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A Framework for Climate Change Mitigation in India

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A Framework for Climate Change Mitigation in India
Prepared by Jean Chateau, Geetika Dang, Margaux MacDonald, John Spray, and Sneha Thube*

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ABSTRACT: Climate change poses challenging policy tradeoffs for India. The country faces the challenge of raising living standards for a population of 1.4 billion while at the same time needing to be a critical contributor to reducing global GHG emissions. The government has implemented numerous policies to promote the manufacturing and use of renewable energy and shift away from coal, but much still needs to be done to reach India's 2070 net zero goal. Reducing GHG emissions will almost certainly have a negative impact on growth in the short run and have important distributional consequences for individuals and communities who today rely on coal. But with the right policies, these costs—which are non-negligible but dwarfed by the cost of climate change over the next decade if no action is taken—can be significantly curtailed. This paper provides an in depth review of the current climate policy landscape in India and models emissions trajectories under different policy options to reduce GHG emissions.

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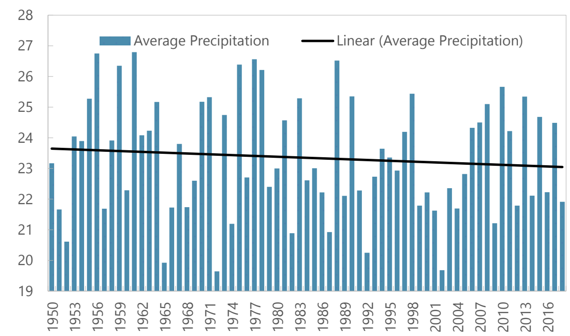
1. INTRODUCTION

1.1 The threat from climate change

Climate change confronts policy makers with difficult policy tradeoffs. On the one hand, the world needs to transition away from the burning of fossil fuels and accelerate climate adaptation. On the other hand, these transitions require new policies which may impose costs, including on short-term growth, and generate winners and losers. Estimates put the cost of transition to net zero in 2050 as high as US $9.2 trillion annually (McKinsey Global Institute, 2022).

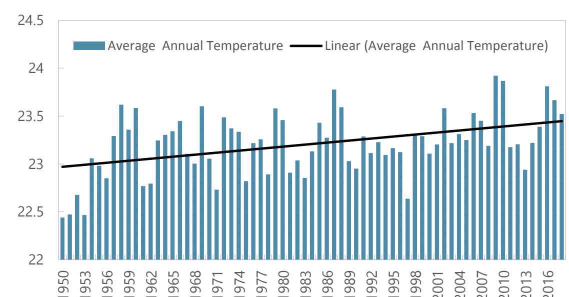
India is no exception to these tradeoffs and is facing increasingly severe risks from climate change. Over the period 1950-2018, average temperatures increased by 0.5°C while average rainfall fell by 0.6m (**Error! Reference source not found.** and **Error! Reference source not found.**). More importantly for India, there has also been an increase in weather variability, with temperatures regularly above 50°C in certain regions and the monsoon season becoming increasingly unpredictable (in timing and quantity of rainfall). The impact is not uniform across states and is harming sectors of the economy which are dependent on the weather such as agriculture and transport (Hasna, Hatton, Mohaddes, & Spray, Forthcoming). Climate change and pollution are also causing stress to health outcomes. Those activities that drive climate change globally also tend to be significant producers of pollution locally, which has direct, negative impacts on individuals' health. Research has found that pollution in India led to US$28.8 billion in output loss due to premature deaths and $8 billion in output loss due to morbidity in 2019, with the poorest disproportionately affected (Pandey, et al., 2021; Kopas, et al., Forthcoming; Xue, et al., 2001). Looking ahead, it is expected that climate change will cause about 250,000 additional deaths per year between 2030 and 2050 due to malnutrition, malaria, diarrhea, and heat stress (Government of India, 2019).

Figure 1. Annual Precipitation
(Meters)



Sources: World Bank Climate Dashboard; and IMF Staff Calculations

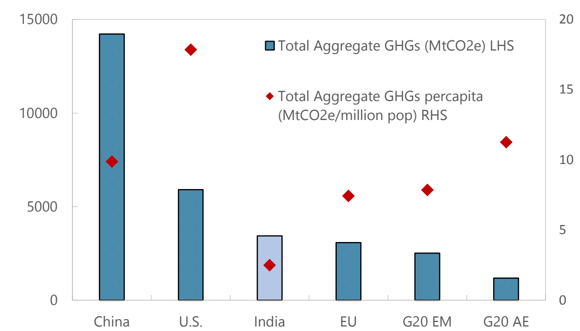
Figure 2. Average Temperature
(Degrees centigrade)



Sources: Willmott Matsuura, University of Delaware; and IMF Staff Calculations

1.2 India's Green House Gas (GHG) emissions

Figure 3. Aggregate GHG Emissions



Sources: IMF; EDGAR; UNFCCC; FAO; EU; and IMF staff estimates.
Note: Values reported in per capita millions. G20 EM and G20 AE are simple averages, excluding EU and including Spain.

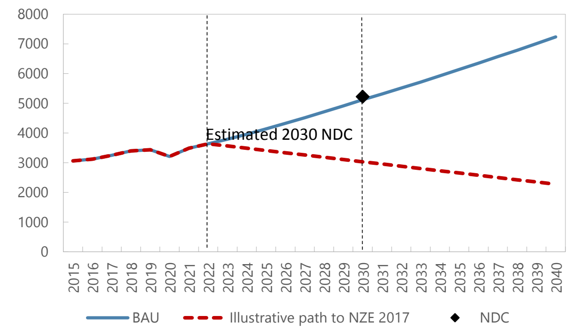
India is the world's third largest greenhouse gas (GHG) emitter, however in terms of emissions per capita it has the lowest level in the G20. Error! Reference source not found. shows India has slightly more emissions than the European Union (EU) but only one third of the emissions per capita, while the United States has 7 times higher emissions per capita. Given India's modern economic development began considerably later than that of advanced economies, it has a small contribution to global historical cumulative GHG emissions of approximately 3 percent (UNEP, 2022).

Under current policies, India's GHG emissions are on an upward trajectory. The power sector is the largest emitter in India, accounting for 37 percent of total GHG emissions, followed by the agricultural sector (21 percent), manufacturing (17 percent) and the transportation sector (9 percent).[1] The blue line in **Error! Reference source not found.** shows India's historical and projected total GHG emissions under current policies. Note that historical emissions have been slowly but steadily rising since 2014 in line with economic development. Over the next two decades, India has ambitious growth plans which, if realized, will see it accelerate from lower middle income to higher middle income (Morgan Stanley, 2022). As average incomes rise, it is expected that firms and households will demand more electricity from amenities such as air conditioners or fridges (Davis, Gertler, Jarvis, & Wolfram, 2021; Akpinar-Ferrand & Singh, 2010; Isaac & van Vuuren, 2009). While this development story is positive, it is anticipated, under current policies, that such a growth path will lead to a 41 percent increase in GHG emissions by 2030. India's NDC target is to reduce emissions intensity of its GDP by 45 percent by 2030 from 2005 level[i] and India will reach this target with the existing policies (Thube, Peterson, Nachtigall, & Ellis, 2021). However, model estimates suggest that it will exceed the NDC emission level in 2031 and continue to see growing emissions levels up to 2040 and therefore, additional mitigation policies would need to be introduced to bring India's emissions towards a trajectory that is compatible with its long-term mitigation goals.

[1] The remaining emissions are from buildings, waste, other fuel combustion, and fugitive emissions Industrial sector is the sum of lime production, aluminum production, cement, cement production, refinery, iron and steel, and nonspecific industries. Source: Third BUR.

Delays in transitions from the current emissions trajectory to India's 2070 net zero goal trajectory will be costly. Economic growth is a key priority for India and would be accompanied by increased demand for energy. However, the status quo energy composition that relies heavily on brown fuels puts India's emission trajectory in the opposite direction of an illustrative linear path to Net Zero Emissions (NZE) by 2070 (shown in red in **Error! Reference source not found.**). Delaying the switch to green energy will be costly for India for three reasons. First, India is currently planning substantial investments in coal-fired power plants which have typical lifespans of multiple decades and significant fixed costs. If the country wishes to close these plants before their full lifespan, these fixed costs will be amortized over a shorter period inducing high transition costs and risking stranded assets. Second, scaling up renewable alternatives requires solving challenges such as intermittency problems, storage and grid connections, which are easier to do over longer periods of time. Third, to ensure a just transition it will be important to retrain workers currently in sectors that we see a decline, assist with the process of finding a new job, and offer income tax credits schemes to provide a safety net whilst also encouraging re-entry into the labor market (IMF, 2022). This is also easier and less disruptive over longer time horizons.

Figure 4. GHG All Emissions (mtCO2e)



Source: IMF staff calculations and IMF-ENV model.
Note: NDC target for India is a 45 percent reduction in emissions intensity of GDP (ceiling) by 2030 relative to 2005 levels. Target is estimated using historical emissions data and GDP growth projections and is met in the baseline. Net-zero target for 2070 is declaration/pledge (purely illustrative near-direct linear path shown).

India is working on addressing its carbon footprint. Domestically, India launched the National Action Plan on Climate Change (NAPCC), in 2008, providing the country with a strategy to adapt to climate change and enhance its ecological sustainability.[ii] Eight National Missions focusing on different aspects of development, adaptation, mitigation, and sustainability

Missions under the Natioanl Action Plan on Cllimate Change

- Natinal Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission for Susutainable Habitats
- National Water Mission
- National Mission for Sustainng the Himalayan Ecosystem
- National Mission for Green India
- National Mission for Sustainable Agriculture

were launched under the NAPCC. From the multilateral side, in 2022, India submitted an updated Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC) and its third Biennial Update Report (BUR) on emissions levels. In addition to previous commitments, the updated NDC committed India to lower the emissions intensity of its GDP by 45 percent from 2005 levels by 2030. It also committed to achieve 50 percent of total installed power capacity from non-fossil fuel-based energy resources by 2030 and to put forward and further propagate a healthy and sustainable way of living (LiFE). India also committed to get to NZE by 2070 at COP26.

1.3 Paper outline

This paper aims to add to the discussion on India's transition to net zero by providing a policy proposal framework, in the context of India's existing policy landscape. Specifically, we consider 1) how India's current policies across all sectors of the economy are addressing its joint need to reduce emissions and transition to net zero while maintaining its development priorities; 2) what would be the policy trade-offs if India accelerates this transition; and 3) what conditions might facilitate a global agreement on more ambitious climate goals including climate financing and technology. The remainder of this paper is organized as follows.

In Section 2 we present a sectoral mapping. This considers which sectors have the largest emissions, which fuels contribute to those emissions, to what extent do current policies target those sectors and emissions, and what challenges they face in their implementation. We find India is making important progress in implementing its climate agenda at the sectoral level. This includes policies to improve energy efficiency, reduced reliance on traditional biofuels, and financial support to renewables and to electric vehicles. However, the power and manufacturing sectors remain the largest driver of emissions. Although renewable energy investment has been impressive, and new supercritical technology to enhance the efficiency of coal fired power plants is coming online, further reducing emissions from fossil-fuel power generation is essential to transition.

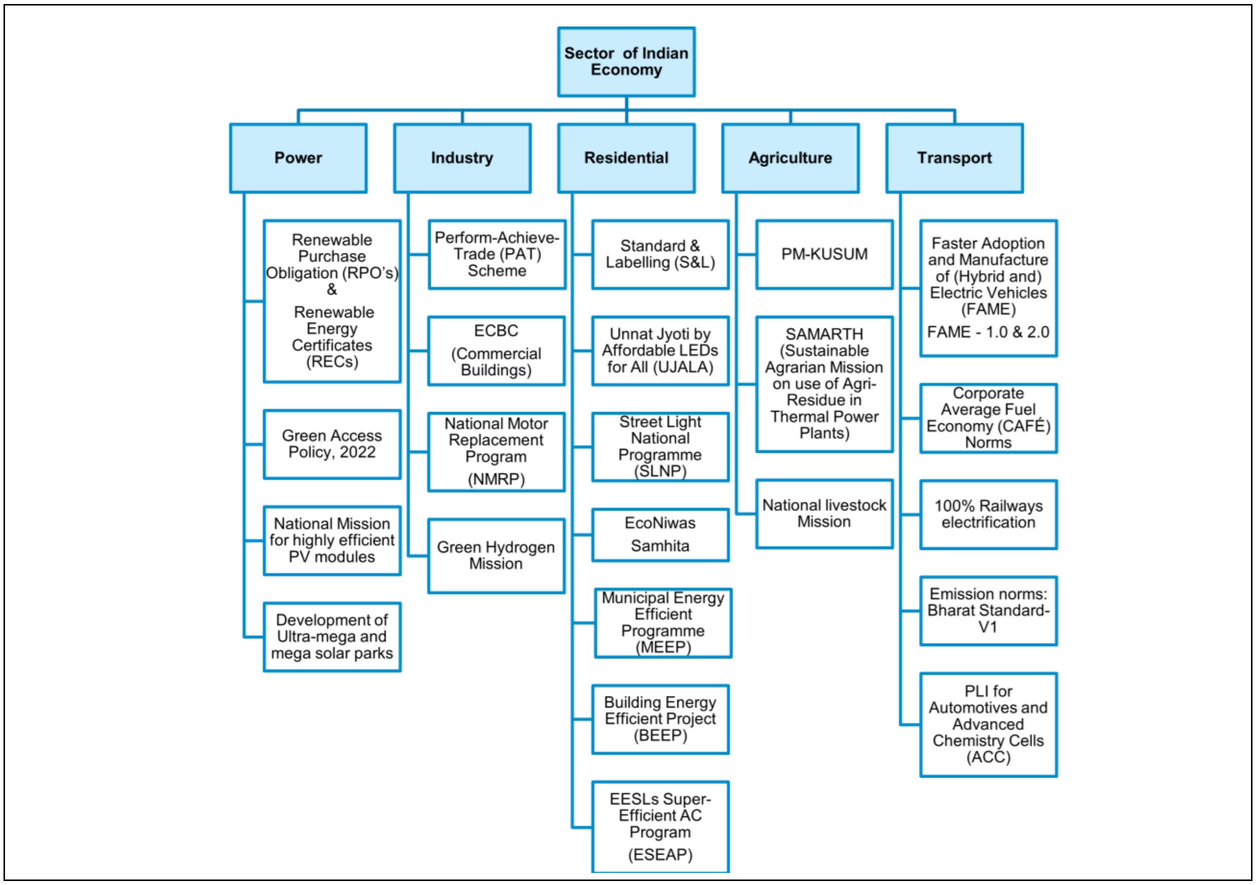
In Section 3 we present a set of policy packages to consider the policy trade-offs behind accelerating the energy transition. We consider three policy packages to mitigate GHG emissions, showing how for same reduction of emission different policy tools will have different impacts on different metrics: GDP, employment, budget structure, income at aggregate and sectoral level and energy security. Each policy package is designed to deliver 15 percent lower emissions by 2030 relative to a "business as usual" scenario. We find ambitious reforms are possible through renewable subsidies or by combining renewable subsidies with higher coal tariffs and carbon trading while providing greater energy security, and a potential increase in fiscal revenues. The corresponding costs include a possible increase in government expenditure, output costs from distortions, and the need for job transitions. In order to mitigate these costs, the GoI could utilize social transfers and active labor market policies to help the transition; and revenue transfers to compensate the poorest and those who are affected by these new policies.

