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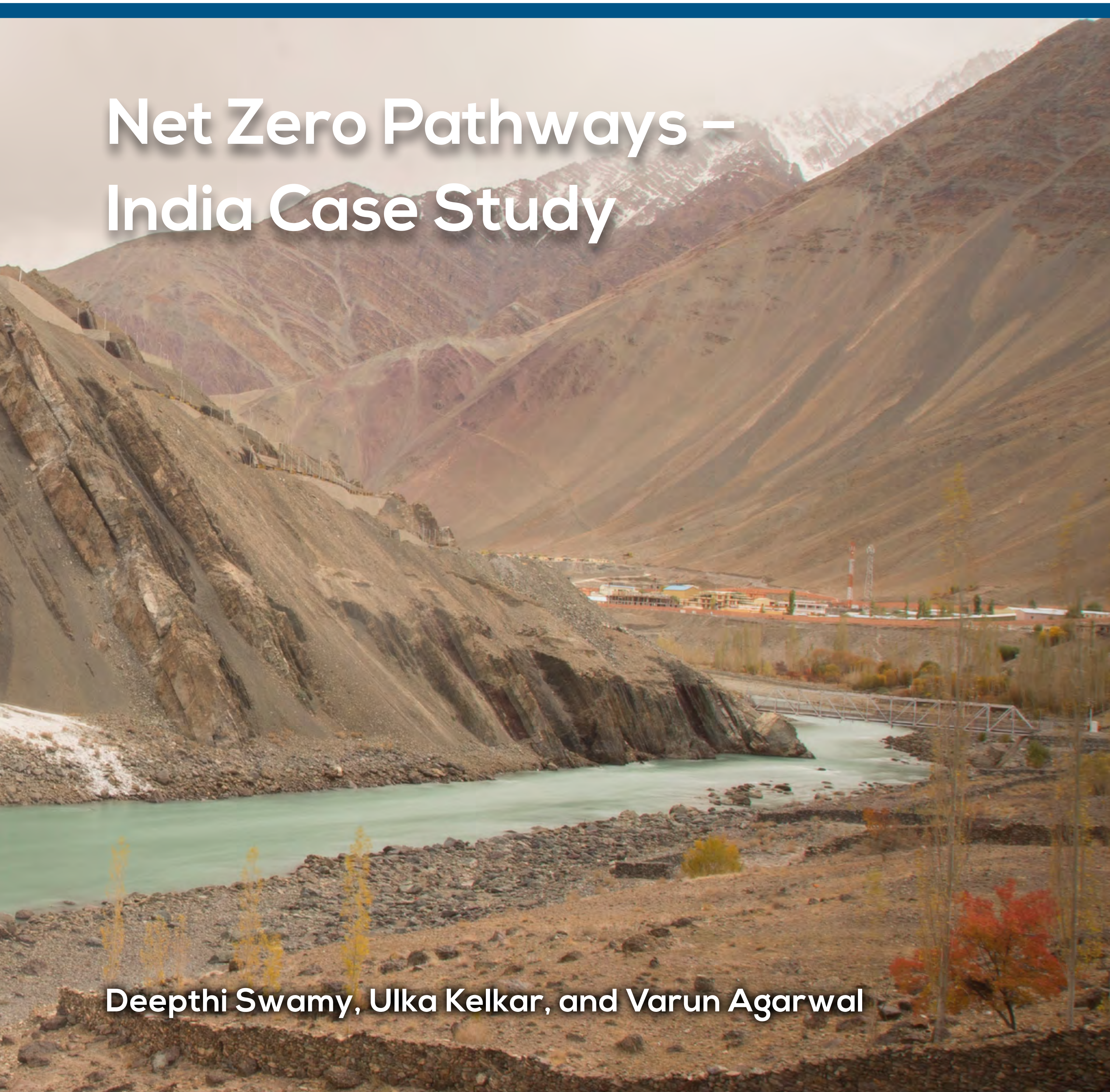
Net Zero Pathways – India Case Study



Deepthi Swamy, Ulka Kelkar, and Varun Agarwal

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Introduction

India announced its long-term climate target to reach net-zero emissions by 2070 at the 26th Conference of Parties (COP26) in Glasgow in November 2021.[i] In August 2022, India also updated its Nationally Determined Contribution (NDC) targets for 2030, committing to reduce the emissions intensity of its gross domestic product (GDP) by 45% from 2005 levels (compared to the earlier target of 33%-35%) and achieving 50% of installed electricity capacity from fossil-free sources (compared to the earlier target of 40%).[ii]

For emerging economies like India, the task of climate policy is to achieve decarbonisation, while also delivering economic growth, jobs, and improved access to energy. In per-capita terms, India's present income and energy consumption, are about a fifth[iii] and a third,[iv] respectively, of the global average. Charting a development pathway that meets both India's climate targets as well as the aspirations of its people requires a deep structural transformation of the Indian economy.

