed, role and nature of monetary policy transmission. For instance, sectors that are more exposed to climate-induced physical risks may face a higher risk premium due to greater credit risk and lower asset valuation. As a result, the credit channel and the interest rate channel of monetary transmission may get impeded. This section delineates the monetary policy tweaks that can encourage green transition.

Green Quantitative Easing

IV.130 In the wake of the global financial crisis, quantitative easing (QE) or large-scale asset purchases, emerged as one of the primary monetary policy tools of central banks in major AEs. With the outbreak of the pandemic, QE was widely adopted by both AEs and EMEs.

IV.131 When central banks purchase corporate debt, they drive down risk premium, thereby improving the ability of the corporates to finance their activities at lower costs. Asset purchases are mostly carried out on the principle of "market neutrality" – bonds are purchased in proportion to their outstanding quantity in the market to minimise the impact of the purchase on the relative borrowing cost across sectors (Papoutsi *et al.*, 2021; Zielińska-Lont, 2019). The presence of externalities, however, often drives a wedge between market prices and efficient asset values. The market neutrality principle is, thus, suboptimal as it results in a pro-carbon bias by benefiting large firms in carbon-intensive industries (Schnabel,

[20] In a seminar organised by the Riksbank in January 2023, the Federal Reserve Chairman mentioned that the Fed would not be a climate policy maker. At the same seminar, a member of the Executive Board of the European Central Bank re-iterated that the fight against climate change was a part of ECB's official mandate as long as it did not hamper its primary task of maintaining price stability. In this context, it was noted that the current tightening phase of monetary policy would not be deviated due to possible concomitant increase in the cost of efforts for de-carbonising the economy.

2021). As per one estimate, over 70 per cent of the ECB's corporate bond holdings belonged to sectors associated with high or very high impact on nature (Kedward *et. al.*, 2021).

IV.132 The ECB began decarbonising its corporate bond holdings in October 2022 (ECB, 2022). Purchases for re-investment purpose are tilted towards issuers with a higher climate score, which, in turn, is compiled from the backward-looking emissions sub-score, forward-looking target sub-score and climate disclosure sub-score. This is helping the ECB in improving the weighted average climate score of its holdings over time. In line with the UK's commitment to net zero GHG emissions by 2050, the BoE started greening its corporate bond portfolio in November 2021, with an intermediate target of reducing the weighted average carbon intensity of the corporate bond purchase scheme portfolio by 25 per cent by 2025 (BoE, 2021).

IV.133 Further, some central banks have introduced new monetary policy tools to provide low-cost funds to financial institutions for channelising them to private firms in sectors such as clean energy, energy conservation and carbon reduction technologies (BoJ, 2021; Abiry *et al.*, 2022). The Bank of Japan (BoJ) started funds-supplying operations to support financing for climate change responses in 2021. Under this, the BoJ provides 1-year loan at 0 per cent interest matching the investment or loans by banks in projects that contribute to Japan's actions to address climate change. The total outstanding loans under this scheme was ¥4.4 trillion as of January 2023 (BoJ, 2023). The People's Bank of China (PBoC) launched the carbon emission reduction facility in November 2021. Under this, it provides commercial banks with funds worth 60 per cent of the principal amount lent by them for emissions-reducing projects at an annual interest rate of 1.75 per cent. The total outstanding loans under this scheme was US$ 43.6 billion as of December 2022, supporting about 0.1 gigatonne of reduction in CO_2 emissions (Central Banking, 2023).

IV.134 Under the extant rules in India, commercial banks are required to invest 40 per cent of their adjusted net bank credit in priority sectors, which include renewable energy[21]. While this policy helps channelise credit towards the renewable energy sector, it could be complemented with a targeted new scheme to provide low-cost funds to banks for onward lending and thereby, lowering the borrowing costs of firms operating in the renewable energy space.

Collateral Policy for Access to Liquidity

IV.135 The ECB has enunciated plans to green the collateral for its liquidity operations. It will restrict the share of assets issued by high carbon footprint entities that can be pledged as collateral for borrowing from the Eurosystem. The new limits would initially apply to marketable debt instruments issued by non-financial corporations and extended to other instruments with improvement in climate-related data. The limit is expected to kick in before end-2024. Further, climate change risks are also set to become a factor for determining haircuts on corporate bonds used as collateral. The ECB is also working on bringing to fruition climate-related disclosure requirements for assets that can be pledged as collateral with a timeline of 2026.

