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# The Economics of Climate Change in India and Relevant Actions: A Systematic Review

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**Abstract**
In this article, researchers analyse how India's climate change policy is framed, formulated & implemented and propose to address various domestic and international interest. This article examines the impact of climate change on India's GDP, with a focus on the Nationally Determined Contribution (NDC) and the commitments made under the Conferences of the Parties (COP). As per the projection of International Energy Agency, "nearly 60% of its CO2 emissions in the late 2030s will be coming from infrastructure and machines that do not exist today". As a result, India's policy change will have a significant weightage on the outcomes of the climate change policies taken globally.
Researchers discuss the global emission trends, climate change impacts and India's international & domestic climate policies—from Paris to UAE. Furthermore, researchers examine the progress that Indian policymakers have made and draw attention to shortcomings in India's climate change policies, particularly concerning continued investment in coal despite the country's widely lauded efforts to embrace renewables. Highlighting the importance of bringing "Just transition" to achieve sustainable development by providing weightage on all three aspects of sustainable development viz: 'Economy, Politics and Social aspect'.
In this paper, analysis of the greenhouse gas emission status, effect of climate change, effect on Indian Sub-continent, policies addressing climate change in India, limitation and opportunities on India's economy has been carried out.

**Keywords:** Climate Change, Gross Domestic Product, Sustainable Development Goal, Nationally determined contribution, Conferences of the parties.

## 1 Introduction

Climate describes the long-term differences in the statistics of weather. As of early six months of 2024, the temperature increased by 1.5 degrees Celsius compared to pre-industrial averages for 1850 - 1900 according to the latest update from the European Union's Copernicus Climate Change Service (C3S).
While crossing the 1.5°C mark in individual months or years does not imply that the Paris Agreement's average global temperature threshold of 1.5°C has been breached, repeated crossings do bring the planet closer to that critical barrier.
The amount of energy radiated by an object is determined by the temperature of the Object and the energy balance and is also applicable to our planet Earth. However, due to the greenhouse gases reduces the temperature to the space which results in increasing the global temperature.
One of the important green-house gases is Carbon Dioxide which is increasing at the beginning of the 19$^{th}$ Century at the same time the world economy began generating energy from fossil fuels (IPCC, 2007) which shows the positive correlation of Carbon-dioxide and burning of fossil fuels.Cumulative Greenhouse matters mostly in the climate change as it is the total stock of Green house Gas, not the annual-flow, that effect into climate change and the largest cumulative Green House Gas emitters are United States followed by European Union.
However, given the Earth's climate is a global public good, and the climate change affects all and in the IPCC report released in March 2022, positioned India as one of the vulnerable hotspots due to physical risk like flooding, rising sea levels and heat waves (IPCC,2022). By 2030, India will have a population of 1.5 Billion, compared to 1.43 Billion (World Bank,2022). The population, the variety of industries and the complexity of policies of India will make the study of climate vis-à-vis GDP very critical for the country as well as the globe.

**2 Green House Gas Emission Status**

There is quite a contrast in emissions between the countries that are currently the largest emitters and those that have cumulatively contributed most to the rising emissions in terms of current emissions.

China has by far outpaced any other country's emission with 31 percent of CO2 emission as of 2022 followed by US (14 per cent) and India (8 per cent) of CO2 emission. The entire European Union accounted for 7 per cent of the global emissions last year, Russia 4 per cent, and Japan 3 per cent.

India's per capita carbon dioxide emissions rose by around five per cent in 2022 to reach 2 tonnes but these were still less than half of the global average (Global Carbon Project Report, 2023). According to the said report, the US topped the chart on per capita emissions (14.9 tonnes of CO2), followed by Russia (11.4 tonnes), Japan (8.5 tonnes), China (8 tonnes), and the European Union (6.2 tonnes). The global average stood at 4.7 tonnes.

In many ways, cumulative emissions matter more because cumulative emissions reflect the stock of CO2 in the atmosphere and it is the total stock, not the annual flow that exhaust the carbon budget to limit global warming to the commonly agreed aspirational target to keep global temperature rise "well below 2 degree above pre-industrial levels" and to "pursuing efforts" to of limiting global temperature to 1.5 degree is codified in the 2021 limit the rise to 1.5 degree in the Paris agreement. The Glasgow Climate Pact recognised the impacts of climate change will be much worse at the temperature increase of 2 degree compared with 1.5 degree.

A useful way to think about this problem is in terms of a carbon budget.Humans have already emitted about 2.2 trillion tonnes between the industrial revolution and the end of 2017, so can stay under 2°C warming if we limit future emission to around 1.5 trillion tonnes.With present day emission exceeding approximately 40 billion tonnes per year, we will blow through our remaining budget by the 2050s.

To stay below 1.5° C is even more daunting. Our emissions budget for that limit is 580 billion tonnes, meaning that we are on track to exceed our budget for stabilizing below this temperature in the 2030s.

For the 1.5°C threshold, net emissions need to decline to 50% of today's value by the mid-2030s and reach zero in 2050. For the 2°C threshold, net emissions need to decline to 50% of today's value by the mid-2040s and reach zero in 2080.

All scenarios that results in the stabilisation of global temperatures, at whatever temperature and over whatever timeframe, end up at net zero and mention carbon removals in their estimation to achieve net zero.

Representative Concentrative Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) are the IPCC scenarios which are agreed upon, projected, plausible emission pathways through 2100s.RCPs are constructed by back calculating the amount of emissions that would result in a given amount of radiative forcing which is the difference between the energy emitted by the Sun and Earth.The SSPs are intended to provide plausible scenarios for how the world evolves in areas such as population, economic growth, education and the rate of technological development and are to be used in conjunction with RCP reports.