Achieving this transformation involves navigating away from the use of the country's abundant reserves of coal, potentially affecting an estimated 2.6 million workers.[v] It also requires finding the upfront capital for creating new green energy infrastructure to decouple emissions from growth, including investment in nascent technologies, such as hydrogen and battery storage.

At the same time, the transformation presents a host of opportunities. India can avoid locking into fossil fuel path dependence, thereby mitigating the risk of stranded assets, lower reliance on energy imports, and improve human health outcomes by cutting particulate matter pollution from fossil fuels. It can safeguard the international competitiveness of the Indian industry in an emerging environment of carbon-based tariffs on emissions intensive goods, such as the carbon border adjustment mechanism (CBAM) proposed by the European Union.[vi]

We explore some of these opportunities and challenges in the context of a net-zero 2070 pathway for India using the Energy Policy Simulator (EPS), a systems dynamics model with an open-access web interface,[vii] which enables an integrated assessment of cross-sectoral climate policy packages for India through 2050, along with their macroeconomic implications.

Analytical framework and approach

The EPS covers the main sectors of the economy: power, industry, transportation, buildings, as well as agriculture and land-use. Policy options available in these sectors include both pricing policies (e.g., taxes and subsidies) as well as mandates (e.g., for technology adoption or retirement). The structure, data sources and assumptions of the model are explained in a technical note available online.viii To project the growth in energy demand across the economy through 2050, the model relies on the respective sectoral demand trajectories in the low-growth Scenario of the India Energy Security Scenarios (IESS)ix as shown in Table 1. It finds the least cost options – subject to any policy mandates – to meet demand in the electricity and transport sectors and assumes falling technology costs based on projected global prices and endogenous learning to account for the effects of local technology diffusion. All monetary estimates are in 2018 constant prices (1 USD = 68.42 INR).

Table 1: Growth assumption underlying IESS demand trajectories used in the India EPS

Annual average growth rate of gross domestic product (at factor cost, at real prices, in %)					
2017–2022	2022–2027	2027–2032	2032–2037	2037–2042	2042–2047
6.2%	6.4%	6.4%	6.3%	5.2%	4.7%

We analyse a policy package focusing on the power, industry, and transport sectors, which would put India on course to achieve net-zero carbon dioxide (CO2) emissions by 2070. Our policy package, which we have named the Long-term Decarbonisation (LTD) Scenario, builds upon existing policy targets for renewable energy (RE), energy efficiency and electric mobility in the short-term. It considers the policy-supported phase-in of currently nascent technologies, such as hydrogen and battery storage, in the medium-term, to reach ambitious levels of implementation by 2050.
We present our results relative to a Reference Scenario that incorporates existing policies, as of 2020. The level of ambition for the policy settings in the LTD Scenario is decided on the basis of a combination of factors, including the existing level of achievement in the Reference Scenario, and a review of literature to identify the technical potential achievable for the technologies modelled within the policies, in consultation with sectoral experts on policy feasibility given on-the-ground implementation challenges in India. The key policy assumptions of the LTD Scenario are summarised in Table 2.

Table 2: Key Policy Levers in the LTD Scenario

Policy	Reference Scenario (2050)	LTD Scenario (2050)[a]
Industrial electrification & hydrogen mandate (% substitution of fossil fuels in industrial sector. Starting from 2025)	0	50%
Hydrogen production via electrolysis mandate (Starting from 2025)	0	100%
Carbon tax (Per metric ton of CO2 in power and industry)	0	INR 3500 (USD 50)
EV/H2V[b] sales mandate (% of new vehicle sales) Cars, Buses Light-freight vehicles, Heavy-freight vehicles 2-wheelers, 3-wheelers (H2V sales mandate starting from 2030)	35%, 23% 14%, 4% 38%, 30%	80%, 50% (+25% H2V) 70%, 25% (+45% H2V) 100%, 100%
Material efficiency mandates (Demand reduction for emissions intensive goods relative to the Reference Scenario)	-	Cement: 15% Iron & steel: 20%
Carbon-free electricity generation (Mandated minimum %)	68% -	93% (75%)
Early retirement mandate for coal power (Starting from 300MW/year in 2027)	-	7 GW/year

Notes:
Unless otherwise noted, the policy is linearly implemented starting from 0 in 2020 to reach the full policy setting in 2050.
EV = electric vehicles; H2V = hydrogen vehicles.

Results

The LTD Scenario yields better outcomes than the Reference Scenario in terms of CO2 emissions, health co-benefits, and macroeconomic impacts (Table 3).