[21] Bank loans up to a limit of ₹30 crore to borrowers for purposes like solar-based power generators, biomass-based power generators, windmills, micro-hydel plants and for non-conventional energy based public utilities, *viz.*, street lighting systems and remote village electrification *etc.*, are eligible for priority sector classification. For individual households, the loan limit is ₹10 lakh per borrower.

IV.136 In India, the only eligible collateral for availing funding from the Reserve Bank is Government securities, issued by the Centre or the States. Currently, the margin requirements on the collateral for availing central bank liquidity increase in line with the residual maturity of the collateral. Further, the margin requirement for unrated State Government securities (SGS) is 1 per cent higher than rated SGS of same residual maturity bucket. A possible revamped collateral policy could help in enhancing flexibility for the Reserve Bank to allow relatively higher relaxation in margin requirements for accepting SGBs, under the Liquidity Adjustment Facility/Marginal Standing Facility to provide liquidity.

CRR Exemptions on Green Credit

IV.137 To enhance credit flows to the low carbon (or green) sectors or industries in transition, reserve requirement could be a possible policy instrument. Among EMEs, Banque du Liban, the central bank of Lebanon, follows a differentiated reserve requirement policy based on the carbon footprint in the loan portfolios of banks (Dikau and Volz, 2018). Banks that have a higher share of green assets in their portfolio are mandated lower reserve requirements. This increases the availability of loanable funds for banks to earn a higher return. Implementation of this policy requires a verifying authority/institution that certifies the utilisation of a loan in green projects. For instance, in Lebanon, the Lebanese Centre for Energy Conservation – a government agency – verifies a project after which a loan becomes eligible for preferential reserve relaxation.

IV.138 In India, since the Reserve Bank is the regulator and supervisor of banks in addition to being the monetary authority, it may not require an additional institutional arrangement for supervising the loan portfolios of the banks. A third-party verification would, however, be required to validate the carbon footprint of projects and determine eligibility for reserve requirement relaxation. Targeted reserve requirement relaxations were adopted by the Reserve Bank in the past to direct lending to certain productive sectors that have multiplier effects. In 2020, during a 6-month period, incremental retail credit to automobiles and residential housing and loans to the Micro, Small and Medium Enterprises (MSMEs) were made eligible for deduction from the net demand and time liabilities for computing the reserve requirement for the tenure of the loan/five years, whichever was lower. After the reserve requirement relaxation, credit offtake to MSMEs improved during the COVID-19 pandemic (RBI, 2022c). Also, to give a fillip to financing of infrastructure, the Union Budget for 2014-15 had announced that banks would be "*permitted to raise long-term funds for lending to infrastructure sector with minimum regulatory pre-emption such as CRR….*". The Reserve Bank issued necessary guidelines in this regard in July 2014. As per sectoral deployment of credit data, the total outstanding credit to infrastructure increased by 62.6 per cent between March 2014 and March 2023.

Central Bank Digital Currency (CBDC)

IV.139 The Indian CBDC or e₹ is in the pilot stage for both wholesale and retail uses and is expected to be more environment friendly compared with cash. CBDC helps curb emissions by nullifying operations such as printing, storage, transportation, and replacement of physical currency. The total expenditure on printing of banknotes in 2021-22 was ₹4,985 crore and it does not account for the ESG costs of printing money (RBI, 2022d). At the outset, instituting a CBDC may entail significant fixed infrastructure costs but subsequent marginal operating costs are estimated to be very low (RBI 2022d).