In Section 4 we review the gap to a global agreement on climate change and cite potential solutions for how to provision climate financing and technology transfer. We find that meeting the Paris climate goal of keeping temperature rises to 2 degrees centigrade will require substantially more ambition from all countries. Given no country can address this gap alone, and given India's position as a global leader, an agreement on a global solution will only be possible with India's participation. An agreement on meeting this ambition gap will likely be accompanied by an agreement on climate financing and technology transfer. Global estimates for required climate financing vary substantially but in all likely instances India will be a net beneficiary. India is already playing a leading role in the global distribution of climate technology and technology transfer, in particular, solar technology.

2. CURRENT EMISSIONS AND POLICY LANDSCAPE

To critically understand India's emissions mitigation strategy, this paper narrows this appraisal to five sectors with the highest emissions intensity. These are the power, industrial, transport, residential and agriculture sectors. Figure 5**Error! Reference source not found.** shows a general flow of implemented programs aimed at mitigation, mapped across the shortlisted sectors.[iii] The qualitative sector analysis is based on a wide literature review of government submissions to the UNFCCC, public resources on government policies and programs, annual reports of relevant ministries and public sector enterprises, impact assessments of programs commissioned by the authorities, among other sources including estimates from the International Energy Agency (IEA).

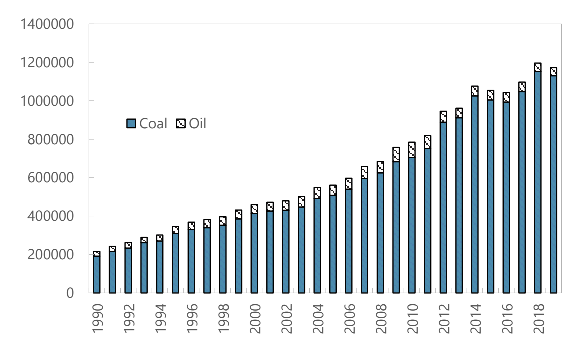
Figure 5. Major mitigation-oriented policies across the five most emission intensive sectors



2.1 Power sector

2.1.1 Context

Figure 6. CO_2 emissions from fuel combustion in **Power sector by fuel type(Ktoe)**



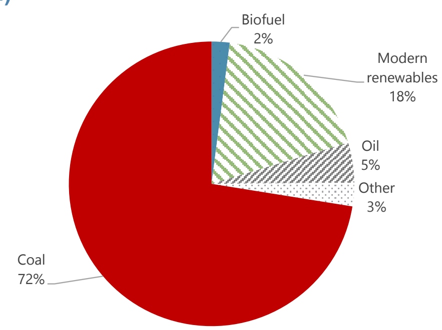
Source: OECD IEA Big CO2; and author calculations.

India's electricity generation is dominated by coal, but there is increasing focus on renewable power generation. Electricity generation accounts for almost 40 percent of total CO2 emissions in India.[iv] This is largely due to the role of coal in the sector, which accounts for over 70 percent of electricity output, 50 percent of installed capacity, and most emissions for the sector (**Error! Reference source not found.**).[v,vi vii] Coal capacity continues to grow, increasing by 3.3 percent since 2019, equivalent to 204 GW. [viii] Renewable energy currently accounts for over 36 percent of all installed capacity in the sector, including hydro (Figure 7). Renewable energy capacity has grown by 150 percent since 2019, but from a low base this amounted to a significantly smaller increase relative to coal, of 60.81 GW.[ix,x] In 2015-16, the Indian government set a target of achieving 175 GW of renewable energy capacity by 2022 (this target was not met by end-2022) and enhanced this target to 500 GW renewable energy capacity by 2030 at

COP26.[xi] India's updated NDC also includes a target to achieve 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, with the help of transfer of technology and low-cost international finance including from the Green Climate Fund.[xii]

2.1.2 Sector Strategy

Figure 7. Electricity generation, by fuel type (2020) (Gwh)



Source: OECD IEA Extended World Energy Balances

Given coal's continued widespread use, the Government of India (GoI) has focused on reducing emissions intensity of existing and new coal-fired generation plants. The GoI has indicated that coal use for electricity will remain a large component of source energy for the foreseeable future, but supercritical technology is being adopted to enhance the efficiency of coal fired power plants. Plans to adopt ultra-supercritical plants and develop advanced ultra-supercritical technology, which are estimated to have emissions savings of 15-20 percent according to the IEA, are in place.[xiii]

Concurrently, the GoI is implementing a host of innovative mechanism for accelerated renewable energy deployment. Requirements for a floor on the share of renewable energy in the electricity source mix of distribution companies (DISCOMs) have been established (21 percent as of 2021/22), known as Renewable Purchase Obligations (RPOs).[xiv,xv] This will be scaled up to 43 percent share by 2029-30.[xvi] DISCOMs that are unable to meet mandated RPOs can purchase Renewable Energy Certificates (RECs)—green certificates that represent the environmental attributes of power generated from renewable energy but not the actual power itself—on national energy exchanges.[xvii] An analysis of the REC market from 2011-2021 showed an initial sharp increase in renewable energy certification rates from 2 percent in 2011-12 to 15 percent in 2014-15, but more recently rates fell to 3.6 percent in 2020-21. The fall coincided with a fall in the average price of solar RECs and a rising inventory of unsold RECs (driven by a lack of demand), as such renewable power producers chose to stay out of the market mechanism, given that returns were decreasing and uncertain (Sawhney, 2022). More recently in 2022 the Green Open Access Policy was established to promote generation, purchase and consumption of green energy including through waste-to-energy plants and by allowing consumers to demand green power from DISCOMS, with no minimum limit for captive consumption. This policy is expected to prompt smaller industries, commercial consumers, and large households into shifting towards green energy, uptake is further incentivized through issuance of green certificates (issued to end consumers of 100 kW or more).

Investments in physical infrastructure to further scale renewable energy capacity, storage, and grid flexibility are also ongoing. More than 40 percent of installed capacity in India is from renewable energy, and that share is rising. Considerable investments have been made in setting up solar parks, a green energy corridor (which aims to synchronize electricity produced from renewable sources with conventional power stations in the grid), smart grids, as well as on transmission infrastructure upgrades.[xviii] To secure domestic supply chains, budget FY 2022-23 committed INR 195 billion to the Production Linked Incentives (PLI) scheme for manufacturing integrated solar panels.[xix] The PLI scheme (which is significantly broader than only solar panels) involves GoI-backed incentives on incremental sales from products manufactured domestically. Other initiatives include research into alternatives to lithium-ion batteries for renewable energy storage. This includes hybrid renewable energy, such as a combination of solar and wind, as solutions for industry requirement of continuous, reliable power.[xx]

2.1.3 Barriers to Decarbonize

One of the key challenges facing the power sector is the debt-distress of state DISCOMs. DISCOMs struggle to raise revenues amid underpriced electricity, inadequate subsidy payments and long-term purchase agreements with electricity generation companies. In addition, they face high energy losses (a combination of technical loss, theft, and inefficiency in billing) and high commercial losses (default in payment and inefficiency in collection). Given their heavy financial losses, DISCOMs have generally under-invested in improving power distribution or in upgrading the energy distribution infrastructure.[xxi] Political economy constraints have historically impeded reforms to DISCOMs and their pricing structure. Furthermore, DISCOMs' payment delays to renewable energy generators act as one of the major barriers to scaling up renewable energy in India.[xxii]

The GoI has undertaken several initiatives to resolve DISCOM debt stress. Around USD 60 billion has been allocated across several programs since 2015 aimed at resolving debt stress while trimming electricity losses, gradually narrowing the cost-revenue gap, improving the reliability and quality of power supplies, and promoting more sustainable competition in the sector (Ujwal DISCOM Assurance Yojana (UDAY) 1.0 and 2.0, and the Revamped Distribution Sector Scheme). State governments took on the debts of DISCOMs in UDAY 1.0, but they nonetheless continued to face financial strains. The use of smart meters has been recognized as an additional solution to minimize DISCOM losses—and that could aid demand side management as well as narrow the cost-revenue gap of stressed DISCOMs—but this has had slow progress.[xxiii] Revising electricity tariffs will also be important to address the question of DISCOM viability. Looking forward, such schemes remain critical as DISCOMs face a further hit to their financial stability (from revenue loss), distribution system issues (from reactive power, voltage impacts and reverse power flows) and demand forecast uncertainty as renewable energy ramps up.[xxiv]

Given India's energy needs, substantially decarbonizing at scale remains a challenge. The country needs to auction around 40 GW of renewable energy projects annually but to date has only been able to auction about 20 GW annually.[2,xxv] Additionally, the Parliamentary Standing Committee on Energy (2021-22)[xxvi] indicated that investments in the renewable energy

[2] The 2015 target of 175GW of RE capacity by 2022 was approximately equal to an additional 40GW. Auctioned amounts were less due to limited financing for RE generators, DISCOMs distress leading to contract renegotiation leading to payment underwriting requests from RE generators and increases in solar PV costs due to supply chain disruptions and import taxation by authorities.

sector have been, at most, half of what is required meet India's 2030 target of 500 GW renewable energy installation. Second, to viably scale up the use of renewable energy, India will also need to better coordinate the flow of power between DISCOMs, which are under the jurisdiction of states. This would allow excess power in one region to be sent to regions with power deficits.[xxvii] It would also be important to ensure energy from fossil fuels, rather than renewables, is curtailed when there is an overall surplus of energy. Third, improvements in renewable energy storage technology—though not a constraint unique to India—will help ensure consistent electricity provision from renewable energy. The international solar alliance has been demonstrating the potential of pumped storage hydropower (PHP), and research is underway to understand the applicability of liquid-based batteries. Finally, the GoI will need to ensure that its investment schemes are able to crowd-in private investment. Evidence has shown that private capital tends to be directed towards more innovative, mature companies with better emissions reducing technologies (Cornelli, Frost, Gambacorta, & Merrouch, 2023)

Delaying action on reducing the use of fossil fuels in the power sector will be costly, but it may be difficult for India to avoid. Given renewable energy technological constraints, existing infrastructure, and India's energy needs, the cost of completely ending India's dependence on coal in the near term may be prohibitively high. At the same time, an energy system comprised mainly of long-lived coal-fired power plants potentially represents a carbon lock-in which may delay investment in, and deployment of, modern renewable energy infrastructure, and threaten the likelihood of meeting long-term climate objectives (SEI, 2022). Reaching the long-term emissions targets may then require premature retirement or coal-fired plants or retrofit with carbon-capture and storage. Both options would result in significant additional costs, and highlight the importance of acting now to start reducing fossil fuel dependence in the sector (Seto, et al., 2016).

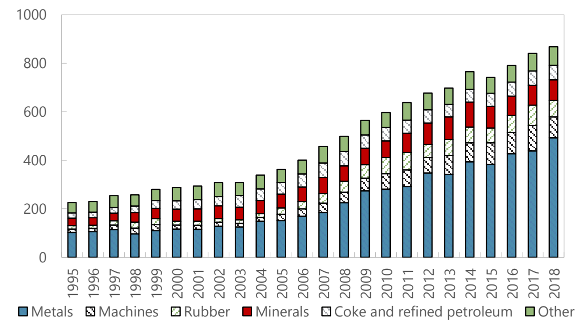
Power Sector – Major policy initiatives				
Policy name	**Description**	**Budget**	**Challenges**	**Emissions saving**
PLI scheme for high efficiency solar PV modules	Production-linked incentive scheme, which provides financial incentives to private companies based on incremental domestic manufacturing of solar panels	FY 23 Budget: Rs. 1.97 lakh crores, over 5 years starting FY 2021-22[xxviii]	Steep targets for incentives. Until 2021, only 3-4 companies achieved the incremental sales targets to qualify for the PLI scheme. Most domestic companies rely on one or two supply chains which have been severely disrupted.	Aimed at reducing emissions intensity of GDP by reconfiguring the energy mix of the country
Repurchase Obligations (RPOs) and Renewable energy certificates (RECs)[xxix]	RPOs are obligations set by state regulators that require large electricity consumers (e.g. DISCOMs) to purchase a certain percentage of their energy requirements from renewable sources. Companies can purchase RECs in lieu of their RPOs. Renewable energy producers sell electricity to distribution licensees at the rate of conventional energy and recover the balance cost by selling RECs to other obligated entities, enabling them to meet their RPOs. Green open access enables Commercial and Industrial Consumers to request green power DISCOMs	NA	Almost all the demand for RECs comes from obligated entities such as DISCOMS (60per cent) and captive power plants or open access consumers (nearly 40per cent), with negligible participation from voluntary buyers.[xxx] Poor enforcement of penalties in case of non-compliance to RPOs: A failure to meet RPOs attracts a penalty defined by the regulator. Discretionary powers given to regulators to specify penalty charges have led to obligated entities being allowed to carry forward their RPOs to next year despite availability of RECs in the market, causing a shortfall in demand in the market.[xxxi]	NA
Green open access, 2022		NA	Under the original open access plan (2016), uncertain/high open-access charges posed a key challenge, with varying state policies inhibiting the broader adoption of open-access regulations.[xxxii] [xxxiii] [xxxiv] Many states do not allow inter-state open access due to potential revenue losses for state DISCOMs.[xxxv]	NA
Development of ultra-mega and mega solar parks[xxxvi]	A series of solar power parks planned, with minimum capacity of 500 MW.	Estimated Central Financial Assistance (CFA) of Rs.8100.00 crore under the National Solar Mission (NSM)[xxxvii]	Acquiring contiguous land close to power grids. According to the draft scheme, the park must have at least 5 acres per MW towards installation of solar projects and land acquisition is the responsibility of the state government.[xxxviii,xxxix]	The GoI estimates that when fully operational an ultra-mega solar plant is expected to generate 6,000 million units of electricity annually for 25 years and offset more than four million tons of CO2 a year.[xl]

2.2 Industry

2.2.1 Context

The industrial sector in India accounts for around 22 percent of total GHG emissions and is less efficient than equivalent sectors in other countries. Within the sector, around 98 percent of emissions are from CO2 and, of those, over 90 per cent are concentrated in four broad sub-sectors (metals, minerals, machines, and rubber and plastics) and are largely related to fossil fuel combustion (Figure 8). These sub-sectors also tend to have very high emissions intensity both relative to other sectors and other countries, largely due to the reliance on coal power to fuel manufacturing activity (Figure 9).[xli] Despite significant emissions, the industrial sector in India accounts for only about 25 percent of both gross value added and employment.

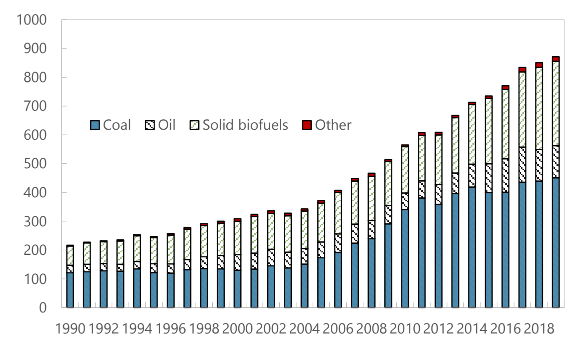
Figure 8. Industrial sector emissions, by sub-sector (MtCO2e)



Source: IMF Climate Dashboard; and author calculations.
Note: 'Other' category includes: food, beverages and tobacco; paper products and printing; wood and " "wood products; textiles, leather, footwear; chemicals and pharmaceutical products.