**Table 1:** RCP Scenarios:

| Pathway Name | Corresponding Rise in Global Average Temperature by 2100 | Emissions Trend to 2100 |
|---|---|---|
| RCP 1.9 | -1.5 Degree | Very strongly declining |
| RCP 2.6 | -2.0 Degree | Strongly declining |
| RCP 4.5 | -2.4 Degree | Slowly declining |
| RCP 6 | -2.8 Degree | Stabilizing |
| RCP 8.5 | -4.3 Degree | Rising |

Source: By authors from IPCC and Paris Conference

Some of the economic wide and Sector specific emissions reduction polices are appended below:

**Table 2:** List of Emission Reduction Policies:

| Economic Wide and Sector Specific Emission Reduction Policies | | | |
|---|---|---|---|
| ***Sl. No.*** | ***Policy*** | ***Sector*** | ***Description*** |
| 1 | Carbon Tax | Cross Sectoral | Tax per ton of Carbon dioxide will disincentives emission and the tax mobilisation can be used for Climate adaption/mitigation. |

| | | | |
|---|---|---|---|
| 2 | Renewable Portfolio Standard | Power Generation | Quota based regulation aims to increase the supply of renewable energy by requiring commercial power producer to source Certain Proportion of electricity generation coming from renewable sources |
| 3 | Emission Trading Scheme | Cross-sectoral | The same is better known as cap-and-trade schemes. The scheme sets caps on total emissions on total emissions for specific industries. However, it allows sectors to trade with each other, so emissions are reduced where it is easiest and cheapest to do so. |
| 4 | Fuel Tax | Transport, Heating | A fuel tax can lower the demand for fuel or be used to disincentives the use of dirtier fuel |
| 5 | Automobile Fuel Efficiency Requirements | Transport | To be legally complied, the individual cars /fleet owners must satisfy minimum fuel standards |
| 6 | Building heating efficiency requirements | Building | Renewable energy to be favoured to use in New Buildings |
| 7 | Green Low Carbon Public Procurement | Transport, Buildings and others | Government can support green and climate friendly alternatives through their purchasing power |

*Source: GARP SCR Text Book, 2024*

Along with the emission reduction polices, there are worldwide climate and financial groupings to combat the climate change worldwide:

**Table 3:** List of Climate groups

| Climate Grouping | | | |
|---|---|---|---|
| ***SI No.*** | ***Name*** | ***Members*** | ***Description*** |
| 1 | Taskforce on Climate-related Financial Disclosures (TCFD) | Cross-Sectoral | Prescribed set of disclosure on climate related risk that has been accepted and advocated by financials and non-financials firms. |
| 2 | Science-Based Targets initiative (SBTi) | Cross-Sectoral | An Organisation with voluntary standards set for net zero targets |
| Financial Grouping | | | |
| SI | Name | Members | Description |
| 1 | Institutional Investors Group on ClimateChange (IIGCC) | Asset Managers and owners | The group was formed in 2001, and now encompasses over 300 members (mostly asset managers and pension funds) in 22 countries and represent over USD 40 trillion in asset management aims to support net zero and resilient future through capital allocation, stewardship and engaging with companies, policy makers and other stakeholders. |
| 2 | Principles for Responsible Investment (PRI) | Asset Managers | Early Coalition formed in 2006 which advocates for incorporating ESG in Investment, seeking disclosures on ESG Issues and reporting activities. |
| 3 | Climate Action 100+ | Investors of all kinds | An investor coalition with 575 members that representsover USD 54 trillion in assets under management targetingthe world's 100 most heavily emitting publicly listed |

| | | | |
|---|---|---|---|
| | | | companies, with the goal of pressuring them to reduceemissions and conform to climate targets |
| 4 | Glasgow Financial Alliance for Net Zero (GFANZ ) | All financial players | The main aim of the alliance is to increase net zero commitments among Financial Institutes and provides a forum to solve the bottleneck for achieving the net zero goal |
| 5 | Net Zero Asset Owners Alliance (NZAOA) | Asset Owners | 37 investors who have committed with their entire portfolio to net zero GHG emissions by 2050 – consistent with a maximum temperature rise of 1.5 degree |
| 6 | Net Zero Banking Alliance ( NZBA) | Global Banks | It is an alliance of leading Global Banks committed to align with Net Zero by 2050 and 1.5 degree scenario with a stringent interim target for 2030 |
| 7 | Net Zero Asset Managers Initiative | Asset Managers | The Net Zero Asset Managers initiative is a formal partner of the UNFCCC's Race to Zero Campaign which will support net zero gas emissions by 2050 with a 1.5 degree scenario. |

*Source: GARP SCR Text Book, 2024*

The world faces a massive challenge in achieving net zero emissions by 2050 and the world energy outlook 2023 published by the International Energy Agency (IEA) highlights that Investment in clean energy has risen by 40% since 2020 and the emergence of new clean energy economy, led by solar PV and electric vehicles (EVs), provides hope for the way forward. This momentum is why the IEA recently concluded, in its updated Net Zero Roadmap, that a pathway to limiting global warming to 1.5 °C is very difficult – but remains open.
The outlook provides three scenarios that provide a framework for exploring the implications of various policy choices, investment and technology trends:

- The Stated Policies Scenario is based on current policy settings and also considers the implications of industrial policies that support clean energy supply chains as well as measures related to energy and climate. The temperature rises to 1.9 °C in 2050 and 2.4 °C in 2100. This is 0.1 °C lower than projected in the STEPS from the World Energy Outlook-2022, but far above the levels of the Paris Agreement.