IV.140 If designed with ESG objectives in mind, a CBDC could be more environment friendly compared to alternative cashless methods. Payments effected through CBDC would be instantaneous and final, and reduced reliance on clearing corporations and other settlement infrastructure could cut down energy consumption. The energy requirement of a digital currency depends on its underlying technological stack. Central banks may issue CBDCs based on energy-efficient algorithm-driven processes as against mining by numerous agents working under competitive reward structures. This can help CBDCs have higher transaction throughput compared to crypto currencies for the same energy input. Further, contingent on specific details of how they are configured, CBDCs can be more energy efficient than much of the current payment landscape, including credit and debit cards (Agur *et al*., 2022). Estimates indicate that non-Proof of Work permissioned[22] networks – what CBDCs are likely to be – are significantly more energy efficient than current credit card processing centres, in part because the latter involve energy-inefficient legacy systems.

8. Nudging Behavioural Change

IV.141 Mission LiFE introduced by India at COP 26 aims to nudge individuals and communities to adopt environmentally sustainable lifestyles. Behavioral changes that are required to mitigate climate change include responsible consumption, a circular economy *i.e.*, reuse and regeneration of materials or products, living in harmony with nature, sustainable resource management, co-existence and cooperation (PIB, 2022b). Two measurable objectives of the mission are to: (a) mobilise at least one billion Indians/other global citizens to take individual and collective action for protecting and conserving the environment during 2022–28; and (b) make at least 80 per cent of India's villages and urban local bodies environment-friendly by 2028 (NITI Aayog, 2022c). The transition process may involve distinct shifts in demand, supply and policies – a shift in demand patterns of individuals preferring environment-friendly goods and services; a shift in supply in response to anticipated changes in demand pattern and also following a large number of firms voluntarily embracing greener business practices; and a shift in policy stance to support sustainable consumption and production.

IV.142 Mission LiFE 2022-23 enlisted 75 specific, easy-to-practice actions across seven categories – saving energy; saving water; reducing single-use plastic; adopting sustainable food systems; reducing waste generation; adopting healthy lifestyles; and reducing e-waste. A Government programme to provide individuals with an informed choice about one of the actions – energy saving – is the "Standards & Labelling Program" by the BEE. Star labelling of appliances is a cost-effective policy tool for improving energy efficiency and lowering the energy cost of appliances for the consumers. This programme aims to foster a sustainable "market transformation" by shifting the market towards increased sales of energy-efficient star-labelled products. The Government's zero subsidy domestic lighting programme, *Unnat Jyoti* by Affordable LEDs for All (*UJALA*), launched in

[22] Not publicly accessible.

2015, enhanced consumer awareness on financial and environmental benefits associated with energy efficiency. The scheme makes affordable energy accessible and has successfully reduced the retail price of LED bulbs from ₹300-350 per bulb to ₹70-80 per bulb (PIB, 2022c).

IV.143 GOBARdhan is another multi-stakeholder driven Government scheme. Under the *Swachh Bharat Mission Grameen* – Phase II, *GOBARdhan* scheme is being pursued with the objective of supporting villages in managing their cattle, agro residues and biodegradable waste effectively. The Department of Drinking Water and Sanitation is providing technical assistance and financial support of up to ₹50 lakh per district, aiding villages in converting their waste into wealth, improving environmental sanitation, curbing vector-borne diseases, and converting organic waste to biogas and organic manure for use in rural areas.

IV.144 A voluntary energy saving plan introduced by the EU in 2022 in the backdrop of tight natural gas supplies following the Russia-Ukraine war – "Save Gas for a Safe Winter" – proposed a voluntary gas demand reduction target of 15 per cent from August 2022 to March 2023. It suggested various measures such as norms for use of air conditioning, street lighting, air drying laundry, switching off lights when not required, and improving home insulation to reduce the demand for gas across the economy from the public sector, businesses, as well as households (European Commission, 2022). Similar voluntary norms could also be envisaged for reducing food wastage – estimated at around 14 per cent of total production – between harvesting and retail, to reduced GHG emissions (Singh and Chaudhary, 2023).

IV.145 Nudging behavioural changes would be the least cost yet effective way to pursue the green transition agenda. Interventions such as awareness creation through advertising, labelling and certifications (carbon labels on the lines of food labelling), legislation (such as the recent ban on single-use plastic), incentivising purchase of sustainable products (such as subsidies by the Government for EV adoption), could empower consumers with information required for adoption of low carbon products (Rajan and Vani, 2023).