To achieve India's desired development trajectory, the industrial sector will need to grow to supplement the already large services sector. In particular, the industrial sector will need to help support the large share of the population currently living and working in rural and agricultural sectors. Under current production technologies in India, this will put further upward pressure on the sector's emissions which have already been rising over time, with coal playing an ever-important role in fueling final consumption (both directly and through electricity) and emissions. Without policy intervention to reduce the industrial sector's carbon intensity, this will lead to a significant rise in emissions.

Figure 9. Industrial sector, emissions by fuel type (MtCO2e)



Source: OECD IEA Big CO2 database; and author estimates.
Note: Other includes biogases and natural gas.

2.2.2 Sector Strategy

GoI is using a multi-pronged approach to meet the challenge of decarbonizing the hard-to-abate industrial sector. There has been a strong focus on enhancing energy efficiency of industrial units that predominantly use fossil fuels for the energy and process requirements. More recently, there has been a growing strategic focus on enabling clean energy for the energy intensive sector.

Several programs to boost efficiency of energy consumers have been implemented. The Perform Achieve and Trade (PAT) is a market-based mechanism wherein large energy consumers trade excess energy savings certificates (issued when plants achieve a reduction in energy consumption in excess of their government mandated target) that can be traded on the power exchanges.[xlii] The Energy Efficiency Services Limited (EESL)[xliii] company was created as a joint venture of several public sector undertakings (PSUs), with the aim to facilitate energy efficiency projects, with one of the implemented programs designed to stimulate supply for high efficiency motors in the country (the National Motor Replacement Program (NMRP)) to decarbonize the industrial sector.[xliv]

Programs targeting energy efficiency of the Micro, Small and Medium enterprises (MSME) are also critical for reducing emissions. MSMEs constitute about 90 percent of India's industrial sector, and it has been estimated that 10-30 percent of energy consumption and GHG emissions could be reduced if MSMEs adopted energy efficient technologies.[3] [xlv,xlvi] The Ministry of MSMEs has implemented programs to assist firms in improving their operational technology and competitiveness in the market while reducing emissions including financial support to reduce emissions, a capital subsidy for loans to adopt new technology, and financial assistance to improve efficiency and obtain certification for meeting national and international efficiency standards. These policies can be seen as a part of a wider policy program which aims to facilitate the renewable energy transition in MSMEs while ensuring global competitiveness.

New minimum energy standards for commercial buildings will help reduce the sector's overall emissions. The Energy Conservation Building Code (ECBC) is estimated to lead to a 50 percent reduction in energy use by 2030, which is estimated to lead to a reduction in CO2 of 250 million tons. As of December 2021, only 264 existing buildings have adopted Bureau of Energy Efficiency (BEE) star ratings and 18 States, and 2 Union Territories have notified ECBC.[xlvii,xlviii]

Programs to increase options for industrial feedstocks will help reduce the hardest to abate emissions in the industrial sector. With a significant decline in the cost of renewable energy several heavy industries have voluntarily shifted to renewable energy as their primary energy source.[xlix,l,li] Pumped storage hydropower and group captive renewable energy generation (when a project is developed for the collective usage of one or many corporate buyers) are enabling this shift. The Ministry of Petroleum and Natural Gas (MoPNG) is preparing a strategy for the development and implementation of carbon capture utilization and storage techniques in the oil and gas sector in India.[lii]

Lastly, an increased policy focus on green hydrogen is laying the pathway for cleaner energy for industries in India. The National Hydrogen Energy Mission (NHM) will provide a roadmap for green hydrogen (hydrogen produced from electrolysis powered with renewables), with the aim to develop India as a global hub for hydrogen technologies manufacturing; to this end, a framework to support manufacturing via incentives and facilitation will be developed. The Government will also facilitate demand creation in specific areas, including mandates for using green hydrogen in industry (fertilizer, steel, petrochemicals etc.) and in transport. The provision

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[3] This estimate is based on energy saving potential across key industrial sectors in the MSME sector (Biswas, Sharma, & Ganesan, 2018) .

of free and easy open access to the inter-state transmission system network for 25 years for capacity installed up till June 2025 will bring down costs significantly. Green hydrogen can also be used to fulfill RPOs according to the green Open Access Rules 2022.[liii]

2.2.3 Barriers to Decarbonize

Abating emissions in the industrial sector, particularly for heavy industries, is significantly more challenging than in other sectors given the capital-intensive nature of the sector and the high energy-intensity of many production processes. Shifting to alternative fuel sources may require a complete change in production processes and technologies, which may not be financially viable for many firms. In some cases, the technologies needed to run these processes on renewable energy have yet to be developed. For the MSMEs segment, given the fragmented and often informal nature, a key challenge lies in regulating and monitoring the set standards of emissions.

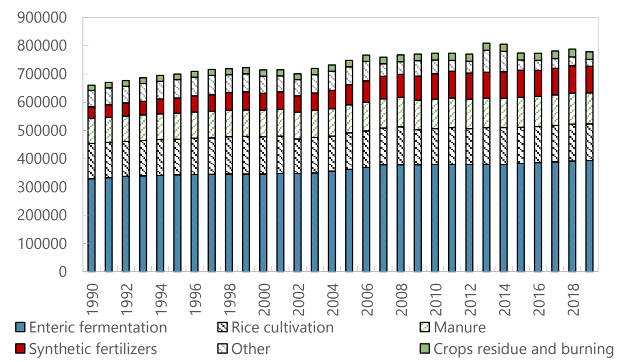
Other sources of decarbonization for the sector will likely need to include demand management measures. This would include greater use of recycled inputs, thus bypassing the process emissions of new products. It may also include carbon capture and storage, especially for industries where zero-carbon products are nearly impossible (such as steel and cement). That said, carbon-capture and storage is not yet affordable at a large scale.[liv] Switching fuels to zero-carbon fuels such as (green) electricity will be critical. While green hydrogen and biomass could be used for higher-temperature processes that are difficult to electrify, the projected costs of such technologies are significant. The MoPNG has recently notified a draft framework for a voluntary carbon credit trading scheme in India. The PAT scheme, focused on energy savings particularly in the industrial sector, is proposed to transition into a nation-wide cross-sector compliance market for carbon trading.

Industrial Sector				
Policy name	**Description**	**Budget**	**Challenges**	**Emissions saving**
The Perform, Achieve, Trade (PAT)	A regulatory instrument to reduce energy consumption in energy intensive industries, with an associated market-based mechanism to enhance the cost effectiveness through certification of excess energy saving (EScerts) which can be traded.	NA	Continued surplus supply of EScerts in the market and muted demand leads to sustained lower prices in EScerts trading, eventually deterring consumers to make investments in energy efficient technologies.[lv]	BEE has rolled out six PAT cycles from 31st March 2020 with 1073 consumers covering 13 sectors. It is projected that total energy savings of about 26MTOE translating into 110 million tons of avoided CO2 emissions by March 2023.[lvi] The latest PAT cycle (VII, for the period 2022-23 to 2024-25) targeted 509 consumers with an estimated energy saving target of 6.627 MTOE.lvii
National Motor Replacement Program (NMRP)	Enables easier and faster adoption of efficient motors by addressing the barrier of paying a higher upfront cost by the industry.	NA	Risks in program execution[lviii]: 1. High upfront costs for consumer/non availability of funds for capex 2. Apprehensions about 'shared savings model' in context of motors 3. Longer delivery time of motors and after sales service 4. Lack of demand from industry	EESL signed agreements with over 30 major industries to replace over 1,200 inefficient motors with IE3 motors, enabling energy savings of 48,16,535 kWh and emission reduction of 4,240 tCO2, annually[lix#]
ECBC-commercial[lx]	Sets minimum energy standards for commercial buildings.	NA	Slow uptake: As on 31st March 2021, only 227 buildings have been registered under ECBC. The 227 constructed and ECBC compliant buildings with total area of 3.52 million square meter have led to energy savings of 141.65 MU[lxi]	It is estimated that India will add 1 billion new commercial buildings with increased demand for air conditioning. BEE estimates that if the future stock is built in compliance with ECBC, about 300 BU electricity will be saved by 2030. This translates to 15 GW peak demand reduction and 250mtco2 co2 abetment.

2.3 Agriculture

2.3.1 Context

Figure 10. Agriculture sector emissions, by activity (KtCO2e)



Source: FAOSTAT Database
Note: Other includes drained organic soils; Savanna, forest, tropical forest, and organic soil fires; on farm energy use; and drained organic soils. Enteric fermentation is fermentation that takes place in the digestive system of animals, primarily cattle, sheep, goats, and camels.

Emissions in the agriculture sector stem primarily from livestock's enteric fermentation and rice cultivation (methane) and from manure and residue burning (nitrous oxide) (Figure 10**Figure 10**). The sector represented 14 per cent of the total GHG emissions. Despite a decline in cattle population since 2014, the sector nonetheless still accounts for about 74 percent of the country's methane emissions, which have an outsized impact on temperatures (Parry, Black, Minnett, Mylonas, & Vernon, 2022). The agriculture sector also accounts for 20-25 percent of electricity consumed in the country, predominantly for irrigation, despite only 40 percent of arable land being irrigated.[lxii,lxiii] Further, the issue of stubble burning causing air pollution between cropping cycles has been an area of policy focus.

2.3.2 Sector Strategy

Given food security needs, India has exempted agriculture from its energy intensity reduction commitments but has nonetheless implemented policies that help reduce emissions.[lxiv,lxv] To date, most of the climate-related policy action in the sector has focused on enhancing the adaptation through insurance, direct benefit transfers, crop diversification, and research on climate-stress resilient seed varieties.

Given the national grid configuration and significant demand for electricity by the sector, load is usually met at night. While the power costs Rs 2.75 per kilowatt-hour (kwh) at most during the day on energy exchanges, the rate surges to as high as Rs 12/kWh in the night.[4] Since electricity is heavily subsidized (or free) for agriculture, this practice causes heavy losses to DISCOMs. The current policy focus to solarize agriculture is designed to not only ease financial stress on DISCOMs,[lxvi] and enable day irrigation for farmers, but has also created opportunities for round the clock energy availability for green hydrogen production by renewable energy banking.[lxvii]

[4] To ensure the industrial sector has reliable power during the day, agriculture electricity load is typically shifted to nighttime. However, given the limited of renewable energy storage, DISCOMs supply power at night using mostly thermal energy. Currently, a unit of thermal energy is more costly than a unit of renewable energy. Power supplied to the agriculture sector is also often free of the cost, resulting in massive losses to the DISCOMs. Some of these losses are offset by heavy tariffs on the industrial sector.

Policies to boost the use of solar energy, which eases financial stress on DISCOMS while reducing emissions, have been prioritized. Given the sector accounts for a fifth of all the power used in the country, efforts are underway to ensure energy security for farmers ("PK-KUSUM" scheme). This includes deploying 10 GW of solar capacity through installation of small solar power plants of capacity up to 2 MW, installing 2 million standalone solar powered agriculture pumps, and solarizing agricultural feeders for 1.5 million grid connected pumps.[lxviii] The first goal is directly linked to enhancing clean energy capacity, and when combined with goal two, also aids in the domestic market development of solar cells, while the third goal is related to deepening the integration of renewable energy in the electricity infrastructure of the county. Further, the second goal to deploy two million standalone solar pumps in off-grid areas will help reduce the use of diesel in pump sets, directly reducing emissions.[lxix]

Mandated blending of coal and biomass also aims to reduce emissions. To incentivize farmers away from stubble burning, the MoPNG issued a policy for biomass utilization for power generation through cofiring in coal-based power plants, mandating a 7 percent blend of biomass pellets made from agro-residue along with coal.[lxx] While aiding reduction in pollution, the program also aids coal-fired plants to reduce coal utilization per unit power generated.

The GoI is also committed to mitigating methane emissions from livestock and rice cultivation. The National Livestock Mission includes a focus on breed improvement and other measures to reduce etheric fermentation. Local research institutes have developed an anti-methanogenic feed supplement which cuts down bovine and sheep's methane emissions by 17-20 percent and results in higher milk production and body weight gain.[lxxi]

2.3.3 Barriers to Decarbonize

To date, there appears to be less effort to decarbonize the agriculture industry relative to other industries in India, largely due to its unique position in the Indian economy. The agriculture sector is omitted from India's long-term climate strategy. Additionally, despite being one of the largest emitters globally of methane, India has not joined the Global Methane Pledge. This Pledge was launched at COP26 in November 2021 to catalyze action to reduce methane emissions by 30 percent by 2030 and signed by 100 countries (Mondal, 2021). There are various explanations for this including, importantly, that India views methane emission as necessary for the survival of small and medium-size farms in India, upon whose production rests the livelihood of millions of people. Additionally, India views the NDC targets, which are agnostic on type of GHGs, as sufficiently strict to reasonably commit to global emissions reductions.

Most farming in India is carried out by subsistence farmers who face high rates of poverty. With small farms and low margins, the cost to adopting new technologies that lower emissions are high. Recent research has shown that despite the promise of solarization of agriculture, states are finding it difficult to get farmers to shoulder the beneficiary contribution under the scheme in the backdrop of free or subsidized power for agriculture.[lxxii,lxxiii] However, without farmer contribution, the viability of the model gets severely constrained. Additionally, limited awareness of mitigation-oriented agricultural practices is also a challenge in scaling solutions, for instance promoting wider uptake of methane reducing cattle feed.

Capacity challenges as well as trust-deficit impair wide adoption of mitigation-oriented solutions. Other challenges to solarization include capacity issues with far fewer solar pump sets sanctioned by the government when compared to the scheme targets.[lxxiv] The grid-connected model also requires pumps to be metered and billed for accounting purposes but suffers from a lack of trust between farmers and DISCOMs since regular power supply to agriculture is heavily subsidized.[lxxv]

High subsidies also distort farming practices in India. The way subsidies are currently provided are either directly (for instance, through minimum support prices and guarantee purchases by the government, which encourage cultivation of high-emissions rice) or indirectly (for instance, through highly subsidized energy and water resources) which tend to lead to an over consumption of energy by farms.