- The Announced Pledges Scenario gives governments the benefit of the doubt and explores what the full and timely implementation of national energy and climate goals, including net zero emissions targets, would mean for the energy sector. The temperature rise in 2100 is 1.7 °C.

- The Net Zero Emissions by 2050 Scenario maps out a transition pathway that would limit global warming to 1.5 °C. The temperature peaks in mid-century and falls to around 1.4 °C in 2100

The global economy is assumed to increase at an average of 2.6% per year to 2050 in the three scenarios, while the global population expands from 8 billion todays to 9.7 billion in 2050. Energy, carbon and mineral prices find different equilibrium levels across the scenarios, but the potential for volatility remains high.

**3 Effect of Climate Change on Indian Sub-continent:**

The likely range of total human-caused global surface temperature increase from 1850-1900 to 2010-2019 is 0.8 degree to 1.3 degree with a best estimate of 1.07 degree.
As per Climate Action Tracker (December,2023) update Current policies presently in place around the world are projected to result in about 2.7°C. NDCs alone will limit warming to 2.5°C. When binding long-term or net-zero targets are included warming would be limited to about 2.1°C above pre-industrial levels.
Climate change further threatens India's development aspirations through so-called 'nonlinear events', where an ecosystem fundamentally shifts after passing a specific environmental level. After this critical tipping point, ecological change can happen rapidly and irreversibly (Hoegh-Guldberg et al., 2018) – a dangerous effect for a country where most people still

depend heavily on agriculture and natural resources for their livelihoods and sustenance. In high-emission scenarios, some of the *tipping points* that might particularly affect India include:

✓ A shift in the timing and magnitude of the Indian monsoon, changing seasonal rainfall that billions of people rely on.

✓ Dissolution of coral reefs in the Indian Ocean because of pollution, destruction of habitats and ocean acidification. Ocean acidification occurs when carbon dioxide is absorbed by the ocean, and once it reaches a certain threshold, it disrupts the calcification process of coral reefs. The coral reefs provide important fish breeding grounds, buffers against storm surge and tourist attractions.
The economic costs will be borne particularly by communities living in the gulfs of Mannar and Kutch and on the Andaman, Nicobar and Lakshadweep Islands, which depend on the reefs both for livelihoods and for protection against the sea.

✓ Greater Himalayan Glaciers has long offset periods of drought in India; more recently; higher rates of melting have offset declining precipitation. However, retreating snow cover and eventually disappearing of snow cover will affect Indians who depend on perennial river flowing out of the Himalayan glaciers. On the same global rating firm Moody's has warned that India's growing water shortage and frequent climate change-driven natural disasters can negatively affect the country's sovereign credit strength.
IPCC, in 2022 recognising India's Heat Action Plans which are using 'cool roofs' technologies and awareness-building campaigns to reduce the impacts of extreme heat.
However, the likelihood of adverse impacts to agricultural and food security in many parts of developing Asia will progressively escalate with the changing climate. The potential of total fisheries production in South and Southeast Asia is also projected to decrease
On the other hand, pursuing a more carbon-efficient and resilient pathway would enable India to climateproof its development gains. The words 'climate' and 'development' are therefore inevitably and closely linked in India for decades to come.
Policy solutions like the rapid expansion of solar power in India, currently the world's fifth largest solar market and on track to have solar contributing 30% of power generation by 2040.
India has also taken other innovative climate policies for a spin, including the country's rapid growth in the e-bus market thanks to a subsidy scheme to encourage the purchase of electric and hybrid vehicles though it requires other structural changes like Carbon Capture Utilisation service or more renewable power plants to avoid green wishing label as India's major energy demand is coming out from thermal power plants.

In perhaps the boldest climate policy strategy yet, India recently launched the Lifestyle for Environment (LiFE) initiative to encourage individuals to adopt sustainable lifestyles across India and to help tackle the challenges of climate change.
The Union Budget of 2024-25 reflects commitment to sustainable development with significant allocations like Rs. 1.52 lakh crore for climate-resilient agriculture and the introduction of initiatives like the PM Surya Ghar Muft Bijli Yojana for rooftop solar.
The budget clearly mentions the establishment of a carbon market, taxonomy and transition pathways mark significant progress in planning towards Net Zero in 2070,"

**4 Climate Change Negotiations: Paris and Glasgow**

The significance of climate change as a global challenge has ultimately led to several international agreements. In 1992, United Nation's Earth Summit has introduced United Nations Framework Convention on Climate Change (UNFCCC). All major global level climate policy agreements from the 1997 Kyoto Protocol to the 2015 Paris Agreement have occurred under the aegis of the UNFCCC.
The COP 15 in Copenhagen has established the aspirational goal that global warming to be kept below 2 degrees which founded the base of 2015 Paris Agreement.
Unlike Kyoto Protocol which puts emphasis on legally binding agreement among the high Income Annex 1 countries, the Paris Agreement uses the power of Inclusion and Peer pressure. Every country need to ramp up ambitious Nationally determined contributions every 5 years when the other countries do so. For example- Japan's first version of 2020 NDC is

not different then 2015 however when South Korea committed for Net Zero by 2050, Japan followed the same in its 2020 NDC.

Paris Agreement also explicitly recognised that sub-national actors such as cities and regions to private sector business and Financial Institute to contribute climate goals like Andhra Pradesh's State Energy Conservation Mission, which has contributed significantly to India's energy savings, with the Perform, Achieve and Trade (PAT) scheme.