Table 3: Key outcomes for India in the LTD Scenario

Scenario		Reference	LTD
CO2 emissions (Billion metric tons)	2030	2.8	2.3
	2050	4.1	1.1
Emissions intensity of GDP (% change from 2005)	2030	-52%	-61%
	2050	-75%	-91%
Non-fossil electricity capacity (GW) (% share of total capacity)	2030	344 (58%)	383 (63%)
	2050	1044 (76%)	1986 (96%)
Additional annual investment relative to Reference Scenario (billion 2018 USD) (% of GDP)	2030	-	27.5 (0.5%)
	2050	-	247.3 (1.5%)
Change in GDP relative to the Reference Scenario (Billion 2018 USD) (% change)	2030	-	80.4 (1.4%)
	2050	-	362.5 (2.2%)
Change in jobs relative to the Reference Scenario (including direct and indirect jobs, in million)	2030	-	4.4
	2050	-	9.2
Premature deaths avoided from improved air quality relative to the Reference Scenario (Thousand deaths/year)	2030	-	69.2
	2050	-	502.8

Climate and Health Benefits

The Reference Scenario sees India's CO2 emissions double over the next three decades – emissions rise from just over 2 billion metric tons in 2022 to 4 billion metric tons in 2050. The rise in emissions is driven by economic growth and industrialization, despite a 60% improvement in emissions intensity of GDP over this period.

The policies in the LTD Scenario bring down the Reference Scenario emissions by about a fifth in 2030 and two-thirds in 2050 (Figure 1). Total greenhouse gas (GHG) emissions show a similar trend (Figure 2).

Figure 1: Annual CO2 emissions (in million metric tons)

Reference Scenario **Long-term Decarbonization Scenario**

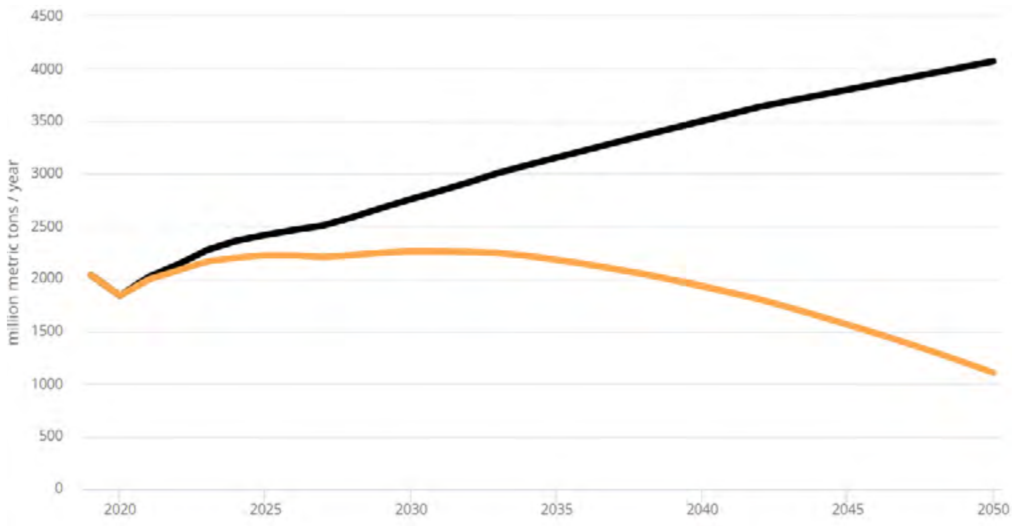
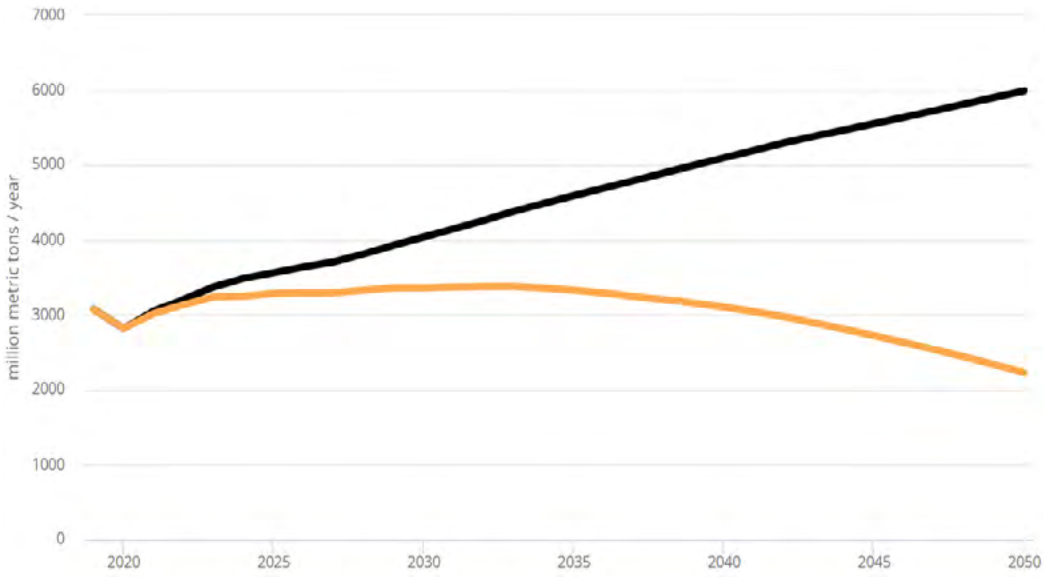