Agriculture Sector

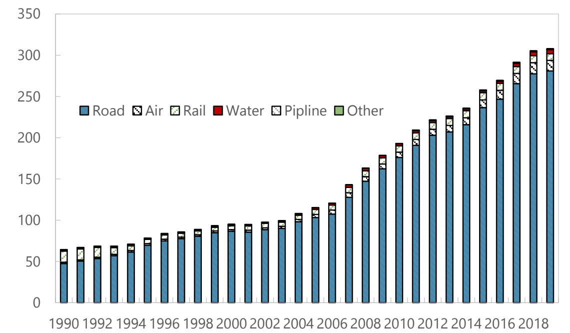
Policy name	Description	Budget	Challenges	Emissions saving
Sustainable Agrarian Mission on use of Agro Residue in coal-fired Power Plants	Replace coal with agro-residue in coal-fired power plants – will reduce emissions from coal-fired plants and reduce air pollution from stubble burning in farms.	FY 2021-22 34.56 Cr[lxxviii]	**Demand:** NTPC (a PSU) accounts for 98.3per cent (58,000 MT) of all the cofiring.[lxxix,lxxx] Lack of awareness among farmers and/ or the compensation for agro waste below the cost of transporting the waste to the plant.	Used in 40/180 coal-fired power plants, 59,000 metric tons (MT) of biomass cofired to date. Biomass has been recognized as a carbon neutral fuel and biomass co-firing is a technology recognized by UNFCCC as a measure of reducing greenhouse gas emission.
National Policy on Biofuels, 2018 and 2022 amendment[lxxvi]	Foster domestic biofuel production, reduce petroleum imports, impose 20$ bioethanol in petrol regulation from 2023.	Unblended fuel has additional differential excise duty of ₹2/ liter since October 2022[lxxxi]	Almost entire quantity of ethanol is transported by diesel-based road tankers adding to cost, potentially increasing GHGs on net. [lxxxii]	The carbon dioxide released by a vehicle when ethanol is burned is offset by the carbon dioxide captured when the feedstock crops are grown to produce ethanol.[lxxxiii]
Agriculture Demand Side Management (AgDSM)[lxxvii]	Reduce the energy intensity of agriculture pumping sector by carrying out efficiency up gradation of agricultural pump sets	FY 2021-22 369.42 in sale of goods. FY 2021-22 540.75 lakhs in services rendered[lxxxiv]	Improper metering and calculations for energy savings. Limited awareness regarding water use efficiency and energy efficiency. The connectivity issues for the smart control panel of the Energy Efficient Pump Set.[lxxxv]	As of 8th Nov 2022, 81,173 pumps replaced amounting to .15Mt CO2 reduction per year.[lxxxvi,lxxxvii] This could result in 54 BU in energy savings, an Rs. 271.9 billion reductions in subsidies, and annual 40 Mt reduction in CO2 emissions[lxxxviii,lxxxix]
The Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM)	Increasing the share of installed capacity of electric power from non-fossil-fuel sources to 40% by 2030. Setting up renewable power plans on barren land and on cultivable land on stilts where crops can be grown below the solar panels.	Budgeted central financial support of Rs. 34,422 Crore including service charges to the implementing agencies.[xc]	Most DISCOMs have a surplus of contracted generation capacity and are wary of procuring more power in the short term. DISCOMs often find utility-scale solar cheaper than distributed solar (under the scheme) due to the latter's higher costs and the loss of locational advantage due to waived inter-State transmission system (ISTS) charges.[xci] States are finding it difficult to get farmers to shoulder the beneficiary contribution under the scheme (40 per cent), given free or subsidized power for agriculture. Without farmer contribution, the viability of the model gets severely constrained.	According to MNRE, nearly 80 lakh pumps out of approximately 3 crore agricultural pumps installed in India are diesel pumps. The total diesel consumption of these pumps in a year works out to 5.52 billion liter per annum along with equivalent CO2 emission of 15.4 million tons. When implemented fully, PM-KUSUM will lead to reducing carbon emissions by as much as 32 MTCo2 per annum.[xcii]
Revamped Distribution Sector Scheme – agricultural feeder component under PM KUSUM[xciii,xciv,xcv]	Seeks to improve the operational efficiencies and financial sustainability of all DISCOMs by providing conditional financial assistance for improving supply infrastructure.	Under the scheme, works of separation of 10,000 agriculture feeders would be taken up through an outlay of almost Rs 20,000 crore.[xcvi][xcvii]	3-4 acres of land required to install one decentralized solar power project of 1 MW capacity for solarization of agricultural feeders, and the land has to be within 2-5 kms radius from the DISCOMs sub-station.[xcviii] For example, 190 sq kms of land is required to solarize all agri feeders in Maharashtra. Metering and billing a large number of dispersed connections and managing the non-participant farmers connected to the feeder make the scheme unattractive for DISCOMS.	

2.4 Transport

2.4.1 Context

India's largely oil-dependent transport sector accounts for about 9 percent the country's GHG emissions.[xcix] Road transport alone accounts for about 90 percent of sectoral emissions (Figure 11).[c] This is primarily due to the number of vehicles on the road as emissions intensity (defined by CO2 per kilometer driven) is substantially lower than in other emerging market economies and closely aligned with intensities observed in advanced economies. India benefits, in part, from the prevalence of smaller vehicles, especially 2- and 3-wheel vehicles which have much lower emissions intensities.

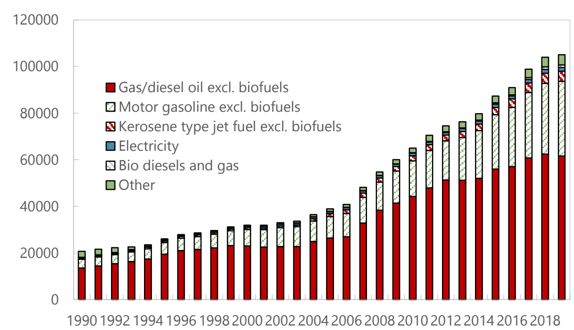
Figure 11. Transport sector emissions, by activity
(MtCO2e)



Source: OECD IEA Big CO2

The sources of fuel in the transport sector are highly specific to the mode of transport. About 97 percent of road transport relies on petrol or diesel, air transport relies entirely on jet fuel, and rail mostly on electricity (Figure 12). Nonetheless, despite a rise in the absolute use of electricity as a fuel source, its share of overall final transport fuel consumption has declined in recent years due to the sharp rise in petrol and diesel consumption.

Figure 12. Transport sector, final consumption by fuel type
(Ktoe)



Source: OECD IEA Extended World Energy Balances
Note: Other includes fuel oil, natural gas, liquefied petroleum gases and other bituminous coal

Absent additional policy interventions, road emissions will continue rising as demand for vehicle ownership rises with an increase in population and real incomes. Similarly, demand for air travel is likely to increase. Attaining India's ambitious 2030 e-mobility vision (70 percent of commercial vehicles, 30 percent of private cars, 40 percent of buses, 80 percent of 2- and 3-wheeler sales to be EVs) requires a significant change in vehicle purchasing trends, investment in EV charging infrastructure, and battery development.[ci,cii]

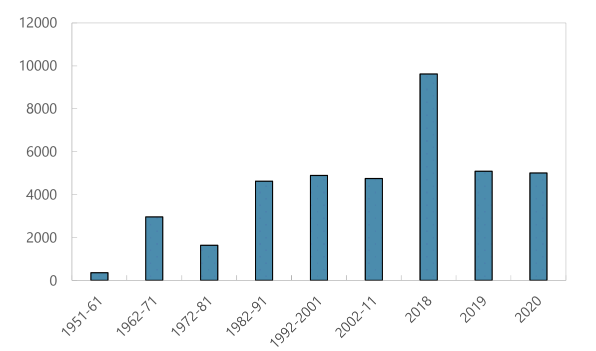
2.4.2 Sector Strategy

India relies on a multi-pronged approach to pursue its transport sector emission goals, including regulatory measures and subsidy schemes. The country is focusing on both enhancing the fuel efficiency of internal combustion engine (ICE) vehicles as well as market development for EVs through subsidies and investments in battery charging infrastructure. Fuel taxes and excise duties also play an important role in the cost of fuel in the sector, and thus affect demand, but they are generally not used to explicitly meet emissions targets.

Fuel-efficiency and fuel-consumption standards are key regulatory measures. Policy programs include passenger vehicle emission standards (Bharat Standard (BS)[5] and overall fuel-economy standards (CAFÉ Norms). A third program aimed at bringing down the absolute share of fuel used in internal combustion vehicles focuses on the production of ethanol from damaged food grains which are unfit for human consumption (National Policy on Biofuels).

Subsidies and policies to boost EV and battery production are another critical aspect of the sector's emissions reduction strategy. To maintain its market share as the third largest auto maker globally and address price sensitivity of customers in the transition to low emissions vehicles, India has announced various polices to boost EV production. these include better integrated supply chains, availability of vehicular components, investments in battery solutions (advanced chemistry cells, battery swapping, and charging), and stronger domestic demand (Faster Adoption of Manufacturing of Electricity vehicles (FAME) 1.0 & 2.0).[ciii] [civ] Specifically, PLI schemes for Advanced Chemistry Cells—the newest generation of energy storage—and for manufacturing of EVs have been introduced.[cv] [cvi] A five-year phased manufacturing mission to set up large-scale, export-competitive integrated battery and cell-manufacturing giga plants has been established which prioritizes domestic manufacturing of the entire supply chain for EVs (The National Mission for Transformative Mobility and Battery Storage) . As a part of this mission, a draft battery swapping policy has been released that emphasizes the need for interoperability standards to improve efficiency in the EV ecosystem.[cvii] Battery swapping is particularly relevant for 2- and 3-wheelers and will be particularly useful in the context of limited charging infrastructure in urban areas.[cviii,cix,cx] Finally, under India's foreign direct investment rules, electric vehicles are permitted to have 100 per cent foreign investment without any requirement for government approval.[cxi]

Figure 13. New rail electrification
(Route kilometers)



Source: Indian Railways Yearbook 2019-20

India has a vast network of railways, used to transport both goods and passengers, with a long-standing goal of electrification. Since 1979 the Ministry of Railways has made electrification of railway tracks over the Indian Railways a key objective. It has electrified 52,247 Route kilometers (RKM), or about 80 percent of the total (broad-gauge) network railways, by March 31, 2022 (**Error! Reference source not found.**).[cxii] The annual level of new electrified railways has been rising at a rapid pace, and the Ministry has targeted the electrification of all routes by December 2023. Railways is also covered under the PAT program.

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[5] Currently, BS VI is being enforced in the country which is like the euro standard IV.

2.4.3 Barriers to Decarbonize

Most of the transition enabling polices in the transport sector are focused on road-based passenger vehicles with minimal focus on emission intensive heavy-duty freight or aviation segment. India's freight sector is dominated by trucks, making it a hard to abate sector due to limited availability of sustainable alternatives. Further, with rising income, the demand for domestic air travel will continue to increase. This is projected to significantly increase the share of aviation in transport emissions due to its high carbon intensity. Focused policy interventions will be required in both heavy-duty freight and aviation to ensure they become sustainable, while remaining competitive.[cxiii] For example, including aviation emissions in emissions trading schemes while also modernizing and improving air traffic management technologies, procedures and systems, as in the EU, could contribute to reducing emissions from the sector.

In the passenger vehicle segment, India's pace of transition to EVs will be determined by the pace of deployment of support infrastructure, primarily battery charging facilities. The proposed Battery Swapping Policy offers a potential solution to the need for charging infrastructure, but it remains in a nascent stage.[cxiv]

Transport sector				
Policy name	**Description**	**Budget**	**Challenges**	**Emissions saving**
100 percent railways electrification	Full electrification of all railways	The rail budget for FY23 gave an outlay of ₹7,452 crore for electrification projects.[cxv]	No-objection certificate for open access: Open access has been granted as a deemed licensee in 11 states and the Damodar Valley Corporation area. However, there have been regulatory challenges in other areas. Wheeling and banking provision: Full deployment of solar potential will become more feasible if states provide wheeling and banking arrangements.[cxvi]	100 percent electrification is estimated to reduce 15 million tons of Carbon Dioxide (CO2).[cxviicxviii,cxix,cxx] This would save Rs 170 billion in fuel costs and other savings per year.
The Faster Adoption and Manufacturing of Electric Vehicles (FAME) 1.0 (2015-2019), 2.0 (2019-)	FAME 1.0 encouraged electric and hybrid vehicle purchase by providing financial support. FAME 2.0 focused on electrification of public transport infrastructure and charging	Fame 1.0's budget outlay of Rs 895 Crore.[cxxi]Fame 2.0 Rs. 10,000 crores for a period of five years.[cxxii]	Regulatory loopholes: Recently, FAME 2 was amended to better account domestic value addition— following allegations that some EV manufacturers were availing the subsidy while importing components significantly from abroad[cxxiii] Industry representatives claim the 50 percent localization policy requirement will make it challenging for industry to avail the scheme.	EVs sold through 2030 could cumulatively save 474 million tons of oil equivalent (Mtoe) worth INR 15 lakh crore and generate net CO2 savings of 846 million tons over their operational lifetime.[cxxiv,cxxv]
PLI for ACC batteries	Production-linked incentive scheme to promote domestic manufacturing of advanced chemistry cell batteries	Rs 18,100 Cr (2.48 bn USD)	Need for standards: Rules and regulations need to be created that require original equipment manufacturers (OEMs) to manage the end-of-life disposal, recycling of, or reuse of batteries after first-life application. A framework of minimum specifications and standards must be established to ensure these second-use batteries can be installed safely and effectively	Batteries and hydrogen are both energy carrier and storage technologies. As such they are only as green as the source of energy that gets stored in them.
BS IV Fuel Economy Standards	Emission standards based on European regulation instituted by the GoI to regulate the output of air pollutants from compression ignition engines and Spark-ignition engines equipment, including motor vehicles.	NA	Cost implications: Changes in engine and after-treatment systems have been estimated to account for a total one-time investment of around Rs 40,000-50,000 crore and an operating cost impact of Rs 30,000-40,000 crore for automotive OEMs. This increase in investment and operating costs, in turn, resulted in increases in vehicle prices.[cxxvi]	Transition is estimated to reduce almost 70 per cent in nitrous oxides and hydrocarbons, and a 50 per cent reduction in particulate matter emissions, compared to BS-IV norms.[cxxvii]
Corporate Average Fuel Economy (CAFE) norms	CAFÉ norms regulate how far vehicles must travel on a gallon of fuel.	NA	Cost implications: Difficult to implement updated CAFÉ II norms (earlier CAFÉ 1) with price increases being passed on to consumers. While BS norms limit the emissions of pollutants like hydrocarbons, sulfur and oxides of nitrogen, CAFE norms deal with overall fuel consumption that are directly proportional to CO2 emission output.	Fuel savings for the period 2017-20 are estimated at 1.2 Mtoe, and the emission reduction is estimated at 3.7 MtCO2 for the same period[cxxviii]

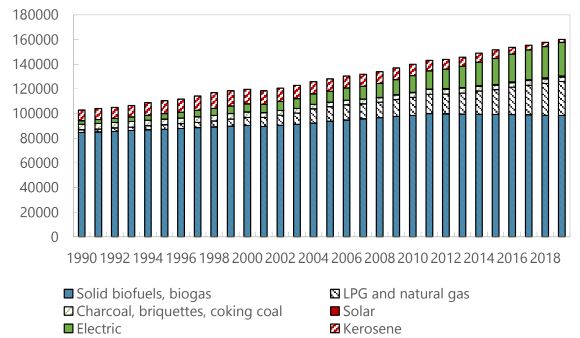
2.5 Residential

2.5.1 Context

India's residential sector contributes about 4 percent to the national GHG emissions.[cxxix] Solid biofuels (e.g., wood) remain the most common source of fuel in the sector, however consumption of electricity has been rising in line with improved electricity access (Figure 14). While this is a cleaner source of fuel for households, it remains an important contributor to emissions because most electricity remains coal-powered (see section 2.1).

Figure 14. Residential sector, final consumption by fuel type

(Ktoe)



Source: OECD IEA Extended World Energy Balances.
Note: Electricity is generally coal-powered in India

Ensuring 24-hour reliable access to electricity for all citizens is a key priority in India. The percentage of households with access to electricity has increased from 55 percent in 2001 to near universal by 2022.[cxxx,cxxxi,cxxxii] Much of this progress was made under the schemes which supported rural electrification and provided free or subsidized electricity connections to homes. Consistent with greater access, electricity consumption has been rising—both overall, and on a per capita basis. Looking ahead, India is set to more than double its building space over the next two decades, with 70 percent of new construction happening in urban areas as migration from rural to urban areas continues.[cxxxiii] Given the country's requirement of new building stock, the extent to which new construction follows energy-efficient building code will shape patterns of energy use for the sector.

2.5.2 Sector Strategy

The GoI has used a combination of approaches to mitigate emissions in the residential sector. The overall strategy is one that allows meeting both the needs of current urban and rural houses, as well as the need for standard setting for the housing stock of the future. Local municipalities and state DISCOMs are critical stakeholders and beneficiaries of the approach.