India's role and position in international climate change negotiations havechanged substantially. Like the Dubash (2009) identified three competing Indian climatechange policy narratives:

(a) Growth first stonewallers—focus on economic developmentand poverty reduction; equity as a principal and strategy.

(b) Progressiverealists—unfair international negotiations, but climate change is seen as a real threat, with opportunities for action and development with co-benefits.

(c) Progressiveinternationalists—poorest countries most affected, opportunities for shaping the internationalprocess and moving to low carbon technology. Mohan (2017) argues that India's climate policy positions evolved from growth first stonewaller (during the1990s), via progressive realists (Copenhagen, 2009), to progressive internationalists (Paris, 2015). The latter policy is best understood as a subset of India's foreign policyagenda and towards playing a more prominent role "in solving global challenges andshaping the rules, norms and processes that guide those efforts." (Dubash, 2009).

Does the Paris Agreement's voluntary approach (in the form of National DeterminedContributions) render it a failure? We must examine the discourse surroundingthe Paris negotiations to answer this question. Many developing countries, including India, argued convincingly that for climate justice reasons, the main pollutersshould be obliged to reduce their emissions first, as was evident in earlier UNagreements. Industrialized countries were to carry the significant burden and helpdeveloping countries sustain their economic development.

In a cartoon titled "India at the Paris Climate Conference," the New YorkTimes depicted India as an elephant blocking a steam engine train labelled "Paris Climate Summit"—with the caption: "The emerging economy could pose manydemands on developed countries before agreeing to a deal." (Kim, 2015) The NewYork Times article "Narendra Modi Could Make or Break Obama's Climate Legacy" (Davenport & Barry, 2015) from a week earlier state these demands clearly: "India isexpected to challenge the United States on three counts: To speed up emissionsreductions by wealthy countries to compensate for emissions growth in poor countries, to pay more to poor countries to assist in mitigation plans and to provide clean-energytechnology to poor countries."

All three are valid bargaining positions, given the historical and current percapita emissions. The arguments are also well considered, given that the US and otheradvanced economies have opted out of the Kyoto Protocol—and given the significantchallenge of development and poverty reduction, the financing gap and the need fortechnology transfer to scale up and speed up mitigation and adaptation efforts ofdeveloping countries and especially of the least developed countries. Therefore, amore fitting depiction might be framing the situation as India joining the big party ofeconomic growth and consumption late and being asked to share the burden of tidyingup the emissions in equal measure.

The same New York Times article points to two crucial aspects of the politics ofinternational negotiations: First, the role of individual leaders: Referring to PrimeMinister Narendra Modi's book on climate change, titled Convenient Action (Modi, 2011); and quoting Anand Mahindra, the chairman of the Mahindra Group: "Ibelieve that Modi wants to be remembered as the person who turned India green".

Second, the two-level game approach of climate changenegotiations: Referring to editorials in India's newspapers "urging negotiators to standtheir ground, even at the cost of being labelled obstructionists or spoilers". (Davenport & Barry, 2015) Quoting the former Indian environment minister, Jairam Ramesh: "Themore criticism India comes under in Paris, the more applause Prakash Javadekar will get in Parliament and elsewhere. This is thedichotomy of the situation." (Davenport & Barry, 2015)

What complicated the bargaining position of India was the 2014 joint statementby China and the US that China's $CO_2$ emissions will probably peak by 2030. Before, China was mainly taking climate change positions like other emerging markets such asIndia and developing countries—especially that developed countries must reduceemissions first before other countries are asked to do the same. However, given thatChina became the most significant contemporary GHG emitter around 2005, it startedto share more climate change positions with the largest historical emitter, the UnitedStates. The pressure on India grew—not least from the US—to commit to a specific, near-term date for its emissions to peak. However, India made it clear that it could notcommit to such a timeline, given its mandate to fight poverty and foster economicgrowth to enhance its people's living standards and overall well-being.

Developed countries promised US$ 100 billion in climate finance for developingcountries per year. Unfortunately, by any measure, the reality is far from this pledge. Moreover, no clear international accounting standards exist that clarify what constitutes'climate finance'. A controversial OECD report claimed that developedcountries have made substantial progress towards this goal and mobilized US$ 62billion in 2014, up from 52 billion in 2013. (Organisation for Economic Co-operationand Development [OECD] & Climate Policy Initiative, 2015) However, this claim wasfirmly rejected by the Indian government, pointing to severe problems with the report'saccuracy, methodology and verifiability. (Climate Change Finance Unit, Ministry of Finance, Government of India, 2015)

In the account of one of the Indian negotiators involved in the Paris agreement, the 2015 agreement preserves India's core interests. First and foremost, the Paris

Agreement is "firmly anchored in the UNFCCC since it safeguards policy space underpinned by key principles such as equity and common but differentiated responsibilities and respective capabilities (CBDR&RC)." (Lavasa, 2019) In other words, India's core interest in (economic) development is not constrained by a top-down approach, as the contributions are nationally determined. That many developing and developed countries perceived the Paris Agreement as an overall success is often attributed to the French leadership of the conference.

Yet, the Paris agreement remains ambivalent. On the one hand, it arguably abandons the ambition of global equitable burden-sharing and of "multilaterally negotiated binding emissions targets and timetables for each country, the foundation of the 1997 Kyoto Protocol" (emphasis added) (Clémençon, 2016). This starkly contrasts the poster child example of successful international environmental agreements—the 1987 Montreal Protocol on ozone-depleting substances, which was built on binding reduction targets and timetables and differentiated responsibilities for developing and industrialized countries (Benedick, 1991). On the other hand, the Paris Agreement was an important milestone to legitimize and prompt more climate action effectively.