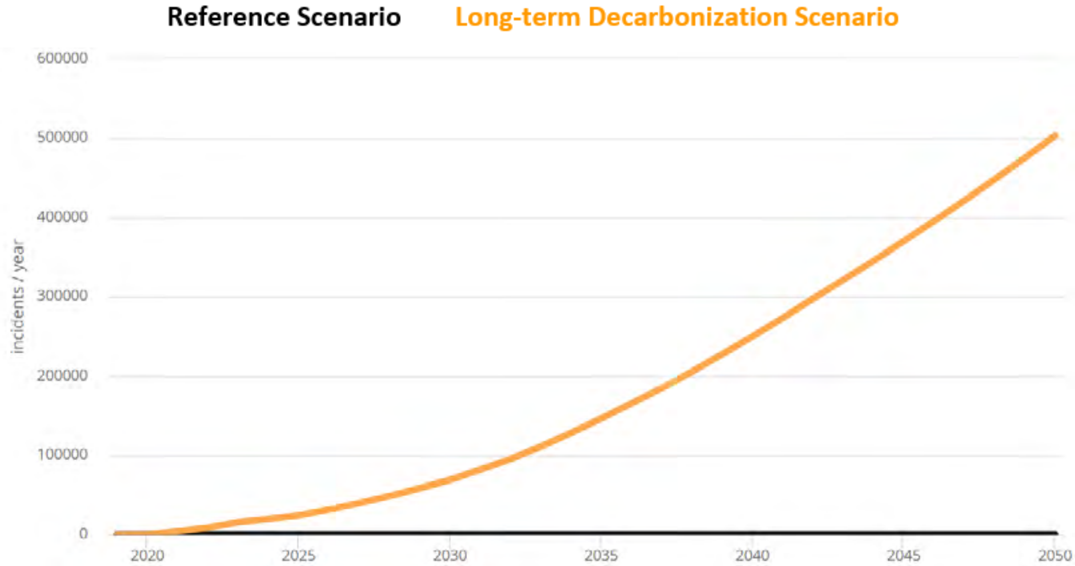
Figure 2: Annual GHG emissions (in million metric tons of carbon dioxide equivalent)

Reference Scenario **Long-term Decarbonization Scenario**



In the LTD Scenario, the reduction in fossil fuel use also improves air quality by cutting particulate matter (PM2.5) emissions to almost half by 2050. This can potentially help avoid 5.8 million premature deaths due to air pollution over the period 2022-2050, compared to the Reference Scenario (Figure 3).

Figure 3: Additional premature deaths avoided annually compared to Reference Scenario



Sectoral transitions

Due to the falling costs of variable renewable energy (VRE) technologies – i.e., utility scale onshore wind and solar PV – in the power sector, the Reference Scenario itself includes a significant amount of renewable energy capacity (Figure 4). Non-fossil electricity capacity reaches 58% of the total installed capacity in 2030, exceeding India's NDC target of 50%.

In the LTD Scenario, non-fossil capacity reaches 63% of the total in 2030, increasing to 96% by 2050 (Figure 5) because of mandates for carbon-free electricity generation and phased retirement of coal power, complemented by a carbon tax (see Table 2). The reduction in the cost of RE due to technology diffusion, initially a result of these mandates, drives further RE capacity addition, which, in turn, exceeds the policy mandated minimum over time. Together, these policies require no new coal capacity to be added after 2025. Grid battery storage capacity to accommodate the increasing share of VRE reaches 64 GW by 2030 and around 300 GW by 2050.