Enhancing energy efficiency is a key feature of the mitigation-oriented demand-side management polices deployed in the residential sector. The BEE and EESL have implemented important work to reduce energy requirements of the residential sector. These include programs to improve energy efficiency of home appliances (the "Standard and Labelling" (S&L) program); programs to purchase LED light bulbs at scale (establishing economies of scale and brining cost of production down) and at discount distribution to consumers through state DISCOMs, with cost savings passed on (Unnat Jyoti by Affordable LEDs for All (UJALA) program); programs to conduct energy audits and implement efficiency measures through Energy Service Companies (ESCOs), including installation of LED streetlights (under the Street Light National Program (SNLP), part of the wider Municipal

Demand Side Management (MuDSM), that focuses on capacity development of municipalities in energy efficiency measures strategy).

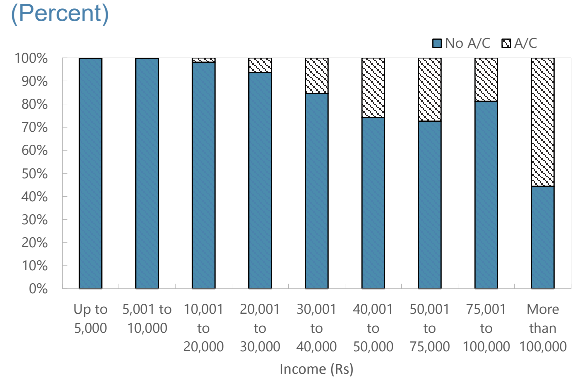
In rural areas, switching to cleaner cooking and heating fuels has been a key priority. The ministry of New and Renewable Energy launched the Biogas program, among other objectives, to provide clean cooking fuel, lighting, meeting thermal and small power needs of users which results in GHG reduction.[cxxxiv,] The scheme promotes biogas based decentralized renewable energy sources of power generation, in the capacity range of 3 kW to 250 kW or thermal energy for heating/ cooling applications from the biogas generation produced from biogas plants of 30-2500 M^3 size.

Over longer horizons, a focus on cleaner fuels for cooling has been prioritized. India is one of the first countries in the world to have a Cooling Action Plan (ICAP), under the Montreal Protocol, to ensure provision of sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits.[cxxxv] While ICAP aims to provide a long-term vision to address the cooling requirement across sectors, including a focus on the residential, the Energy Conservation Bill (2022), recently passed by the Indian Parliament,[cxxxvi] empowers the central government to specify an energy conservation code for residential buildings. This new code will provide norms for energy efficiency and conservation, use of renewable energy, and other requirements for green buildings.

2.5.3 Barriers to Decarbonize

The greatest challenge to reducing emissions in India's residential sector is the need to boost living standards for a large share of the country's population. In both urban and rural settings, many still live in non-permanent housing and use biofuels for cooking and heating. As India continues along its development path, there will be a continued shift towards building more residential housing, and with it, greater electrification, use of appliances, and need for cooling (Figure 15). These factors will all drive emissions up in the sector.

Figure 15. Air conditioner ownership, by income decile
(Percent)



Source: India Residential Energy Survey via Harvard Dataverse; and authors calculations.
Note: The top two income deciles have been collapsed into one for presentation.

Lack of access to financing makes high-up-front-cost efficiency-improving retrofits or renovations to residences and appliances out of reach for many households. Apart from cost-sensitivity of consumers hindering adoption of energy efficient appliances at scale, the frequent change in regulations hinder margins of producers and hence prices have stayed high. Ensuring high energy efficiency standards for new residential buildings will be critical to help offset some of this trend. In this context, the developments on the Energy Conservation Bill (2022) detailed earlier is encouraging.

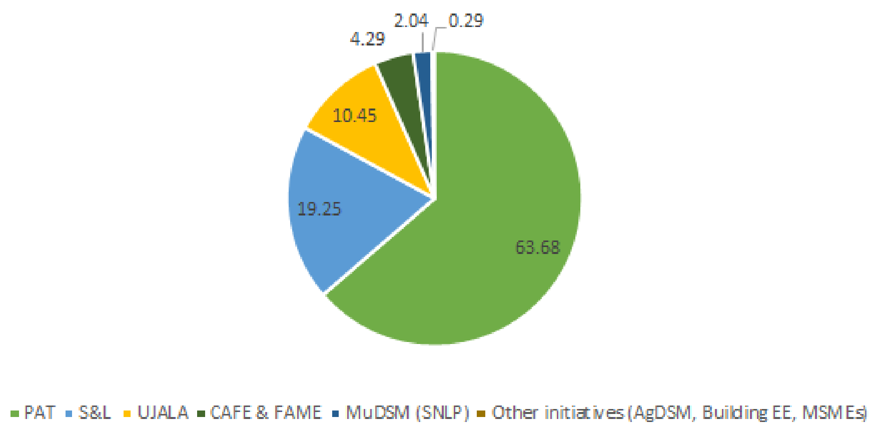
India's residential electricity tariff policy should be rationalized. There is a complex system of cross-subsidization in India's electricity market. Low-income households, whose energy costs account for a significant share of expenditure, as well as agriculture consumers are charged prices below the DISCOM's supply cost. To compensate for these lost revenues, DICOMS charge other customers (typically commercial and industrial users) higher prices and they receive direct subsidies from state governments. As demand for electricity rises by households in India, either subsidy costs will rise, or residential and agriculture customers will transfer to cheaper sources of electricity (e.g. off-grid solar panels)—both of which will exacerbate DISCOMs financial troubles.

Residential Sector				
Policy name	**Description**	**Budget**	**Challenges**	**Emissions saving**
Eco-Niwas Samhita (ENS)	An energy conservation building code for residential buildings that promotes energy efficiency in design and construction. Part-I prescribes minimum standards for building envelope designs.	NA	Greater policy focus is on increasing the efficiency of cooling technologies rather than on efficient building envelopes to reduce the rapidly increasing cooling demand.[cxxxvii.cxxxviii]	Over 1.55 million sqm of the residential built-up area has been compliant with ENS. The residential labelling program takes ENS forward and is estimated energy saving potential is around 388 BU by year 2030.[cxxxix]
Standard and Labelling program (S&L)	Requirement for labels affixed to products to provide consumers an informed choice about the energy saving and consequent cost saving potentials of the respective products.	NA	Frequent change in codes limit producers' ability to produce at scale due to constant cost escalations.[cxl] Labelling is self-declared with limited testing facilities for certification	The S&L program resulted in savings of 69 BU, leading to monetary savings of Rs. 39,000 crores and emission reduction of 53.307 MT per annum[cxli]
Unnat jyoti by affordable LED for all (UJALA)[cxlii]	UJALA: LED bulbs, Tube lights and energy efficient fans provided to domestic consumers for replacement of conventional and inefficient variant.	FY 21/22: Revenue of 960 Lakhs from sale of goods[cxliii]	NA	Over 36.86 Cr LEDs sold, resulting in annual savings of 47.87 billion kWh of electricity, Emission reduction is estimated at 38.78 MtCO2 annually[cxliv]
Street Lights National Program (SNLP)	SNLP is a program to replace conventional streetlights with smart and energy efficient LED streetlights across India. It aids municipality-level power demand management.	FY 21/22: 102850.72 lakhs for services; 9510.18 lakhs for sale of goods[cxlv]	Conflicting budgetary interests of municipalities[cxlvi]	5.99 million tCO2 GHG emissions reduction from installing 12,954,065 streetlamps.[cxlvii] 8700.49 Mus energy saved annually, and 1450.08 MW avoided peak demand[cxlviii]
Super-Efficient AC Program (ESEAP)	Super-Efficient Air Conditioners distributed and subsidized by the Ministry of Power for sale to consumers.	NA	Price sensitivity and brand preference of Indian consumers[cxlix]	Sold more than1,300 air conditioners, leading to an energy saving of 9.2 Lakhs Units annually and CO2 emission reduction of 7.54 lakh kg CO2e
Municipal Energy Efficiency Programme (MEEP)	MEEP replaces inefficient pumps in public water works and sewerage systems at no upfront cost to the municipal bodies, for 500 cities. The investment will be recovered from the savings in energy costs. The program supports municipality-level power demand management.	NA	After 5 years of implementation, IGEA studies for only 338 cities have been executed out of the targeted 500 cities.[cl]	Energy savings of 20 percent to 40 percent, approximately 4800 MUs of energy savings per annum. Reduction of 3.9 million tons of CO2 emissions per annum and Monetary savings of approximately Rs 3200 Crores per annum. [cli]
Building Energy Efficiency Project (BEEP)	Mainstreaming energy-efficient and thermally comfortable (EETC) building design for both commercial and residential buildings.	FY 21/22: Revenue of 360.29 Lakhs from sale of goods and 7296.77 Lakhs from rendering services.[clii]	Ministry limits its service offering to the replacement of selected equipment.[cliii]	A total of 702,959.14 tCO2 emissions reduction from annual 75.64MW avoided demand, resulting in 224,021,105.55 kWh annual avoided energy demand.[cliv]

Text Box 1: India moving towards a National Carbon Market

India's focus on energy efficiency helped achieve total energy savings of 40 Mtoe in 2019-20, corresponding to annual monetary savings worth INR 152,241 crores per annum, which implies an equivalent reduction in CO_2 emissions of around 267.98MT annually.[clv] One of the key drivers in energy savings-based emission reduction was the PAT scheme, accounting for about two-thirds of all the energy savings in FY 2019-20 and more than half (55.4 per cent) in FY 2020-21.[clvi,clvii]

Shares of different schemes in overall energy savings (percent)



To efficiently drive decarbonization across sectors, particularly the industrial sector, the GoI has been working towards the rollout of a voluntary, and eventually compulsory, market for carbon credit trading. The setting up of a carbon market will expand the policy toolkit, beyond the currently emphasized instrument of enhancing energy efficiency across industries and processes. A systematic pivot towards a carbon market is illustrated by following policy developments:

- The Energy Conservation (Amendment) Bill, 2022, equips the central government to specify a carbon credit trading scheme in India. The bill was passed by the Parliament in late 2022 and is awaiting Presidential accent.
- Earlier in 2022, the Bureau of Energy Efficiency (BEE) released a consultation paper on a National Carbon Market.[clviii] The paper proposed that the existing PAT scheme be transition into the national carbon market.
- In December 2022, the Indian Energy Exchange set up the International Carbon Exchange Pvt. Ltd (ICX), to enable voluntary participants to buy and sell voluntary carbon credits at competitive prices.
- Further, in March 2023, the MoPNG released a draft carbon credit trading scheme, with a proposed framework for carbon trading, drawing from the BEE consultation paper released in 2022. The draft proposes the BEE as the market administrator given its experience with administering the PAT scheme.

The compliance market for energy saving—PAT scheme—was particularly successful compared to other BEE programs in achieving emissions reduction. A similar compliance market (cap-and-trade mechanism) for carbon credit trading, leveraging BEE experience, holds the potential to benefit the country with enhanced pace of transitions to cleaner production methods across sectors.

2.6 Sectoral conclusions

While India is making important progress in implementing its climate agenda at the sectoral level, emissions remain on a strong upward trend. The power and industrial sectors are the largest emitters, and ambitious action will need to be taken in addition to existing policies to bring emissions down in a meaningful way. Further support for renewable energy alternatives, for investment in green and efficient new technologies, and for market-based mechanisms to incentivize emissions reductions is needed.

Challenges remain across sectors on the path towards decarbonization. In the power sector, the market structure and precarious financial position of DISCOMS are an important roadblock to increasing the renewables share of electricity, as is the reliance of many communities on coal and related industries. This is further exacerbated in the residential and transport sectors as the expected rise in household incomes will continue to put pressure on demand for electricity, vehicles, and air travel. Heavy industry may need to rely on recycling and on the future viability of green hydrogen to power intensive processes, while others in the industrial sector will need to shift to existing renewable energy sources.

The cumulative impact of the actioned solutions, while ambitious, will nonetheless fall short of meeting the net zero 2070 goal. Investments in the renewable energy sector have been around half of what is required to decarbonize according to the Ministry of New and Renewable Energy.[clix] While technology transfer and international finance will have to be leveraged (see Section 4), domestic debt markets may provide important sources of finance. The schemes already announced or in place cumulatively demand sizeable fiscal space, and given the projected extreme climate events, this will become ever more important. There is merit in considering the efficacy of various fiscal instruments, taxation vs subsidy, in meeting the countries emissions reduction target.

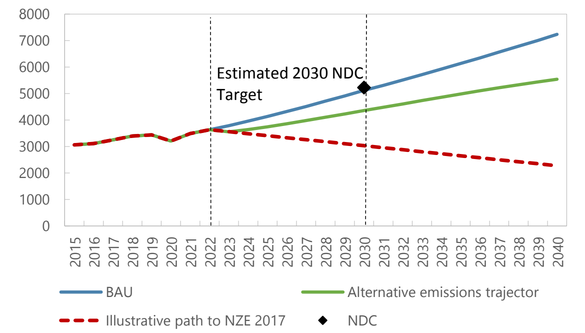
3. MACROECONOMIC MODEL

3.1 Section introduction

India's business as usual (BAU) projected GHG emissions are on a strong upwards trend and moving away from an illustrative near-linear path to net zero emissions by 2070 (Figure 16). As discussed in Section 1, there are significant potential costs with delaying adjustment towards the net zero path. However, given India's ambitious development goals, it is likely to also be prohibitively costly to begin reducing aggregate net emissions immediately.

A middle-ground can be achieved but will require trade-offs between emissions reductions and transition costs. In this section, we consider how feasible it would be for India to tread a middle ground of accelerating the transition towards renewable energy and what are the trade-offs inherent in the different policy options which could be used to meet this goal. This middle ground is shown in the green line in Figure 16**Error! Reference source not found.**. In this scenario, GHG emissions would continue to rise in India but at a lower rate than in the baseline. This would mean emissions are 15 percent lower in 2030 compared to the BAU although they would remain 25 percent higher than current levels. This trajectory was chosen because it is equivalent to the level of emissions that India would produce if the government adopted a US $5/tCO2e carbon price in 2030—lower than the IMF's proposal of US $25/tCO2e and the level needed to meet the Paris Agreement targets,[6] but nonetheless a realistic target to achieve over the next eight years. This trajectory is one of many that could be adopted and is presented to discuss policy trade-offs and not as an explicit recommendation.[7]

Figure 16. GHG emissions path and alternative trajectory
(mtCO2e)



Source: IMF staff calculations and IMF-ENV model.
Note: NDC target for India is a 45 percent reduction in emissions intensity of GDP (ceiling) by 2030. Target is estimated using historical emissions data and GDP growth projections and is met in the baseline. Net-zero target for 2070 is declaration/pledge (illustrative near-direct linear path shown). Alternative emissions trajectory is a reduction equivalent to a 15% GHG emissions reduction in 2030 (or about a $5/tCO2e).

3.2 Model description

We utilize a global dynamic computable general equilibrium model (IMF-ENV) to capture the macroeconomic dynamics of emissions reductions.[8] The model has three core strengths which we utilize in this paper:

1. Macroeconomic dynamics up to 2040;
2. Rich detail on inter-sectoral economic linkages and sectoral emissions; and
3. Accounting of interactions between domestic and international policies.