9. Impact of Policy Interventions on Reducing Carbon Emissions: A Scenario Analysis

IV.146 While all policy options covered in this chapter need to form a part of a comprehensive strategy for reducing carbon emissions in India, fiscal, regulatory, and non-fossil fuel related policies would be particularly important to achieving the intended ultimate net zero goal. Globally, carbon taxes are reckoned as one of the most efficient instruments for reducing carbon emissions, particularly in hard-to-abate sectors such as iron and steel, non-ferrous metals, non-metallic minerals and chemicals (Paltsev *et al.*, 2022; IMF, 2019). ETS – the auction or allocation of emission permits – may also help curb emissions by similar level if applied to a wider canvas of economic activities. Standards for carbon emission rates and energy efficiency prescribed as part of regulatory policies, and feebates/rebates for technologies that emit higher/lower than average emissions could also help in reducing the overall CO_2 emission level in an economy.

IV.147 Recognising that most of the available estimates on the impact of any policy intervention in reducing carbon emissions are not precise and conditional on the validity of assumptions, an attempt is made to generate scenarios of the likely CO_2 emission reduction in India under various policy interventions discussed above. Two broad scenarios relate to imposing a carbon tax of US$ 25 per tonne and US$ 50 per tonne, respectively, of CO_2 emission. Along with the carbon tax, other policies such as feebate, regulatory policies and ETS have been considered. These scenarios mostly use the estimated parameters projected by the IMF (2019). The impact of progress on green hydrogen and EVs has also been considered, as they can help reduce the demand for fossil fuels (Niti Aayog, 2022d).

IV.148 Estimates suggest that a carbon tax of US$ 25 per tonne (US$ 50 per tonne in the second scenario) can reduce carbon emissions by 25 per cent (36 per cent) compared with the baseline scenario of "business as usual" projected for 2030 by the IMF (2019). A combination of other policies such as ETS, feebate and regulatory measures could reduce the CO_2 emissions by nearly 93 per cent of the reduction achieved through carbon taxes. For the hard-to-abate sectors, the adoption of green hydrogen could cumulatively reduce CO_2 emissions by 3.6 gigatonnes between 2020 and 2050 (Niti Aayog, 2022). Similarly, as per the Announced Policies Scenario (APS) of the IEA, the oil (or fossil fuel) displacement as a result of EV adoption in buses, trucks, vans and cars stands at 0.22 million barrels per day by 2030 (IEA, 2023a). Both, the adoption of green hydrogen and the displacement of fossil fuels together can reduce nearly 1.1 gigatonnes of CO_2 emissions between 2021 to 2030[23].

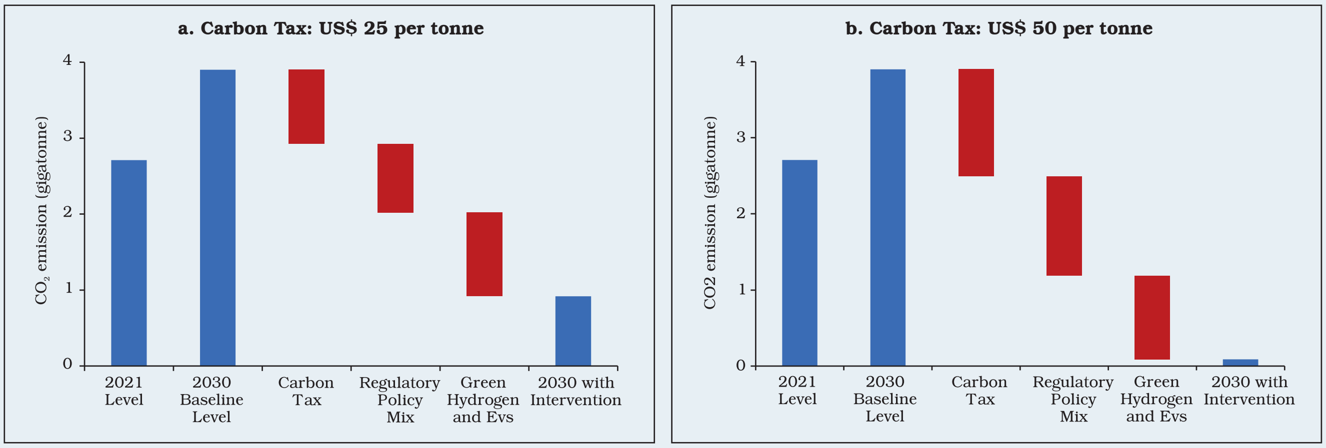
IV.149 As of 2021, India's total CO_2 emissions stood at 2.7 gigatonnes (Our World in Data, based on Global Carbon Project, 2022). In the baseline scenario of no policy intervention, the emission level may rise to 3.9 gigatonnes in 2030 (please refer to Chapter 2). With the implementation of carbon taxes, *i.e.,* US$ 25 per tonne and US$ 50 per tonne under the two scenarios, accompanied by other measures mentioned above, CO_2 emissions can be reduced to about 0.9 and 0.1 gigatonne, respectively (Chart IV.19). The scenario analysis highlights the critical significance of a multi-pronged policy approach to achieving the updated NDC committed in 2022. Besides the current policy thrust on incentivising renewables and EVs, innovative technologies such as green hydrogen, energy efficiency, carbon sink and lifestyle changes, it may be necessary to introduce explicit carbon taxes to reduce carbon emissions from the hard-to-abate sectors.