Figure 4: Installed electricity capacity in Reference Scenario

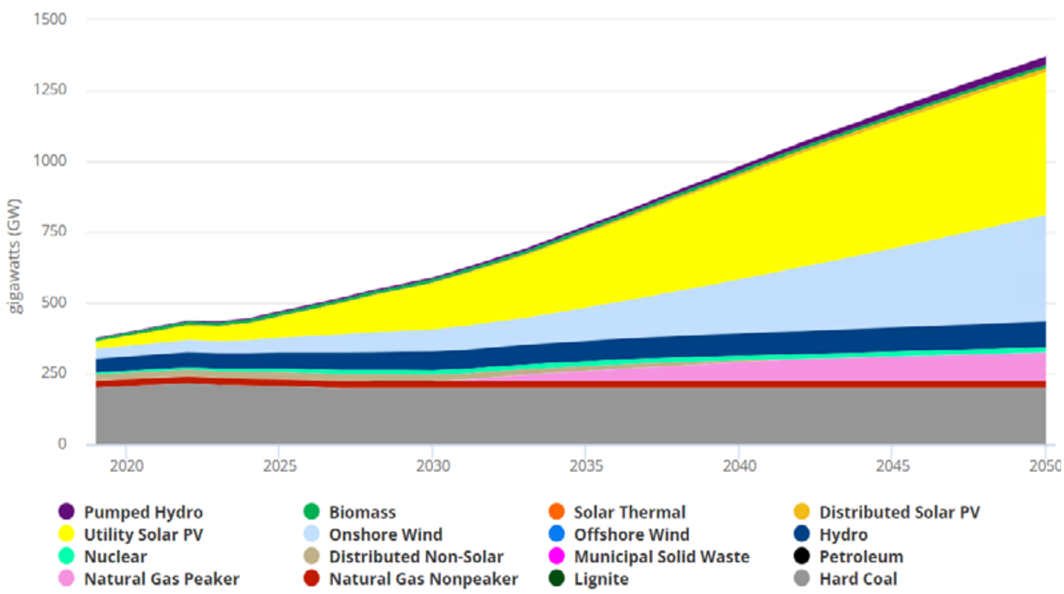
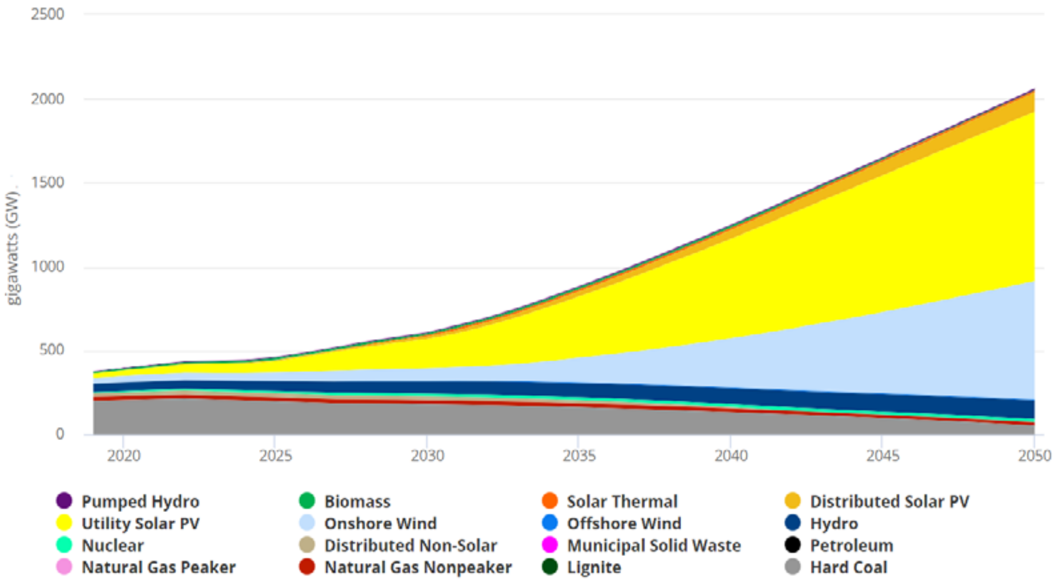


Figure 5: Installed electricity capacity in LTD Scenario



Decarbonisation of the power sector supports mandates for fossil fuel substitution with electricity and/or green hydrogen in the industry and transport sectors in achieving their emissions mitigation potential. These fuel-switching mandates, phased in from 2025 or 2030, serve as the main policy levers to decarbonise these sectors in the long term. At the same time, energy/fuel efficiency policies – that build on the targets set by the existing Perform Achieve Trade (PAT) scheme[x] for the industry and corporate average fuel efficiency (CAFE) norms[xi] for the transport sector – play a role in the short term. As in the power sector, these mandates are complemented by the carbon tax to achieve significantly higher shares of electricity and hydrogen in the overall industrial and transport energy mix, compared to the Reference Scenario (Table 4).

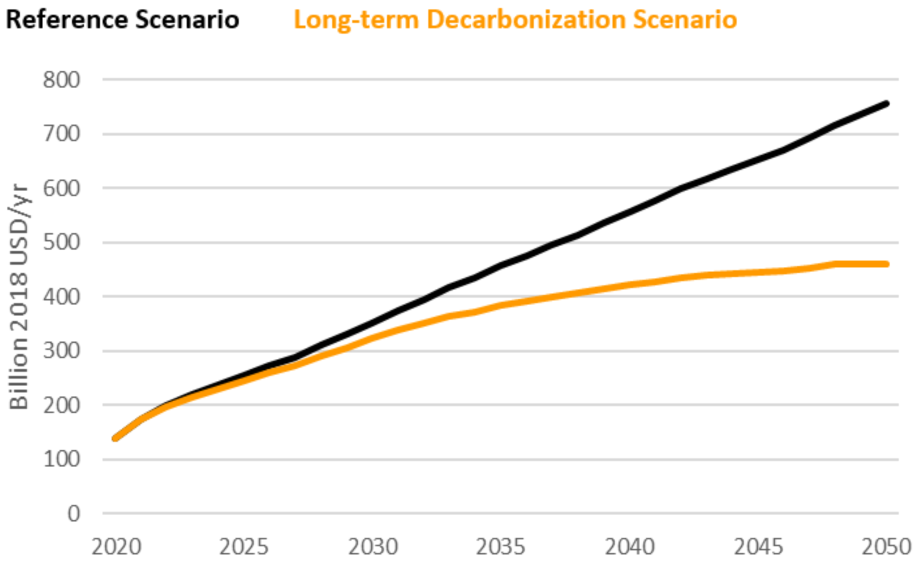
Table 4: Share of electricity and hydrogen in industrial and transport energy-mix