Macroeconomic Dynamics: Production activities are represented by a regionally calibrated nested CES and rely on primary factors (land, labor, capital, and natural resource) and intermediate inputs.[9] The outputs from each production activity could enter as intermediate demand in other domestic sectors, direct demand by households and/or be internationally traded. A key characteristic of the model is that it considers frictions in domestic reallocation of capital (which is unique to among most computable general equilibrium models, and provides more realism) by differentiating capital by vintage types. The model baseline is calibrated to reported data on GDP, GHG emissions, electricity generation between 2014 to 2021 and in the subsequent years to macroeconomic projections from IMF's World Economic Outlook (WEO) and GHG and electricity generation projections from Climate Policy Assessment Tool (CPAT). In the policy scenarios the, the policies are introduced starting 2022 and the model solves for an equilibrium in commodities and factor markets in each year from 2022 to 2040, allowing us to consider the trajectory of sectoral growth over a horizon of about 25 years.

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[6] See Parry, Black, and Roaf, 2021, "Proposal for an International Carbon Price Floor Among Large Emitters" and Gaspar and Parry, 2021, "A Proposal to Scale Up Global Carbon Pricing"
[7] A larger policy shift, equivalent to a US$ 25/tCOe was also considered in the 2022 Article IV for India (Country Report No. 2022/386). Results are shown in the India 2022 Article IV Box 4, page 43.
[8] Model described in detail in Annex 1.
[9] Land is used as input in the agriculture sector. Natural resource is necessary for economic activities associated to forestry, fisheries, minerals, and fossil extraction sectors.

Inter-sectoral economic linkages and sectoral emissions: The model provides rich detail on economic impacts and related GHG emissions for each of the 36 sectors. Sectors which determine GHG emissions are modelled in more detail including fossil fuel goods (coal mining, crude oil, refined oil, gas extraction, gas distribution), power generation (coal, oil and gas-powered electricity, hydro power, solar, nuclear, and other) and energy intensive and trade exposed (EITE) sectors (iron and steel, non-metallic minerals, chemical, pulp and paper, and non-ferrous metals). The growth or decline in these sectors will then determine the level of GHG emissions produced in the country.

Accounting of domestic and international policies: Each of the G20 countries are individually calibrated in the model and the rest of the world is aggregated into six model regions. Model regions are linked to one another via bilateral trade across sectors. Thus, the model captures the cross-border spillovers of policies via changes in bilateral trade and thus, can also quantify global impact of domestic and international policy changes on international trade, international commodity prices, and global GHG emissions.

While the model has rich detail in its treatment of the local and global macroeconomic structures, there are also important caveats. It has less detail in its incorporation of microeconomic frictions and in assumptions of technological change. For example, the model assumes that labor can move between sectors without frictions such as retraining or migration. This means the model may underestimate the cost of policy changes in the short-run due to missed adjustment costs. The model does not explicitly model the role of technological change potentially leading to overestimating the cost of transition in the long-term. For instance, if green hydrogen becomes economically viable this could make reducing GHG emissions less costly. A second important caveat of the model is that it does not capture the distributional impacts nor co-benefits like the human health impacts of changes in policy.

3.3 Scenarios and intermediate pathway

We consider three policy packages which lower the emissions trajectory to meet the green *Alternative Emissions Trajectory* lineError! Reference source not found.**, but which have significantly different costs.** All of scenarios lower emissions in 2030 by 15% relative to BaU and are closely aligned with India's current policy mix: (i) only a renewable subsidy, (ii) a renewable subsidy + coal excise tax (iii) a renewable subsidy + medium coal excise tax + a carbon price.[10] All three policies are introduced in a budget-neutral way. The green subsidy rate in India is endogenously determined in the model and is financed by increasing wage taxes. In all three scenarios we assume that high income countries meet their NDC targets by 2030 using carbon pricing and governments balance their budget by adjusting labor income taxes. Middle income countries and other low-income countries only continue with their current policies, and this is a conservative illustration of the pace of global decarbonization by 2030. Carbon tax

[10] A carbon tax differs from the coal excise tax in two ways. First, a carbon tax is calculated based on the carbon intensity of the fuel versus the coal tax that is applied per unit of output of coal. Second, the carbon tax disincentivizes the use of brown energy sources (coal, oil and gas) while the coal tax only disincentivizes the production of coal, which is the most carbon intensive brown fuel.

revenues in all regions are recycled by reducing the wage taxes. All policies are gradually phased in to allow an orderly transformation in the sectors.

The three policy packages are:

1. **A subsidy to renewable power**

In the first policy package, the entire emission reduction target is met using only a subsidy on the production of solar and wind power. This policy tool similar to the Indian government's current approach in using renewable purchase obligations (RPO) and production linked incentive (PLI) schemes to support expansion of green power sectors.[11]

2. **A subsidy to renewable power + coal excise tax**

In the second policy package, in addition to a subsidy on renewable, coal excise taxes are increased to meet the mitigation goal. This policy tool is effectively ramping up the Indian government's current excise duty on coal. The combination of the renewable power subsidy and coal tax works similar to a feebate[12]. Since there are two mitigation tools- one that incentivizes the use of green power and other that disincentivizes the production of coal, the subsidy to renewables that is needed to deliver the emission reduction is smaller in package 2 versus 1.

3. **A subsidy to renewable power + coal excise tax + a carbon price**

In the third policy package, we introduce a carbon price on all CO_2 emissions from fossil use. The renewable subsidy needed to meet the emissions goal in package 3 is the lowest among the three policy packages. This is because both carbon tax and coal excise tax discourage the use of carbon-intensive fuels and therefore, contribute towards the emission target while leaving a lower mitigation target that needs to be delivered by the subsidy on green power.

3.4 Results

a. Energy mix

In the baseline, India's electricity demand is forecast to rise rapidly from about 1500 Twh in 2020 to almost 5500 Twh in 2040 (Figure 17, panel 1). Under current policies, part of this demand is met by an expansion in renewable energy, nuclear and hydropower sources which grow to meet 44 percent of total electricity demand in 2040. Although the proportion of electricity from coal is falling, still 49 percent of demand is forecast to be met via coal power production in 2040 with the level of electricity from coal set to grow by almost 150 percent compared to 2020

[11] Neither policy is identical to simply subsidizing energy. The RPO scheme is not technically a subsidy as it mandates an amount of certain types of renewable energy that must be purchased by distribution companies (DISCOMs). In practice, this will act in a similar way to a subsidy if the cost of renewable electricity exceeds that of alternative forms. The PLI schemes are supporting the manufacturing industry in renewables, which should lower the cost of renewable energy but is not a direct subsidy to renewable energy generation.

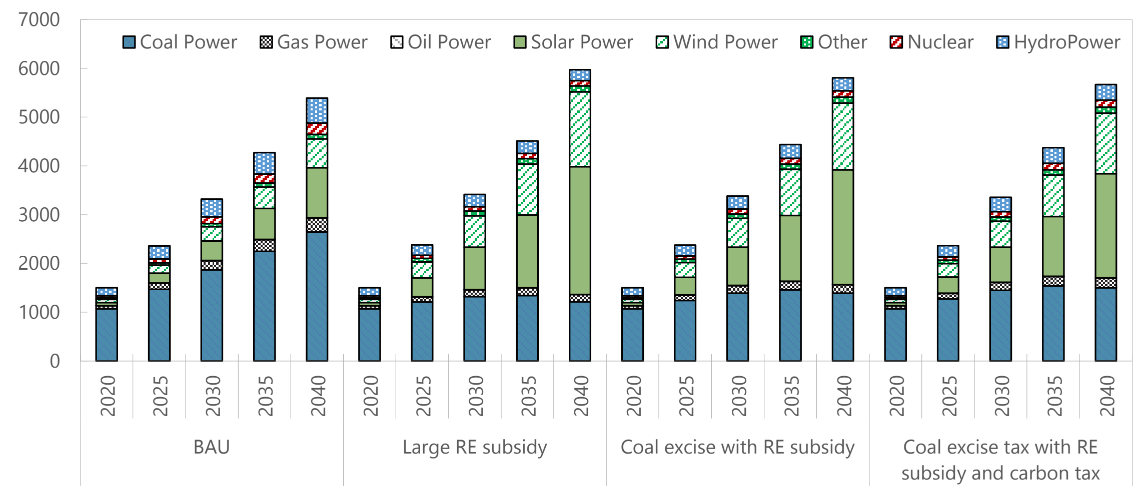
[12] A feebate is a system that charges fees to higher emitting firms or sectors and rebates to those firms or sectors which produce lower carbon. This incentivizes lower carbon usage without the problem of substantially raising the price of the good.

levels.[13] Indeed, power generation, iron steel, and nonmetallic minerals are set to make up 66 percent of India's CO_2 emissions by 2030.

Total electricity supply increases when renewable power is subsidized. Under each of the policy package, the subsidy on production of renewable power supports the rapid expansion of the wind and solar sectors and overall electricity supply increases by almost 10 percent relative to BaU in 2040. The second panel of Figure 17 shows the impact on the energy mix from only a large renewable subsidy. Given the production prices in these sectors are lower with subsidy relative to BaU, they also contribute to a gradual decline in coal power production.

With a combination of renewable power subsidies, carbon tax and coal taxes, the share of renewables in the energy mix also rises. The third and fourth panel of Figure 17 show the impact of combining renewable subsidies with taxes on emitting sectors. Policy packages 2 and 3 work like a feebate and the subsidy increases the production of renewable power with the net effect on the electricity price being a decline between 7 to 11 percent relative to BaU in 2040. Nonetheless, since renewables are still relatively cheaper, the energy mix remains tilted heavily towards renewable energy sectors.

Figure 17. Electricity Mix in India
(Twh)



Source: IMF staff calculating using the IMF-ENV model.
Note: BAU is business as usual scenario, with no change in currency policy. All other scenarios assume that high income countries (excluding Saudi Arabia) meet their NDC pledges and India reduces emissions by 15 percent relative to the BAU by 2030, starting in 2023. Labels indicate the policy choices to achieve the 15 percent relative reduction in emissions. The size of the RE subsidy differs across scenarios, see main text for details.

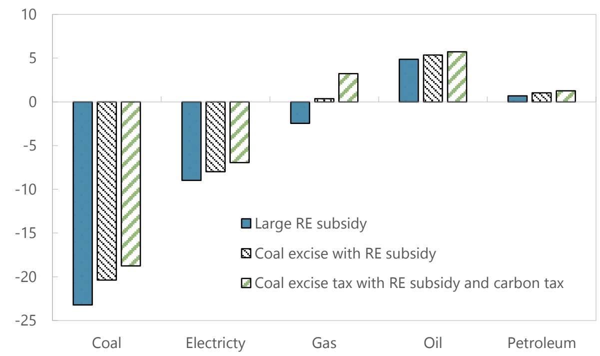
b. Energy security

[13] The estimates are broadly in line with the coal capacity increase envisioned in the Draft National Electricity Plan from 2022 to 2027 (Ministry of Power , 2022)

A key outcome from the three scenarios is that all of them increase energy security in India. Figure 17 shows imports of fuels under the three scenarios by 2035 when compared to the BAU scenario. In this exercise the change in import of fuel depends on the price of fuels, which themselves depend critically on both the domestic and (simultaneous) international mitigation efforts. In all three scenarios coal imports decline substantially as demand declines and can be met domestically. The domestic price of coal also does not rise as much as the international price, contributing to lowering imports. Electricity imports also decline across all

three sectors, as it is replaced by the subsidized renewable electricity which is produced domestically. Across all three scenarios oil and petroleum imports continue to rise, because international emissions mitigation efforts reduce the international (pre-tax) price of oil and petroleum. Global mitigation effort also lowers international gas prices, though by a lower amount than oil, with mixed effects on gas imports, depending on the extent of subsidization of renewables.

Figure 18. Import of Energy
(Percent change wrt BAU by 2035)



Source: IMF staff calculations using the IMF-ENV model.
Note: Changes calculated in volume of commodity with respect to a baseline of no change in policy.

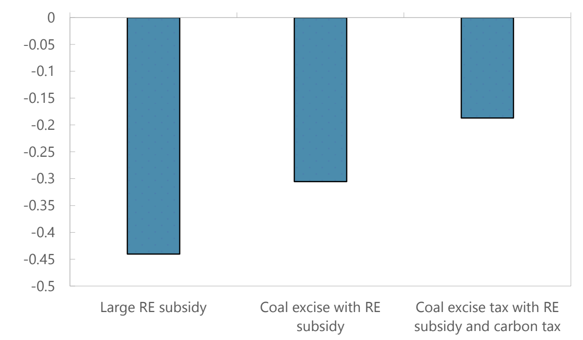
c. Output costs

While the policy packages will all result in lower emissions, increased renewable energy and greater energy security, they all come with trade-offs. By design, each of the policy packages delivers identical emission reduction but because of differences in the policy tool, they have different impacts on output, as shown in Figure 19 **Figure 18**.

Only subsidizing renewable power without complementary measures to mitigation is more expensive. The model estimates that this would lead to a 0.45 percent of reduction in GDP by 2030 compared to baseline. This is because – (i) financing the subsidy by increasing wage taxes reduces the demand for labor and (ii) lowers labor income received by households consequently also lowering consumption. Together, both these channels contribute to lower growth. The decline in GDP growth, however, is relatively small – about 0.05 percentage points per year, on average.

Figure 19. Real GDP
(% diff. wrt BAU, 2030)

The other two policy packages also lead to a decline in output, albeit smaller. Complementary mitigation policies ease the fiscal pressure of financing the subsidy to renewable power and thus, GDP costs are more modest 0.18 to 0.3 percent by 2030. By design, a feebate is fiscally less expensive because it finances green subsidies with higher taxes for emitting sectors, which generate revenue. Thus, relative to only green subsidies financed via income taxes, a feebate can be financed via revenues from the carbon tax and therefore, a lower increase in income taxes is needed. Revenues from the carbon tax are recycled to reduce wage taxes. Therefore, adding a carbon tax on top of the coal excise tax dampens the wage tax increase needed to finance the green subsidies while incentivizing a move away from carbon-intensive sectors by correcting the price signals. The accompanying switch from carbon-intensive to low-carbon or carbon-neutral sectors contribute to mitigation thereby, reducing the pressure on public finances for green power subsidies needed to reach the same GHG emissions.



Source: IMF staff using IMF-ENV.