Attending the COP26 in Glasgow in person, Prime Minister Modi finally did commit the country to a net zero pledge (the last remaining G20 country to do so), although, unlike others, with a target of 2070. While this may have been a decision taken under international pressure, reports also highlighted how India and China were behind the last-minute watering down of the Glasgow Pact. This included altering the language to ensure it was a "phase down of unabated coal power" rather than "phase out" and the "phase out of inefficient" fossil fuel subsidies. Glasgow made progress in that it was the first U.N. climate agreement to mention coal as the fuel most responsible for warming the planet. However, India's stance and strategy blindsided negotiators and almost threatened to derail the final talks.

COP 28 was particularly momentous as it marked the conclusion of the first 'global stocktake' of the world's efforts to address climate change under the Paris Agreement. Having shown that progress was too slow across all areas of climate action – from reducing greenhouse gas emissions, to strengthening resilience to a changing climate, to getting the financial and technological support to vulnerable nations – countries responded with a decision on how to accelerate action across all areas by 2030. This includes a call on governments to speed up the transition away from fossil fuels to renewables such as wind and solar power in their next round of climate commitments.

## 5 Case Studies of Economic costs on climate change in India

### 5.1 Climate change and agriculture

With only about 9% of the world's arable land, agriculture in India feeds about 17.2% of the global population.

Over 56% of the country's total agricultural area is rain fed. This means thatIndia's food security and agricultural livelihoods depend heavily on the monsoon, which makesit particularly vulnerable to climate change (Goyal and Surampalli, 2018).

Climate change has already affected hundreds of millions of rice producers and consumers in India.

Auffhammer et al. (2012) found that rice yields would have been nearly 6% higher on average wereit not for more frequent droughts, warmer nights and lower rainfall. In combination, these changeswould have increased the cumulative harvest during 1966–2002 by an amount roughly equal toa fifth of the increase caused by better farming technologies. This is also equivalent to the riceconsumption of an additional 30 million people every year over that period (FAO, 2017).

Some agricultural regions are more susceptible than others. South-eastern, western andnorthern India may be able to maintain or improve rice yields with adaptation, and parts ofsouth-west and central India may benefit from increased rainfall.

However, parts of southwest, central and northern India will face lower rice yields even with climate adaptationmeasures – with a mean reduction across the considered emission scenarios estimated to bearound 7% in 2050 and 10% in 2080 (Soora et al., 2013).
Wheat yields are projected to declineby 22% by 2100 (Birthal et al., 2014), and yields could become more erratic in response toextreme weather and other climate hazards. There would therefore be years with crop failure, causing food insecurity, income loss, and/or displacement (Naqvi et al., 2020).

**5.2 Climate change and energy**

In 2018, 72% of India's greenhouse gas emissions could be attributed to the energy sector (WRI, 2021), and the country's power-generation systems are vulnerable to the impacts of climate change.
Most of India's thermal power plants require a sufficient water supply forcooling and, as outlined above, India faces growing risks of water scarcity. Forty per cent ofthe country's thermal power plants are in regions with high water stress and consequentlyhave a capacity factor that is 21% lower than their counterparts in regions with low ormedium water stress (Luo et al., 2018).
In 2016, India lost 14 terawatt-hours of thermal powergeneration due to water shortages – nor was this an isolated case. Between 2013 and 2016,14 of India's 20 largest thermal utility companies experienced one or more shutdowns dueto water shortages, at a cost of more than 91 billion Indian rupees ($1.4 billion) in potentialrevenue from the sale of power (ibid.).
Renewable energy offers a partial solution. India is the seventh largest producer of hydropower globally and possesses vast, untapped potential in this sector. Moreover, all seven of India's largest reservoirs are in regions that are projected to be up to 18% wetter by the end of the century (Ali et al., 2018). However, other regions will experience smaller stream flows and less precipitation, so hydropower does not offer a solution for these communities. Solar photo voltaics have immense potential since India receives an average of 300 days of sun eachyear (Shukla et al., 2018); concentrated solar power will need to play a smaller role in water-stressedparts of the country as it also depends on water for cooling.
Lastly, a large part of India's fossil-powered energy infrastructure lies in areas with highexposure to climate-related hazards. For example, one of the world's largest oil and gasfacilities, the Jamnagar refinery in Gujarat, is only slightly above sea level (Roy and Sharma, 2015). Ports where crude oil is imported are similarly vulnerable (Garg et al., 2015). This is not a risk limited to fossil fuel infrastructure only: the construction of new solar farms, hydropower plants and other renewable energy systems should be informed by robust projections offuture climate conditions.