Year	Industrial Energy Mix				Transport Energy Mix			
	Share of Electricity		Share of Hydrogen		Share of Electricity		Share of Hydrogen	
	Reference	LTD	Reference	LTD	Reference	LTD Sce	Reference	LTD
2030	16%	20%	0%	2%	3%	6%	0%	0%
2050	16%	40%	0%	18%	9%	29%	0%	7%

Financing the transition

The deployment of clean technologies requires additional capital expenditure compared to the Reference Scenario. The total additional expenditure in the LTD Scenario amounts to approximately USD 100 billion within this decade, and increases to USD 790 billion and USD 1.9 trillion, respectively, over the next two decades, as RE infrastructure, EV deployment and green hydrogen production is ramped up. While the scale of upfront capital investments presents challenges in terms of financing, the uptake of clean technologies also yields increasing savings, primarily from reduced expenditure on fuels, in the medium to long term. For instance, the reduction in India's energy import bill could amount to USD 30 billion in 2030 and USD 296 billion in 2050 (Figure 6).

Figure 6: Annual energy import expenditure (in billion 2018 USD



The power sector undergoes an expansion relative to the Reference Scenario, in addition to its transformation. Policies for electrification and green hydrogen production increase the demand for electricity by 25% in 2050, despite an 18% higher efficiency of energy-use across the economy, compared to the Reference Scenario. The LTD Scenario sees installed capacities of solar PV and onshore wind increase over twenty-fold and sixteen-fold, respectively, by 2050, compared to the present.

Total battery storage capacity required – including for grid storage and electric vehicle (EV) deployment reaches 8.5 TWh. Green hydrogen production for use as fuel in industry and transport reaches 22 million metric tons, compared to negligible levels at present. Table 5 provides the estimated capital expenditure by decade in these key technologies in the LTD Scenario.

Table 5: Capital Expenditure* by decade for key technologies in LTD Scenario (in billion 2018 USD)

	2020 – 2030	**2030 – 2040**	**2040 – 2050**
Solar PV	101.18	207.21	194.28
Onshore Wind	33.06	145.43	231.24
Battery Storage#	109.00	381.98	843.91
Hydrogen Electrolysers^	7.86	96.57	198.15

Notes:
* Does not include capital expenditure on supporting infrastructure, e.g., EV charging stations, hydrogen supply and distribution networks, required for clean technology deployment. Assuming no depreciation of capital or discounting of investments made in the future.
# Including grid storage and electric vehicle deployment.
^ Required for green hydrogen production for use as fuel. Use of green hydrogen as feedstock not included.

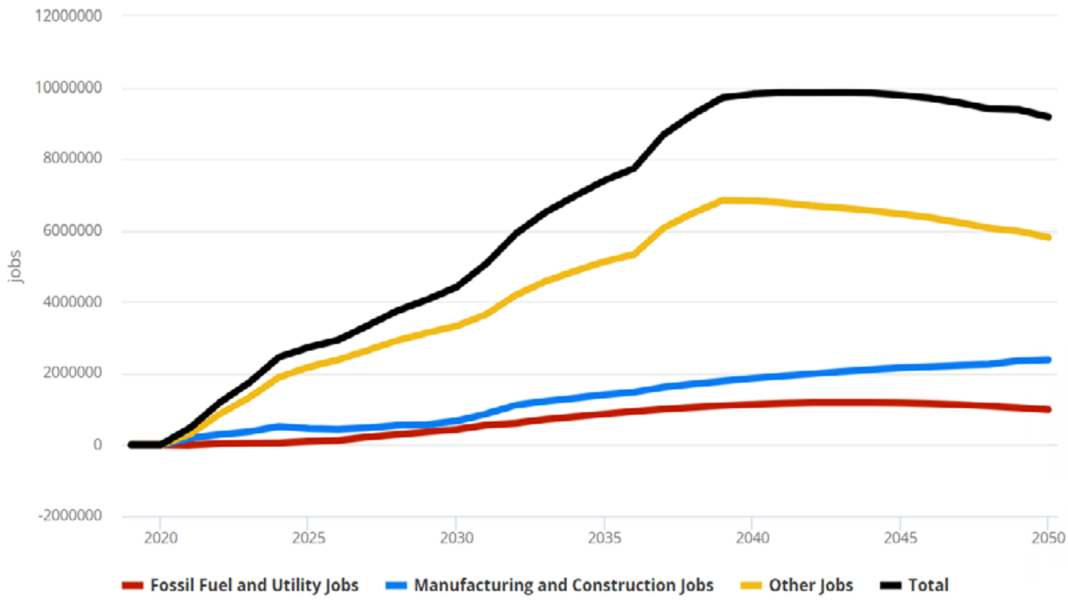
Over the last decade, policy support for solar PV and onshore wind has resulted in increasing investment. In 2021 India was among the top ten countries in the world in terms of annual capacity added for both solar and wind power, which together saw a total investment (in 2018 USD) of approximately USD 10 billion.[xii] However, this represents only about a third of the annual average investment required in these technologies over the next three decades, to achieve the scale of transformation required.