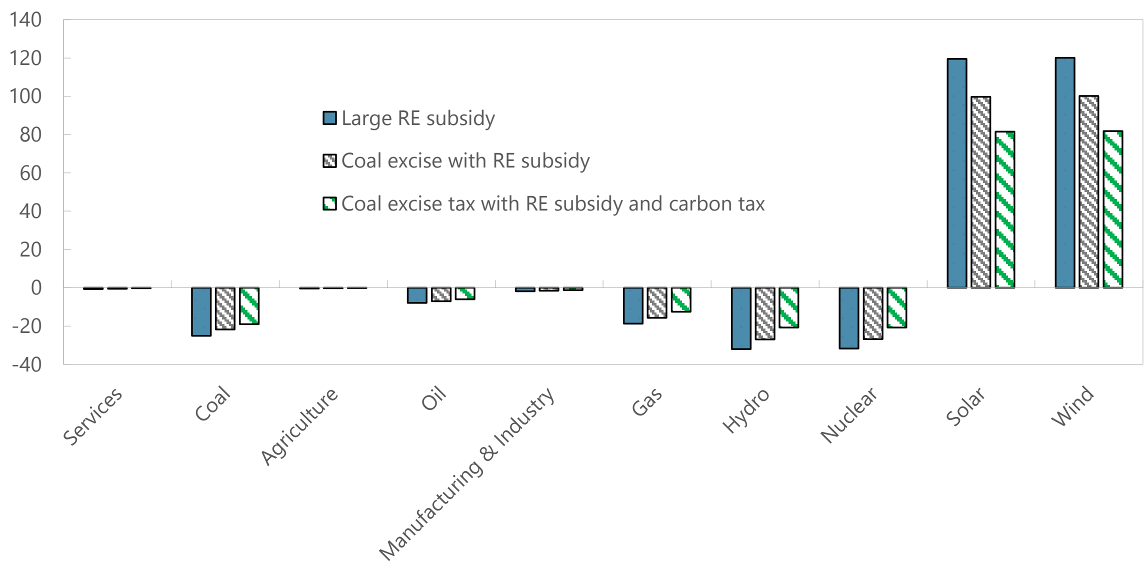
Alternate ways of recycling the carbon revenues could impact GDP differently. For instance, GDP losses are greater when revenues from carbon taxes are distributed via lump sum transfer to households than when they are used to fund public investment or reduce labor taxes (Black S. , et al., 2022).

d. Just transition

In addition to considering aggregate losses, it is also important to consider the impact on labor. Figure 20 shows the change in employment in selected sectors compared to baseline. Importantly, there will be sectors which expand such as solar and wind, and some which shrink such as coal and gas. As a conservative estimate, more than 13 million people are employed in coal mining, transport, power, sponge iron steel, and bricks sectors (National Foundation for India, 2021). This figure does not include those in the informal sector in coal mining, labor involved in coal imports (at the ports or transport from ports to coal-fired power plants), indirect activities in the iron and steel sector including third party sellers, warehousing staff, iron ore mining, the dependents of workers or even third-party vendors like equipment manufacturers. Including indirect jobs, there are likely more than 20 million people dependent on the sector.[clx] What makes this even more challenging is that the Indian states with currently high levels of employment in the coal sector tend to have less optimal conditions for solar and wind energy and consequently have few jobs in these sectors (Ordonez, Jakob, Steckel, & Ward, 2021). This is not just unique to India: a recent cross-country analysis found that the probability of workers in pollution-intensive jobs moving to a green-intensive job is very low, between 4-7 percent (IMF, 2022). That said, in other sectors the transition may be somewhat easier: it is estimated that electric vehicle production in India will create 10 million direct and 50 million indirect jobs by 2030, which will offer an opportunity to upskill and integrate the existing 35 million workforce currently producing internal combustion engines (Sattva Consulting and Skill Council for Green Jobs, 2023).

Modelling work undertaken as part of the IMF's World Economic Outlook demonstrated three policies are crucial to help these workers. First, training programs can help displaced workers to develop new skills making them more able to work in modern sectors. Second, assistance with finding jobs can help reduce matching frictions. Third, an earned-income tax credit which reduces taxes owed by lower-income workers can encourage them back into the work force. Where informality in employment is high, such as in India, the earned income tax credit should be supplemented with cash transfers for income support, targeted toward those most likely to be working informally (IMF, 2022).

Figure 20. Change in employment
(Percentage change wrt BAU)



Source: IMF staff using IMF-ENV.

e. Other impacts

The transition towards greater use of greener fuels will impact all aspects of life and the economy in India, not all of which can be modelled with the IMF-ENV. Importantly, studies have found that by lowering GHG emissions local air pollution will also improve substantially, thereby reducing the welfare costs of such policies (Black S. , et al., 2022). This will both improve health outcomes (including preventing air pollution deaths) and lead to fewer lost work and school days, thereby supporting productivity and ultimately output (Parry, Mylonas, & Vernon, 2017).

Any transition will not pose an equal burden on all of society. Several policy instruments could be mildly progressive in India including carbon taxes, coal taxes, electricity tax and road fuel tax (Parry, Mylonas, & Vernon, 2017). Furthermore, the widespread digitalization of their public welfare distribution system and in particular, its ability to target recipients can also help make any regressive options progressive with targeted transfers to households.

4. TOWARDS A GLOBAL AGREEMENT ON CLIMATE CHANGE

India's climate change mitigation needs are not only domestic, but global. As such, consideration must also be given to what might help facilitate a global agreement on more ambitious GHG reduction goals. A recent IMF paper estimates that even if fully achieved, current country pledges would cut global emissions by just 11 percent by 2030 compared to 2019 levels. This falls well short of the required 25-50 percent cut needed to keep global warming to between 2°C and 1.5°C (Black S. , et al., 2022).

In order for the Paris process to be a success, the world will need to work together. The Indian government has highlighted that for this to succeed the world will need to properly respect the principles of equity and common but differentiated responsibilities and respective capabilities and that commitments should be accompanied by climate financing and technology transfer (Ministry of Environment, Forest and Climate Change, 2021). The next section draws on work from the IMF and other institutions to consider possible options for global agreement.

4.1 Climate financing options

There are many proposals for how to adequately finance the global transition. In 2009 at COP15, developed countries agreed to mobilize $100bn a year in climate financing from 2020 onwards for developing countries. This commitment however was loosely defined. Developing countries have noted that a large portion of the materialized finance comes from multilateral development banks and privately leveraged sources, and thus much of it is lending rather than transfers. Actual financing, whether lending or transfer, has fallen significantly short of pledges. Even when taking the broadest possible definition, the current annual flows are approximately $80bn (Black S. , et al., 2022).

It has been estimated that under 2°C consistent pathways compensating the abatement costs of countries with per capita income below $4,500 would cost $60 billion in transfers annually in 2030. These estimates are calculated by considering the climate financing requirements needed to compensate lower income countries (including India) for their pure abatement costs[14] under a scenario designed to meet a global 2 degrees centigrade reduction in emissions (Black S. , et al., 2022).. The authors also estimate that to fully compensate countries for their pure CO2 mitigation costs alone would require annual transfers of about $30 billion. In three modelling scenarios, the authors illustrate the GDP effects of transfers from HICs in the amount of $30 and $60 billion to provide compensation to LICs for their mitigation burdens:

[14] Pure abatement costs refer to the area under the marginal abatement cost curves which, at the economy-wide level, illustrate the cumulative emissions reductions from abatement opportunities in different sectors by ascending order of cost.

- *Ability & Need:* High-income countries contribute based on their share of emissions while middle and low-income countries receive transfers in proportion to their share of their population.
- *Compensate:* High-income countries contribute based on their share of emissions. Transfers are made in the amount equivalent to the abatement cost of the country until cumulatively $60bn (or $30bn) are disbursed. In this scenario, India is fully compensated with $60bn and partially compensated with $30bn.
- *Per capita emissions:*[15] A country's role as contributor or receiver of payments is based on the deviation of domestic per capita emissions from the global average. Regions with higher (lower) per capita emissions than global contribute (receive) an amount equal to the deviation benchmark times the regional population multiplied by a global carbon incentive (GCI). The GCI is $4/tCO2 in 2030 and is calibrated to make the total amount of transfers equal to $60bn.

In all of the potential scenarios India is a recipient of transfers (30-39 percent of total transfers), due to its large population size and relatively small emissions per capita. The model also projects that Indian GDP would rise in all scenarios, due to a combination of the direct climate financing and lower costs on fossil fuel imports coming from the global transition away from fossil fuels. Importantly, all scenarios could be feasibly funded via carbon taxes in high income countries. To meet the $60bn ($30bn) goal the size of contributions from high-income countries is 3.4 (1.7) percent of carbon tax revenues.

While this exercise represents one potential methodology, there are many alternatives. For example, the great carbon arbitrage project estimates that to phase out coal starting in 2024 India would require 3.418 tr USD in present value of climate financing (or 1.7% of GDP every year until 2100), which would cover the opportunity cost of coal and needed investment in renewables (Adrian, Bolton, & Kleinnijenhuis, 2022). The Centre for Energy Finance has estimated that investments worth over USD 10 trillion are needed to achieve Net Zero by 2070. Consequently, the authors argue for support of $1.4tr in concessional financing (Pratap Singh & Sidhu, 2021). Both estimates are based on much more ambitious targets that what is examined in this paper, hence the significantly higher costs as well as a focus on the total green investment rather than incremental costs of green over carbon-intensive investments, as this paper has done. Nonetheless, both of these large estimates argue that these very large values can be made feasible through blended financing. For example, they suggest concessional financing can take a first-loss tranche in a large public-private partnership climate fund. This can increase the investment grade of the fund and crowd in private investment. Another potential source climate financing comes from both public and private green bonds. India has already made progress in this regard, with the first two sovereign green bonds issued in 2023, the RBI working on a taxonomy for green bonds, and India's participation in the Network for Greening the Financial System .

4.2 Technology Transfer

[15] This is a scenario first proposed by Raghuram Rajan.

Many low-income countries also argue that there is a need for the transfer of technology, or sharing of patents, of frontier GHG-emissions reducing technologies. The Indian authorities submitted a list of technology needs as part of their most recent UNFCCC bi-annual report. This includes making available cutting-edge technologies in renewable energy generation (Ministry of Environment, Forest and Climate Change, 2021). In this area India is already playing a leading role through leadership of the International Solar Alliance, which aims to mobilize USD 1,000 billion of investments in solar energy solutions by 2030. However, challenges remain including how to encourage knowledge sharing across countries when patents are privately held, how to ensure that the right technology is made available, and how to ensure critical minerals are widely available for purchase by all countries.

5. CONCLUSION

Climate change poses challenging policy tradeoffs for India, but a path towards greener, stronger, and inclusive growth is possible. India faces important development goals, including to continue raising living standards for over a billion people. At the same time, it must be a critical contributor to reducing global GHG emissions as it is one of the largest emitters today in absolute terms. The government has implemented numerous policies to promote the manufacturing and use of renewable energy, including through PLI schemes, RPOs, and PAT, among many others, and most recently a carbon trading market. More efforts are needed to reach the 2070 net zero goal.

Shifting away from coal is a formidable challenge, and the Indian government is taking a multipronged approached. The Indian economy relies heavily on coal which powers over 70 percent of electricity generation, and accounts for almost 40 percent of India's CO2 emissions. Much of the industrial sector also runs on coal, and over 20 million people are dependent on the mineral, its extraction and use for employment either directly or indirectly. In its effort to shift towards renewable energy sources and reduce emissions, the Indian government has deployed many policy tools. Various forms of subsidies for renewable energy adoption and generation are widespread (e.g., PLI schemes for solar module and battery manufacturing, National Motor Replacement Program, FAME for EVs, LED streetlights and bulbs), as are regulatory requirements (e.g., RPOs for electricity, building efficiency standards, vehicle emissions standards, standards & labelling, bioethanol), and tradable energy certificates (RECs, PAT). These policies are helping India begin its shift towards lowering emissions. Without further efforts, however, India's emissions are on track to continue to increase at a rapid pace. Investment in renewables will need to be scaled up substantially. This will require leveraging, in particular, technology transfer, international finance, and domestic debt markets.

Depending on which policy prescriptions India chooses to reach its net zero goal, there will be both costs and benefits. Modelling emissions trajectories under different policy options show that reducing GHG emissions will almost certainly have a negative impact on growth in the short run and have important distributional consequences for individuals and communities who today rely on coal. But with the right policies, these costs can be significantly limited. On the positive side, there will be many benefits of reducing emissions. This includes improved health outcomes and productivity from reduced pollution. Policy will also need to focus on ensuring those most impacted by the shift to cleaner energy are not left behind – this will have to be done through a combination of transfers and re- or up-skilling. Any delays in transitioning from the current emissions path towards a more sustainable one will increase costs and decrease cumulative benefits.

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ANNEX 1 - AN OVERVIEW OF THE IMF-ENV MODEL

The IMF-ENV model is a recursive dynamic neoclassical, global, general equilibrium model, built primarily on a database of national economies and a set of bilateral trade f lows. The model describes how economic activities and agents are interlinked across several economic sectors and world countries or regions. The central input of the model is the data of the Global Trade Analysis Project version 10 database (Aguiar and others 2019). The database includes country - specif ic input-output tables for 141 countries and 65 commodities and real macro flows. It also represents world trade flows comprehensively for a given starting year. The currently used version 10 is based on data f rom 2014. The model is based on the activities of the key actors: representative firms by sector of activities, a regional representative household, a government, and markets. Firms purchase inputs and primary factors to produce goods and services, optimizing their profits. Households receive the factor income and in turn buy the goods and services produced by firms; household demands result from standard welf are optimization under households' budget constraints. Markets determine equilibrium prices for factors, goods, and services. Frictions on factor or product markets are limited, except as described elsewhere below.

The model is recursive dynamic: it is solved as a sequence of comparative static equilibria. The fixed factors of production are exogenous for each time step and linked between time periods with accumulation expressions, like the dynamic of a Solow growth model. Output production is implemented as a series of nested constant-elasticity-of-substitution functions to capture the different substitutability across all inputs. International trade is modeled using the so-called Armington specification, which posits that demands for goods are differentiated by region of origin. This specification uses a full set of bilateral flows and prices by traded commodity. In contrast to intermediate inputs, primary factors of production are not mobile across countries. Model closures assume real government expenditure and current account to be constant to baseline values.

While the capital market is characterized by real rigidities, the labor market is not. One major characteristic of the model is that it features vintage capital stocks in such a way that a firm's production structure and a firm's behavior are different in the short and long term. In each year, new investment is flexible and can be allocated across activities until the return to the "new" capital is equalized across sectors; the "old" (existing) capital stock, on the contrary, is mostly fixed and cannot be reallocated across sectors without costs. As a consequence, short-term elasticities of substitution across inputs in production processes (or substitution possibilities) are much lower than in the long term and make adjustments of capital more realistic. In contrast, labor (and land) market frictions are limited: in each year, labor (land) can shift across sectors with no adjustment cost until wages (land prices) equalize, and the labor (land) supply responds with some elasticity to changes in the net-of-taxes wage rate (land price).

The model also links economic activity to environmental outcomes. Emissions of greenhouses gases (GHGs) and other air pollutants are linked to economic activities either with fixed coefficients, such as those for emissions from fuel combustion, or with emission intensities that decrease (nonlinearly) with carbon prices—marginal abatement cost curves. This latter case applies to emissions associated with non-energy-input uses (e.g., nitrous oxide emissions resulting from fertilizer uses) or with output processes (like methane emissions from waste management or carbon dioxide emissions from cement manufacturing). In the very long term, the model may overestimate the cost of decarbonization, since it does not take into account radical technology innovations that could materialize at this longer horizon (hydrogen, second generation of nuclear and biofuel technologies, carbon capture and storage technology). While some of these new technologies are at an experimental stage, it is dif ficult to include them in the model at the moment because of a lack of information about the future costs of these technologies if they were deployed at industrial scale.

The model can be used for scenario analysis and quantitative policy assessments. For scenario analysis, the model projects up to 2050 an internally consistent set of trends for all economic, sectoral, trade-related, and environmental variables. In this context, the model can be used to analyze economic impacts of various drivers of structural changes like technological progress, increases in living standards, and changes in preferences and in production modes. A second use for the model is quantitative economic and environmental policy assessment for the coming decades, including scenarios of a transition to a low-carbon economy. In this case the model assesses the costs and benefits of different sets of policy instruments for reaching given targets like GHG emission reductions.