**5.3 Disastrous flooding in Mumbai:**

Greater Mumbai is home to over 20 million people and is one of the most densely populated cities in the world. It is the financial capital of India with a large commercial and trading base.
However, most of the coastal city lies less than 15 m above sea level (D'Monte, 2017) and almost a quarter lies below or at mean sea level (Kumar et al., 2008). As a result, it is among the most vulnerable port cities globally, exposed to various climate-related risks such as storm surges, flooding, coastal erosion, and rising sea levels (Murali et al., 2020).
Climate change is not the sole factor contributing to environmental risks in Mumbai. The city was originally developed on a group of islands along the coastline. However, its lakes, rivers, mudflats, wetlands, mangroves, woods and coastline have gradually been built over to serve a growing population and economy. The increase in hard surfaces and loss of tree cover has prevented rainfall from seeping into the groundwater. Instead, it runs rapidly over the asphalt and concrete, pooling in low-lying parts of the city instead of flowing into the sea (Patankar et al., 2010; Sen and Nagendra, 2019). Poor sewage and drainage systems exacerbate the health risks of flooding, which include diseases such as malaria, diarrhoea and leptospirosis (Kumar et al., 2008).
Mumbai is already experiencing catastrophic floods. Hallegatte et al. (2013) rank major coastal cities according to flooding risk, and place Mumbai fifth in the world with annual losses of $284 million.
In July 2005, flooding killed 5,000 people and caused economic damage totalling $690 million (Nagendra, 2017). Floods will only get worse when combined with the heavier rains, higher sea levels and more severe storms associated with climate change.
Hallegatte et al. (2013) project that annual losses from flooding will reach $6.1 billion per year in 2050. Most of these losses are uninsured and borne by individuals or small businesses (Patankar and Patwardhan, 2016)

### 5.4 Deadly heatwaves in Ahmedabad

In 2020, a number of Indian cities reported temperatures of 48°C or more (Golechha and Panigrahy, 2020). While these extremes captured international attention, there has been less scrutiny of the potentially devastating effects of the combination of heat and humidity (Zhang et al., 2021). Heat stress has long posed a threat to the health and productivity ofurban dwellers in India. In 2010, one heatwave killed more than 1,300 people in Ahmedabad alone (Mazdiyasni et al., 2017)

Low-income urban residents are disproportionately vulnerable to high temperatures. Studies in Ahmedabad show that homes in informal settlements are more likely to have roofs made of uninsulated metal or asbestos sheets, which can aggravate heat impacts. Informal settlements are also likely to have less tree cover or green space that can mitigate extreme heat (Mahadevia et al., 2020). People who work outdoors, such as street vendors and construction workers, are also particularly at risk. Studies in Chennai found that heat stress reduces the productivity of construction workers by 18–35% (Chinnadurai et al., 2016).

Based on its tragic experience in 2010, Ahmedabad has developed a Heat Action Plan to address health threats from extreme temperatures. The city has established an early warning system to alert residents about heatwaves, and provides cool spaces and potable water to vulnerable communities during these events. Ahmedabad has also undertaken extensive public outreach to raise awareness about heat preparedness, and trained health care professionals to prevent and manage heat stress. These preventative measures save an estimated 1,100 lives every year (Hess et al., 2018).

## 6 Policies governing climate change in India

The 2008 National Action Plan on Climate Change (NAPCC) was a program launched by the Government of India in 2008 to help the country adapt to and mitigate the effects of climate change.

The NAPCC outlines eight national missions to address climate change in specific areas which are enumerated in the below table:

**Table 4:**

| SI | Mission Name | Start Date | Objective |
|---|---|---|---|
| 1 | National Solar Mission (NSM) | 2010 | The objective of the National Solar Missionis to establish India as a global leader insolar energy, by creating the right policy conditions for its acceptance across the country as soon as possible. Its focus is on setting up an enabling environment for solar technology penetration in the country both at centralised and decentralised level |
| 2 | National Mission for Enhanced Energy Efficiency | 2011 | It aims to strengthen the market for energy efficiency by creating conduciveregulatory and policy regime and has envisaged fostering innovative and sustainable business models to the energy efficiency sector. |
| 3 | National Mission on Sustainable Habitat | 2010 | The key deliverables of the mission include:<br>a. Development of sustainable habitat standards that lead to robust developmentstrategies while simultaneously addressing climate change related concerns<br>b. Preparation of city development plans that comprehensively addressadaptation and mitigation concerns<br>c. Preparation of comprehensive mobility plans that enable cities to undertakelong-term, energy efficient and cost effective transport planning<br>d. Capacity building for undertaking activities relevant to the Mission |
| 4 | National Water Mission | 2011 | The mission identifies five goals which are appended below: |

| | | | |
|---|---|---|---|
| | | | a. Comprehensive water data base in public domain and assessment of theimpact of climate change on water resource.<br>b. Promotion of citizen and state actions for water conservation, augmentation and preservation<br>c. Focused attention to vulnerable areas including over-exploited areas<br>d. Increasing water use efficiency by 20 per cent<br>e. Promotion of basin level integrated water resources management |
| 5 | National Mission for Sustaining the Himalayan Eco-system | 2010 | The mission attempts to address the below mentioned important points concerning:<br><br>a. Himalayan Glaciers and the associated hydrological consequences<br>b. Biodiversity conservation and protection<br>c. Wildlife conservation and protection<br>d. Traditional knowledge societies and their livelihood and<br>e. Planning for sustaining the Himalayan Ecosystem |
| 6 | National Mission for a Green India | 2014 | The main objective of the mission are:<br><br>a. Increase forest cover on 5 m ha of forest/non-forest lands and improved qualityof forest cover on another 5 m ha (a total of 10 m ha).<br>b. Improved ecosystem services including biodiversity, hydrological services and carbonsequestration as a result of treatment of 10 m ha.<br>c. Increased forest-based livelihood income of about 3 million households living in andaround the forests.<br>d. Enhanced annual CO2 sequestration by 50 to 60 million tonnes in the year 2020 |
| 7 | National Mission for Sustainable Agriculture | 2010 | The mission aims at making agriculture more productive, sustainable, remunerative and climate resilient by promoting location specific integrated /composite farming systems; soil and moisture conservation measures; comprehensive soil health<br>management; efficient water management practices and mainstreaming rain-fed technologies |
| 8 | National Mission on Strategic Knowledge for Climate Change | 2010 | The mission seeks to build a vibrant and dynamic knowledge system that would inform and support national actionfor responding effectively to the objective of ecologically sustainable development. |

*Source: FAQs on National Action Plan on Climate Change (https://static.pib.gov.in/WriteReadData/specificdocs/documents/2021/dec/doc202112101.pdf )*

The missions should be formalized by the appropriate ministries and coordinated through cross-sectoral teams that involve experts from industry, academia, and civil society, along with representatives from relevant ministries, the Ministry of Finance, and the Planning Commission. As of March 2022, 33 states and UTs in India have their own State Action Plans on Climate Change (SAPCCs) that are consistent with the NAPCC approach.