10. Concluding Observations

IV.150 Climate policies hold the key to disaster risk reduction and protecting people and the planet. A comprehensive climate action plan, building on growing public and political will, has three broad dimensions – design, implementation, and a constant review to assess what works and what does not. The strategic action plan covers both mitigation – reducing CO_2 emissions, and adaptation – learning to adapt, while pursuing climate resilient economic development. As the scale of the challenge is enormous and still growing, the battle against the climate crisis has to be sustained, notwithstanding misinformation and greenwashing tendencies that may occasionally disrupt the process. In 2022, the world population crossed the 8 billion mark, while the global growth outlook has remained subdued since the

[23] Using a conversion factor of 0.43 metric tonnes CO_2/barrel as provided in the US EPA (2023).

Chart IV.19: Scenario Analysis for CO_2 Emission Reduction



Note: The 2030 baseline level of CO_2 emissions without any policy intervention is as estimated by the IMF (2019). A carbon tax of US$ 25 per tonne (US$ 50 per tonne) could reduce emission by 25 per cent (36 per cent) in the hard-to-abate sectors. The regulatory policy mix consisting of ETS, feebates, and regulatory measures can contribute about 93 per cent of the emissions reduction that could be achieved through a carbon tax. Green hydrogen and EVs can reduce CO_2 emission by 1.1 gigatonnes. Carbon capture and storage can raise further the estimated benefits from technology. CO_2 emission can be reduced to nearly 0.9 gigatonne (0.1 gigatonne) from a baseline level of 3.9 gigatonnes if all possible policy interventions are made in a co-ordinated manner as part of a national level strategy. The combined impact estimated here is indicative, based on available independent estimates for the impact of each specific type of policy intervention.
Source: Authors' calculations.

COVID-19 pandemic with rising concerns about possible moderation in trend growth (World Bank, 2023). Climate action plans of countries, therefore, may have to balance the trade-off costs of green transition. The unavoidable preference for fossil fuel in several countries since the start of the Russia-Ukraine war highlights the need for flexibility in implementing the climate action plan. India already has in place a well-designed action plan, with specific policy interventions aimed at collectively pursuing the overall net zero target. This chapter reviews all feasible policy actions – existing and more – with an assessment of their likely contribution to reducing carbon emissions relative to India's updated NDC commitments.

IV.151 Fiscal policy has a prominent role in driving green transition given its high potential effectiveness and the trust of the public in the Government's actions being in the broader national interest. Under fiscal policy, the various instruments available are carbon pricing using carbon taxes or ETS; green bonds issued by the Government and public sector enterprises for deployment of resources in green projects; feebates; and public green investment. First, India needs to introduce a broad-based carbon pricing system in line with emerging global best practices to meet its climate goals. Second, a carbon tax may need to be accompanied by complementary redistributive policies due to its regressive nature, in view of the inability of the weaker sections of the society to move to eco-friendly modes of production and patterns of consumption. Third, an ETS, linked to green taxonomy, covering all sectors of the economy may be introduced, which can partly balance subsidy (less polluting industries getting carbon credits for trading) and tax (more polluting industries that should have to buy carbon certificates). While a carbon tax may be more effective, an ETS may be less politically contentious. Fourth, there is a need for an effective green taxonomy to identify sustainable green assets and activities and limit the potential risk of greenwashing. Finally, once a green taxonomy is in place, there is a need to properly record public spending on climate change and related issues and report them in a climate budget report as a supplement to the annual budget.