Ongoing government programs, such as consumer subsidies for electric vehicles under the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme,[xiii] as well as production linked incentives (PLI) for advanced chemistry cell battery production[xiv] – with a planned budgetary outlay (in 2018 USD) of approximately USD 1.2 billion (over a period of 3 years) and USD 2.2 billion (over a period of 5 years), respectively – are aimed at attracting private investment in EV and battery production. While this is a good start, significant additional effort, including internationally-supported technology partnerships and concessional financing schemes, is likely to be required for attracting investment at scale in nascent technologies such as battery and green hydrogen production.

Impacts on GDP and Employment

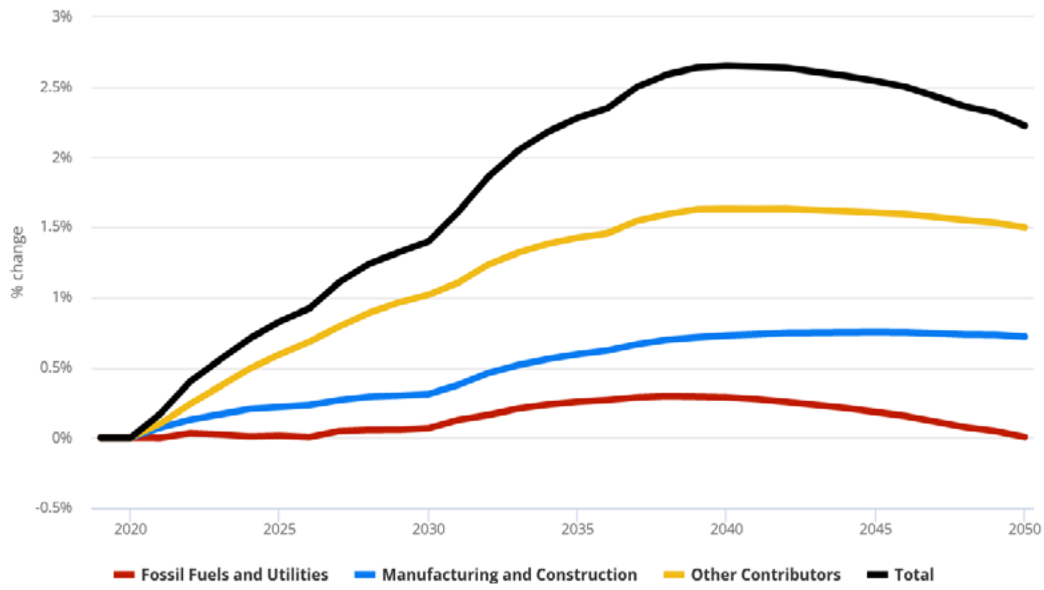
The LTD scenario yields better economic growth and employment results than the Reference Scenario. In aggregate terms, the overall shift towards cleaner energy sources would lead to a net positive effect on the GDP and jobs created in the economy. By 2050, the LTD Scenario can generate a total of up to 9.2 million additional direct and indirect jobs as well as increase the GDP of the country by 2.2% over expected Reference Scenario levels (Figures 7 and 8).

Figure 7: Change in direct and indirect jobs relative to the Reference Scenario



Gains in GDP and jobs are mainly driven by direct increase in economic activity in new industries like clean electricity generation, green hydrogen production, and electric vehicle manufacturing. They are indirectly reinforced by an increased activity in secondary industries providing supply inputs to these new industries. Moreover, there are additional jobs created in other sectors of the economy from induced economic activity due to re-spending of consumer savings on fuels and government expenditure of carbon tax revenues.