The Indian Government submitted its Intended Nationally Determined Contribution (INDC) in 2015 (Government of India, 2015). The latest update is a five-fold strategy for India to play its part in helping the world get closer to 1.5 degrees Celsius on the first day of the global climate meet in Glasgow which are appended below:

- India will get its non-fossil energy capacity to 500 gigawatts by 2030
- India will fulfil half of its energy needs through renewable energy by 2030
- India will meet half of its energy demands with renewable energy by 2030
- India will reduce the carbon intensity of its economy by 45 per cent by 2030
- India will achieve net zero by 2070

The latest target of India was widely criticised. However, it seems surprisingly that the country ranks high in the Climate Change Performance Index (CCPI). The CCPI is an independent, annual tracking of countries' climate change mitigation performance. The CCPI covers 57 countries, which account for 90% of global green- house gas (GHG) emissions. India is ranked 7$^{th}$ in the CCPI, 2024 ranking.

The greenhouse gas (GHG) emissions ranking contributes 40% to the overall score. It captures the complication that large emerging markets like India embody. On the one hand, current levels of GHG emissions per capita are (still) minimal—hence the very positive ranking of India as "very high".

While on the other-hand, the current trend of GHG emissions per capita is a substantial increase of emissions due to high economic growth (fuelled predominantly by fossil fuels. Hence the very negative ranking of India as "very low". On the positive side, the GHG 2030 Target is also ranked as "very high" and compatible with a well-below-two-degree benchmark.

Similarly, while the current level of renewable energy is rated "medium", the corresponding trend is ranked as "high" (Germanwatch, 2022)

Some of the notable features related to climate change of Budget 2024-25 are appended below:

a) Comprehensive review of the agriculture research setup to bring focus on raising productivity and developing climate resilient varieties.
b) 109 new high-yielding and climate-resilient varieties of 32 field for cultivation by farmers.
c) 1 crore farmers across the country will be initiated into natural farming, supported by certification and branding in next 2 years.
d) 10,000 need-based bio-input resource centres to be established.
e) Promote water supply sewage treatment and solid waste management projects and services for 100 large cities through bankable projects.
f) Pumped storage facility for electricity storage and facilitation of smooth integration of the growing share of renewable energy.
g) PM Surya Ghar Muft Bijli Yojna will be providing free of cost solar energy to approximate 1 crore households.
h) Taxonomy for climate finance: Enhancing the availability of capital for climate adaptation and mitigation related investments.
i) Exempted custom duty on capital goods for manufacturing of solar cells & panels.

To summarize: At the 26th Conference of the Parties (COP 26) in Glasgow in November 2021, Prime Minister Modi announced India's target of Net Zero by 2070, with the interim goal of an emissions reduction of 33–35% by 2030 compared to 2005 levels. While this commitment is less ambitious than that of OECD countries, it reflects India's concern about how fast the triangulation of poverty reduction, sustainable growth and climate change action is feasible. Therefore, the Indian government reemphasized the essential role of climate finance in supporting developing countries in their transition to net zero.

Recently in a statement issued after IEA's 2024 ministerial meeting in Paris, the agency said the talks with India's membership of IEA is advocating the country's "strategic importance" in tackling global energy and climate challenges.

**7 Limitation and Possibilities on India's Renewable Energy:**

One of the main caveats regarding India's climate change ambitions is the country's plan for coal mining and the construction of additional coal power plants like the recent announcement of the supercritical (AUSC) thermal power plant which will be set up by the National Thermal Power Corporation (NTPC) and Bharat Heavy Electricals Limited (BHEL)

in the Union Budget 2024-25. The silver lining is that the share of renewable is increasing at a rate of 22% from 2006 to 2023 as per the tabulated details mentioned below:

**Figure 1:** Data on Renewable sources:

| Year | Source | Energy Supply (mtoe) |
|---|---|---|
| 2006 | Renewables | 0.59 |
| 2007 | Renewables | 0.87 |
| 2008 | Renewables | 2.28 |
| 2009 | Renewables | 2.68 |
| 2010 | Renewables | 3.12 |
| 2011 | Renewables | 3.71 |
| 2012 | Renewables | 4.56 |
| 2013 | Renewables | 5.17 |
| 2014 | Renewables | 5.80 |
| 2015 | Renewables | 7.02 |
| 2016 | Renewables | 7.65 |
| 2018 | Renewables | 8.96 |
| 2019 | Renewables | 11.22 |
| 2020 | Renewables | 12.44 |
| 2021 | Renewables | 13.28 |
| 2022 | Renewables | 15.28 |
| 2023 | Renewables | 18.27 |

*(Source: NITI Ayog (iced.niti.gov.in))*

From a global levelized cost of electricity (LCOE) as high as USD 347 per MWh for solar PV as recently as 2009, USD 190 for offshore wind, and USD 111 for onshore wind, the LCOE for all three had dropped to USD 39, 78, and 44 for solar PV, offshore, and onshore wind, respectively, as of 2020, according to data from research firm Bloomberg NEF. Without taking any sort of subsidies or tax credits into account, wind and solar are now the cheapest forms of new-build electricity generation for two-thirds of the global population, and the economic incentive is strong for them to displace fossil-fuel generation even without further policy action.