IV.152 The role of new technology and supportive policies for innovation is critical for progress on both mitigation and adaptation fronts. The spurt in technological progress seen recently in renewable (solar and wind) energy, EVs, green hydrogen, carbon capture and storage, and energy-efficient appliances would require a global framework to ensure easy access to technology for all, and an efficient global supply chain with access to key minerals to make the green transition cost affordable. First, India needs to acknowledge that the technological advances and the associated fall in prices of key inputs have been driven by targeted policies and R&D investments by Governments the world over, and the same should be sustained, while exploiting ways to improve access to technology and critical mineral resources through multilateral, regional and bilateral strategic partnerships. Second, India has achieved significant progress in renewable energy generation capacity, and efforts need to be stepped up in addressing the variability in wind and solar power supply through appropriate energy storage technology and demand management mechanisms using smart grids. Third, for enhancing domestic energy security given the risks from ongoing global geo-economic shifts, current policies focussing on developing an indigenous renewables supply chain would require ramping up of domestic capacity to mine lithium, cobalt and rare earth elements and/or procure them through long-term contracts and outward FDI; and domestic manufacturing of critical equipment such as batteries, electrolysers, PV cells, EVs, and other associated components. Fourth, continuing advances in application of AI and ML present an opportunity to tackle climate change through better resource management. In the transport sector, the concept of MaaS and ITS may be explored in India's smart cities. Further, green building standards may be complemented with IoT based monitoring and AI and ML driven optimisation to manage and reduce energy demand. Fifth, climate resilient agriculture is the need of the hour for a sustainable future, and climate-smart agriculture practices such as integrated pest management, conservation tillage and enhanced nutrition management may be promoted, in addition to the development of a climate-resilient infrastructure network. The production of green hydrogen using renewable energy and investment in carbon capture and storage technologies would provide further impetus to sustainable energy security for the nation.

IV.153 While carbon emissions could originate from any country, climate disaster risk is a global concern. Trade policies have the potential to contribute to risk mitigation. Liberalisation of cross-border trade could provide gains to developing countries in terms of economic growth and enhanced productivity; however, its impact on environment remains debatable. India needs to recognise that protectionist policies of countries are increasingly becoming sensitive to the carbon content of imports, which could affect India's medium-term export outlook unless Indian exports meet green standards of importing nations. At the global level, various steps also need to be taken to facilitate the diffusion of green technologies and improve the carbon efficiency of international trade. First, RTAs should increase their focus on green and clean energy products. Second, concerted efforts should be made to increase the export share of climate-friendly goods across India's key trading partners. Third, active steps may be taken towards reducing the carbon content of international trade. Fourth, expertise in negotiating trade agreements needs to be developed so that effective environmental provisions can be incorporated while retaining autonomy in formulating domestic trade policy. Fifth, a level playing field may be created for clean and dirty industries in the domestic market so that inefficiencies in resource allocation through policy biases may be avoided. Sixth, eco-labelling – a market-based tool – may be used to encourage the demand for and supply of environment-friendly goods. Also, small or medium scale producers need to be provided with sufficient handholding for making progress towards sustainable growth through eco-labelling.

IV.154 In India, the SEBI and the Reserve Bank are taking steps to facilitate green transition by enhancing disclosure requirements and strengthening risk assessment and management of regulated entities. The Reserve Bank is expected to set out the disclosure framework on climate-related financial risks and guidance on climate scenario analysis and stress testing shortly. Central banks are still exploring ways to speed up the flow of finance to green projects and prevent misallocation/mispricing of assets through appropriate regulatory policies, including green capital regulation, prescribing exposure limits to brown sectors and lowering risk weights for green sectors. To increase green lending, banks would need to invest in upskilling human resources for the entire gamut of the credit appraisal system. While green finance has grown in prominence, it thus far has had limited regulatory guidance. The Reserve Bank announced the framework for acceptance of green deposits in April 2023 to spur the green finance ecosystem in India. As mentioned earlier, there is however, an urgent need for a "green taxonomy" in India – clearly spelling out what constitutes green can, *inter alia*, help direct investment through better-designed policies and improve the monitoring of progress. The SEBI's recent move to objectively specify the end-uses of a green debt security is an important development.