End Notes

[i] India's submission to UNFCCC in August 2022
[ii] doc202112101.pdf (pib.gov.in)
[iii] Some programs, like the ECBC, that target commercial buildings, have been added to industry to ensure major policies deployed that impact MSMEs are captured.
[iv] Third BUR
[v] Generation share: Dashboard - Central Electricity Authority (cea.nic.in), Last visited on 19-12-2022
[vi] Power Sector: Stumbling block in India's net-zero journey | ORF (orfonline.org)
[vii] https://powermin.gov.in/en/content/power-sector-glance-all-india
[viii] ibid
[ix] https://www.renewablesindia.in/
[x] https://pib.gov.in/Pressreleaseshare.aspx?PRID=1555373
[xi] https://pib.gov.in/PressReleasePage.aspx?PRID=1795071
[xii] https://unfccc.int/sites/default/files/NDC/2022-08/India%20Updated%20First%20Nationally%20Determined%20Contrib.pdf
xiii IEA https://www.iea.org/reports/the-role-of-ccus-in-low-carbon-power-systems/the-co2-emissions-challenge
[xiv] https://rpo.gov.in/Home/Objective#:~:text=RPOs%20are%20categorized%20as%20Solar,trajectory%20up%20to%20year%202022
[xv] https://rpo.gov.in/Home/About
[xvi] https://powermin.gov.in/sites/default/files/Renewable_Purchase_Obligation_and_Energy_Storage_Obligation_Trajectory_till_2029_30.pdf
[xvii] POSOCO.2018. "REC Mechanism- Key learnings, Data analysis and way forward."
[xviii] Significant transmission infrastructure upgrades have been made under the Integrated Power Development Scheme (IPDS)
[xix] Budget FY 2022-23. https://www.financialexpress.com/budget/union-budget-2022-pli-scheme-extended-to-solar-equipment-allocates-rs-19500-cr-boost-for-modules-2422284/
[xx] Renewable hybrid energy systems as a game changer in India | McKinsey & Company
[xxi] NITI Aayog Electricity distribution report 2021
[xxii] https://www.ceew.in/cef/masterclass/analysis/streamlining-open-access-alternative-to-scaling-renewables-in-india
[xxiii] A surprise hurdle for India's smart meter plans | Mint (livemint.com)
[xxiv] See IEA for further discussion of these issues.
[xxv] https://energy.economictimes.indiatimes.com/news/renewable/india-to-auction-40-gw-renewables-every-year-till-2028/64811779
[xxvi] Parliamentary Standing Committee on Energy (2021-22), 2022, Financial Constraints in Renewable Energy Sector: Twenty First Report
[xxvii] The Draft Electricity Bill, 2022 covers some of these issues https://prsindia.org/billtrack/draft-electricity-amendment-bill-2020#:~:text=Sources%3A%20The%20Draft%20Electricity%20(Amendment,)%20Rules%2C%202020%3B%20PRS.&text=The%20Act%20empowers%20SERCs%20to,regulations%20on%20tariff%2Drelated%20matters.
[xxviii] https://mnre.gov.in/img/documents/uploads/file_f-1612941710983.pdf
[xxix] RECs are traded in the India Energy Exchange (IEX) and Power Exchange India Ltd (PXIL) at a price within the forbearance and floor price determined by the Central Electricity Regulatory Commission (CERC).
[xxx] https://www.intellecap.com/in_the_media/few-takers-for-renewable-energy-certificates-despite-policy-push/
[xxxi] In FY2020, only 5.3 million RECs were bought against an expected demand of 72.5 million RECs from 27 non-compliant discoms that did not meet their RPO targets. There was a shortfall in demand amounting to 67.2 million RECs. Source: Few takers for renewable energy certificates despite policy push | Mint (livemint.com)
[xxxii] Open-access charges include central transmission charges, state transmission charges, wheeling or distribution charges, cross-subsidy surcharge, additional surcharge, SLDC charges, etc. https://www.ceew.in/cef/masterclass/analysis/streamlining-open-access-alternative-to-scaling-renewables-in-india
[xxxiii] The recently notified Green Open Access Policy, 2022, is designed to homogenize the state-level policies and pricing calculations.
One such varying component is the "cross subsidy charge" –it was designed to be phased out over time but has kept growing its share in the overall cost structure.
[xxxiv] However, it still allows for variable cross-subsidisation component.
[xxxv] Inter-state open access allows a consumer to procure power from a generator within as well as outside of the state of consumption., ibid
[xxxvi] Schemes | Ministry of New and Renewable Energy, Government of India (mnre.gov.in)
[xxxvii] https://mnre.gov.in/img/documents/uploads/file_f-1628669249447.pdf
[xxxviii] https://www.seci.co.in/web-data/docs/Draft-Scheme-Solar-Park-and-Ultra-Mega-Solar-Power-Projects-for-comments.pdf
[xxxix] https://scroll.in/article/1017015/in-india-desolate-solar-parks-reveal-the-dark-side-of-renewable-energy
[xl] Who needs ultra mega solar power plants? (downtoearth.org.in)
[xli] IMF Climate Dashboard
[xlii] ESCerts are issued to overachieving DCs, and underachieving DCs have to purchase ESCerts if they fail to meet their specific energy consumption (SEC) reduction targets. One ESCert is equivalent to one metric tonne of oil equivalent (toe).
[xliii] EESL helps drive prices of advanced tech down by subsidizing products for market off take which enable production at scale
[xliv] EESL signed agreements with over 30 major industries to replace over 1,200 inefficient motors with IE3 motors, enabling energy savings of 48,16,535 kWh and emission reduction of 4,240 tCO2, annually. Ibid
[xlv] Factors-influencing-uptake-of-EE-initiatives-by-Indian-MSMEs.pdf (shaktifoundation.in)

[xlvi] European Union and SIDBI (April 2016); Financing Sustainable Production among MSME Clusters -Experiential Learnings and Policy Recommendations
[xlvii] https://powermin.gov.in/sites/default/files/uploads/MOP_Annual_Report_Eng_2021-22.pdf
[xlviii] https://www.nrdc.org/experts/sameer-kwatra/constructing-change-building-energy-codes-india
[xlix] Developing clean energy alternatives for industries | ORF (orfonline.org)
[l] Jindal Stainless Ltd taking measures to reduce carbon emissions: MD | Business Standard News (business-standard.com)
[li] Tata Steel | Climate Action
[lii] https://mopng.gov.in/files/article/articlefiles/Draft_UFCC_Roadmap_2030.pdf
[liii] https://static.pib.gov.in/WriteReadData/specificdocs/documents/2023/jan/doc2023110150801.pdf
[liv] Racing to Net-Zero: A Captivating but Distant Ambition (ssir.org)
[lv] https://beeindia.gov.in/sites/default/files/NCM%20Final.pdf, PDF pg 14
[lvi] BEE annual report FY 2020-21. Annual Report | Bureau of Energy Efficiency (beeindia.gov.in)
[lvii] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1811051#:~:text=These 135 DCs are under,saving target of 6.627 MTOE.
[lviii] https://united4efficiency.org/wp-content/uploads/2020/11/U4E_Case-Study_India-Motor_2020-11-26.pdf
[lix] https://eeslindia.org/wp-content/uploads/2021/02/Newsletter-Jan-2021-FINAL-1.pdf
[lx] FY 2021-22, GoI Budget
[lxi] *Impact Assessment 2020-21_FINAL.pdf (beeindia.gov.in)
[lxii] Renewable Energy: Revolutionizing Farmers' Incomes (investindia.gov.in)
[lxiii] Agricultural irrigated land (% of total agricultural land) - India | Data (worldbank.org)
[lxiv] COP27: India welcomes 'loss & damage fund', says 'world has waited far too long for this'. Source
[lxv] the reasons for not signing up for the Global Methane Pledge at COP26 in Glasgow: http://164.100.24.220/loksabhaquestions/annex/177/AU2478.pdf
[lxvi] Further, according to MoP, With solarization, while the electricity to farmers would be available free of cost/at very low cost during the day time, savings would accrue to the State Government on account of subsidy being paid to the DISCOMs for electricity supply to farmers at subsidized tariff. Such savings can be utilized by the State to pay off the loans to be availed from FIs/Banks/NABARD and once repayment is done, the State Government would be free of the burden of this subsidy and deploy this resource for other developmental activities. PDF pg 11/240
[lxvii] https://www.bqprime.com/business/daytime-solar-power-to-farms-can-ease-discom-stress-heres-how
[lxviii] Originally, the third goal was solarization of 15 million Grid-connected Agriculture Pumps, which was recently redesigned to solarize separate agricultural feeders at DISCOMs instead.
[lxix] https://mnre.gov.in/img/documents/uploads/file_f-1632204688401.pdf
[lxx] https://pib.gov.in/PressReleasePage.aspx?PRID=1885751
[lxxi] https://indianexpress.com/article/india/feed-developed-by-icar-also-increases-weight-milk-production-feed-supplement-reduces-methane-emissions-by-livestock-7389140/
[lxxii] PM KUSUM attracts 30% Central Financial Assistance for stand-alone solar agriculture pump, the state government assists with at-least a subsidy of 30%; and the remaining at-most 40% will is provided by the farmer. Bank finance can be availed by farmer with a 10% initial payment of the cost and remaining up to 30% of the cost as loan.
[lxxiii] Subsidies alone will not scale-up solar pumps | CEEW
[lxxiv] PM KUSUM (mnre.gov.in)
[lxxv] Revitalising PM-KUSUM - The Hindu
[lxxvi] The amendment, among other provisions, focuses on allowing more feedstocks for production of biofuels, and to advance the ethanol blending target of 20% blending of ethanol in petrol to ESY 2025-26 from 2030. For full scope of amendments see: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1826265; https://mopng.gov.in/files/article/articlefiles/Notification-15-06-2022-Amendments-in-NPB-2018.pdf
[lxxvii] EESL aims to replace 21 million inefficient pumps with BEE 5-star rated pumps with no upfront cost to the farmer, with cost recovery through reduction in state government subsidies over 5-10 years.
[lxxviii] Refer pg 387/644, https://www.ntpc.co.in/sites/default/files/downloads/Annual-Report-2021-22.pdf
[lxxix] https://pib.gov.in/PressReleasePage.aspx?PRID=1790832
[lxxx] Torrefied biomass co-firing up to 20% and provision of CCU of up to 10-20% is being kept in the future NTPC thermal projects
[lxxxi] https://economictimes.indiatimes.com/industry/energy/oil-gas/budget-2022-additional-excise-duty-to-promote-ethanol-blending/articleshow/89285768.cms
[lxxxii] To carry the entire quantity of required ethanol, about 3,50,000 tanker trucks shall be required based on one truck carrying 29,000 litres. "Movement of these number of trucks would result in GHG emission of 76 million tonnes, unless most of the ethanol is moved either through pipeline or by Railways." https://www.thehindubusinessline.com/economy/agri-business/20-ethanol-blending-target-likely-to-be-achieved-by-2025-but-may-add-76-million-tonnes-of-ghg-emission/article65918703.ece
[lxxxiii] https://afdc.energy.gov/fuels/ethanol_benefits.html
[lxxxiv] https://eeslindia.org/wp-content/uploads/2022/09/Annual-Report-FY-2021-22.pdf pdf pg 239/246
[lxxxv] https://eeslindia.org/wp-content/uploads/2022/05/AgDSM-impact-assessment-report.pdf PDF pg 41/66
[lxxxvi] NATIONAL AgDSM DASHBOARD | EESL
[lxxxvii] Methodology for estimating emissions reduction from AgDSM (pdf pg 128/154): https://beeindia.gov.in/sites/default/files/BEE_Final%20Report_Website%20version.pdf
[lxxxviii] Page not found – Energy Efficiency Services Limited (eeslindia.org)
[lxxxix] Method for calculating energy saving – PDF pg 28 BEE_Final Report_Website version.pdf (beeindia.gov.in)
[xc] https://pmkusum.mnre.gov.in/landing.html
[xci] Revitalising PM-KUSUM - The Hindu
[xcii] https://mnre.gov.in/img/documents/uploads/file_f-1632204688401.pdf

[xciii] Revamped Distribution Sector Scheme has an outlay of Rs.3,03,758 crore with an estimated budgetary support from Central Government of Rs. 97,631 crores, which would be available till FY 2025-26. Source: https://pib.gov.in/PressReleasePage.aspx?PRID=1785248
[xciv] https://pib.gov.in/FactsheetDetails.aspx?Id=148576
[xcv] Feeders having major load for agriculture may also be considered for solarization under the Scheme.
[xcvi] https://pib.gov.in/PressReleasePage.aspx?PRID=1731473
[xcvii] https://economictimes.indiatimes.com/industry/renewables/new-plan-worth-20k-cr-to-solarise-agri-feeders-singh/articleshow/83616981.cms?from=mdr
[xcviii] https://timesofindia.indiatimes.com/city/aurangabad/30-agri-feeders-to-be-solarized-in-state-provide-day-time-power-supply-to-farmers/articleshow/94849510.cms
[xcix] https://unfccc.int/sites/default/files/resource/INDIA_%20BUR-3_20.02.2021_High.pdf
[c] Civil aviation accounts for 6 percent of emissions from the energy sector, followed by railways adding up to another 3%, domestic water-borne navigation accounts 1 percent
[ci] https://e-amrit.niti.gov.in/national-level-policy
[cii] https://www.niti.gov.in/e-mobility-national-mission-transformative-mobility-and-battery-storage
[ciii] India becomes 3rd largest auto market globally, surpasses Japan: Report | Mint (livemint.com)
[civ] GoI NEMMP and FAME Press Release
[cv] https://www.india-briefing.com/news/india-incentives-for-acc-battery-storage-manufacturing-pli-scheme-3-companies-get-approval-22349.html/
[cvi] In coordination with the inclusion in the PLI, the GoI reduced the GST on EVs from 12 per cent to 5 per cent and on chargers and charging stations from 18 per cent to 5 per cent. Furthermore, battery-operated vehicles will be given green license plates and be exempted from permit requirements, and states were advised to waive road tax on EVs.Ministry of Heavy Industries
[cvii] https://www.niti.gov.in/draft-battery-swapping-policy
[cviii] https://www.energy-storage.news/india-approves-national-mission-on-transformative-mobility-and-battery-storage/
[cix] https://www.livemint.com/budget/news/budget-2022-announcements-on-electric-vehicles-evs-by-fm-nirmala-sitharaman-11643696316767.html
[cx] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1567807
[cxi] Invest in India
[cxii] Indian Railways
[cxiii] Kamboj, Puneet, Ankur Malyan, Harsimran Kaur, Himani Jain and Vaibhav Chaturvedi. 2022. India Transport Energy Outlook. New Delhi: Council on Energy, Environment and Water
[cxiv] https://www.niti.gov.in/sites/default/files/2022-04/20220420_Battery_Swapping_Policy_Draft.pdf
[cxv] https://www.livemint.com/budget/expectations/budget-may-propose-record-7k-km-of-track-electrification-11643225349881.html
[cxvi] https://www.downtoearth.org.in/blog/renewable-energy/indian-railways-likely-to-become-world-s-first-net-zero-carbon-emitter-by-2030-79797
[cxvii] According to GoI, Carbon emission by 2029-30 as per Business-as-Usual mode is estimated to be 60 million tons which would be offset by various measures planned by IR. https://pib.gov.in/PressReleasePage.aspx?PRID=1865754
[cxviii] https://climatetrends.in/wp-content/uploads/2022/08/riding-sunbeams-in-india.pdf
[cxix] https://indiaghgp.org/sites/default/files/Rail%20Transport%20Emission.pdf
[cxx] http://www.irgreenri.gov.in/pdf/Decarbonization/2_Assessment_Solar_Plant.pdf
[cxxi] https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/jul/doc202271169601.pdf
[cxxii] https://pib.gov.in/Pressreleaseshare.aspx?PRID=1566758
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