Given this price competitiveness of renewables and instances like California-based Pacific Gas & Electric (PG&E) which was held liable for wildfires in 2018 leading to first climate-change bankruptcy closure along with public pressures regarding climate change adaptation and mitigation, energy analyst warns about newly built coal plants turning into stranded assets.

As per International Energy Association's World Energy Investment 2024 report India's clean energy investment reached USD 68 billion in 2023, up by nearly 40% from the 2016-2020 averagealmost half of this was devoted to low-emissions power generation, which includes solar PV. These milestones are achieved mainly with Initiatives like Production Linked Incentives scheme to set up domestic manufacturing of solar modules, batteries and other clean energy equipment as well as new hydrogen policy and two tranches of sovereign green bond market valued at USD 1 billion (INR 80 billion) were marketed primarily to local investors whose proceeds were destined to support renewables, metro rail lines, and low-carbon hydrogen production. The report also highlights that clean energy investment is on track to double by 2030 under today's policy settings, but would need to rise by a further 20% to get fully on track for the country's energy and climate goals. Addressing risks that push up the cost of capital will be critical in this endeavour.

This provides an excellent opportunity for sustainable investment. The switch from fossil fuels to renewable energy requires a substantial surge in power system flexibility so the power is always available and can be modulated to counteract the intermittency of wind and solar. Battery energy storage systems (BESS) may also play a role in two ways:

- Short-term storage (a few hours) can be usedto shift energy produced at the peak of solar power, around local noon, to the peak of demand, in the late afternoon.

- Longer term storage (days to weeks) would potentially displace the need for dispatch-able power.

For some important economic processes like long-distance trucking and flights hydrogen policies might be the way.
As per recent report on businessline dated Aug 08,2024, the Government of India is looking at introducing a mission that will not just promote Carbon Capture Utilisation and Storage (CCUS) technologies, but will also work with the industry and academia to create a roadmap for developing an India-specific ecosystem.
In a significant boost to India's renewable energy infrastructure, Indi-Grid, the country's first and largest listed power sector infrastructure investment trust (InvIT) announced a strategic partnership with British International Investment (BII), the Norwegian Climate Investment Fund managed by Norfund, and Techno Electric and Engineering Company Limited (Techno) for the development of its greenfield Interstate Transmission System (ISTS) projects.
This strategic partnership marks a pivotal development in bolstering India's green energy infrastructure, aligning with national goals for renewable energy capacity and sustainable economic growth.
Also, the transition to green energy must also be managed in a way that ensures that it is economically and politically feasible. This includes ensuring that the transition is equitable and that access to clean energy is available to all, regardless of income level or location. Finally, it is critical to ensure that the transition is done in a way that does not result in too many "stranded assets," such as coal-fired power plants that may become obsolete due to the shift to clean energy.
So, to ensure Just Transition communities and individual's dependent on industries most likely to experience asset stranding, are supported, including, for example, through retraining provided by companies and government. The reallocation of resources and compensation for those individuals and communities affected by climate change and related policies could help facilitate a just transition (Caldecott et al.2016; Newell and Mulvaney 2013). Rosemberg (2010) suggests that job losses are not a direct result of national climate policies, but rather are caused by a lack of social policies and by the anticipation of and investments in alternative mitigation measures. Thus, providing adequate support for sectors that are losing out in a low-carbon future and generating new employmentopportunities in low-carbon sectors are critical to ensuring adjust transition (Jagger, Foxon and Gouldson 2013)

**8 Conclusion**

The paper has sought to understand the developing nation like India's rising GDP and growing population development/energy needs which needs to be sacrificed / balanced to limit global warming. Researchers counter western narrative of developing countries such as India as a roadblock for climate change adaptation and mitigation with the fact that the developed countries are responsible for significant global stock of greenhouse gases and hence are responsible for the adverse global climate change.
This responsibility goes beyond domestic climate change policies and refers to transferring funds and technology to developing countries like the South Africa's Just Energy Transition Partnerships (JETP) was announced at COP26, when France, Germany, the UK, the US and the EU committed a total of USD 8.5 billion. South Africa has since published its Implementation Plan, setting out priority investment required for a transition to a low-carbon and climate resilient economy. A key area of focus lies on accelerating the decarbonisation of the South African electricity grid by scaling up renewables and ensuring the early retirement of South Africa's large coal generation fleet. Similar kind of JETP was carriedout where the beneficiary countries are Indonesia and Vietnam. India and Senegal are currently negotiating to establish similar JETPs with donor governments in the development world.
India arguably can be seen as a leader in climate change performance, as reflected in its top rating in the CCPI. Researcher showed that the current government shows ambition regarding climate change mitigation, which is, among other things, reflected in many initiatives like Hydrogen policies and climate taxonomy in the budget.
However, researchers also would like to draw attention to the substantial shortfall in India's climate policies like the current role of and worse the recently announced plans for coal power plant construction in the Union budget 2024-25 viz: thermal power plant which will be set up by the National Thermal Power Corporation (NTPC) and Bharat Heavy Electricals Limited (BHEL).
There are also debates on fossil fuel subsidises which are delicate and hence importance needs to be given on just transition from fossil-based power plants to climate friendly / green power plants.

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