IV.155 The CSR Act is an important supplementary tool for achieving, *inter alia*, climate goals. To incentivise and strengthen the corporates' green transition efforts, the CSR Act could be tweaked to widen the scope of geographies, businesses and timelines over which green projects are adopted and undertaken by companies. If the gains from the first-mover advantage for any industry are communicated effectively, it could further enhance the green agenda. The Government could also prescribe regulations for entities operating in certain domains to contribute to green transition. For instance, the Union Budget for 2023-24 announced that in due course a 5 per cent compressed biogas mandate will be introduced for all organisations marketing natural and biogas. The NITI Aayog's initiative to rank states on the basis of performance in green transition, besides working as a gentle nudge to improve performance, also aids in fine-tuning policies in the energy sector, leveraging both co-operative and competitive federalism.

IV.156 Recent regulatory measures taken in the country make India a front-runner in developing a robust regulatory framework for ESG-themed investments. There is, however, a need to move cohesively to prevent the emergence of a multitude of disconnected regional standards for ESG-fund classification across the world. The mandated BRSR in India is expected to generate better data on ESG parameters, which would, in turn, help creation of standardised rating products and enhance credibility of companies' disclosures. The recent steps taken by SEBI regarding the framework for ERPs and other aspects of sustainable finance would help address several issues plaguing ESG ratings of financial instruments and entities – definition, methodology and possible conflict of interest. PE investment in ESG assets can be enhanced by continuing with the fiscal and regulatory push towards green transition that helps fetch higher returns as firms with a sustainability focus, *inter alia*, enjoy cost savings on account of greenium, lower regulatory risk and decarbonisation-related efficiency gains while also achieving higher realisation from sale of products marketed as climate-friendly.

IV.157 Along with its primary mandate on price stability, monetary policy can play a complementary role in promoting green transition, taking into account the emerging new initiatives in the sphere of monetary and liquidity management policies in other central banks. A few policies that could be explored include lower margin requirements for SGBs when used as collateral for availing liquidity from the Reserve Bank, and reserve requirement relaxation for green credit. Higher use of CBDCs by the general public can help lower the carbon footprint through a less-cash economy. In the Fintech Benchmarks 2023 survey by centralbanking.com, all 29 institutions polled said that CBDC is a greener option compared with cash.

IV.158 The Union Budget for 2023-24 announced that for encouraging behavioural change, a Green Credit Programme will be notified under the Environment (Protection) Act. This will incentivise environmentally sustainable and responsive actions by companies, individuals and local bodies, and help mobilise additional resources for such activities. Nudging households and business establishments for adopting environment friendly lifestyles and business practices such as energy conservation through prudent use of air conditioning and heating systems, avoiding wastages of food and water, and preferring green products, services and financial assets, could make the net zero goal more attainable.

IV.159 The scale of green transition challenge is both enormous and complex, and only a multi-pronged action plan with a monitorable implementation strategy covering all major carbon emitting sectors can help accelerate India's progress towards the net zero goal. Without any policy action, India's CO_2 emission level may rise from 2.7 gigatonnes (in 2021) to 3.9 gigatonnes by 2030. A policy mix comprising a carbon tax of rupee equivalent of US$ 25 per tonne, current plans on progressively increasing the share of non-fossil (solar, wind) fuel in the energy mix, production and use of EVs and green hydrogen, and regulatory measures to incentivise resource allocation for green projects, could reduce CO_2 emissions to 0.9 gigatonne by 2030. Higher rates of carbon tax can reduce the emission level further. Action on all fronts, to be sustained over decades, however, would invariably require a people's movement, proposing feasible solutions, adapting to green lifestyles, and supporting Government initiatives.

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