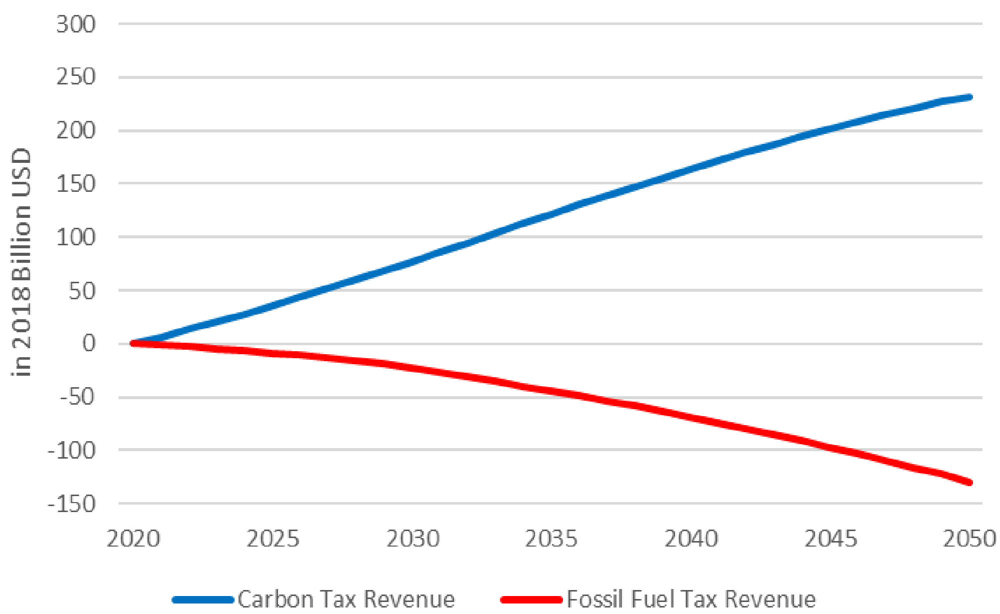
Figure 8: Per cent change in GDP relative to the Reference Scenario



Note: These include direct, indirect, and induced effects.

Carbon tax revenues help mitigate the reduction in government revenue from fossil fuel taxes, largely from petroleum products (Figure 9), which could otherwise constrain productive public expenditure during the transition and, potentially, adversely impact economic growth and employment. Together, these effects can adequately compensate for the jobs and GDP losses resulting from the contraction of brown sectors such as coal mining, petroleum refining, and manufacturing of internal combustion engines.

Figure 9: Change in select government revenue components (carbon tax revenues vs. fossil fuel tax revenues) relative to the Reference Scenario (in 2018 billion USD)



Role of Carbon Price

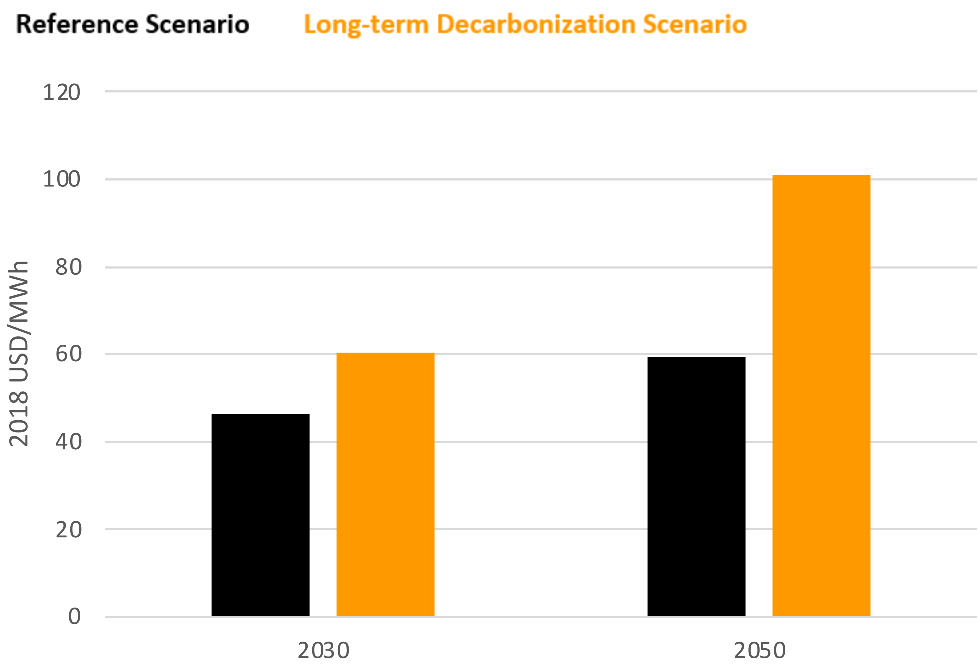
A carbon tax serves two purposes in the LTD Scenario. First, it acts as a complementary policy to the mandates for clean technology adoption by increasing the cost of using fossil fuels. Second, it serves to offset the loss in public revenue from declining petroleum tax collections by widening the tax base to all emissions-causing uses of fossil fuels – thereby helping in sustaining productive government spending during the transition.

The tax, imposed in the power and industry sectors, is increased in a phased manner starting from approximately USD 3.3[xv] per ton CO2 at present to reach USD 17 in 2030 and USD 50 in 2050. This may appear modest in terms of magnitude in the short to medium term. – For example, in comparison to the International Monetary Fund's recent recommendation of a USD 25 price floor, in addition to existing mandates for low-income emerging economies like India[xvi] – this can have a notable effect on essential commodity prices, while the economy is still reliant on fossil fuels. For instance, the LTD Scenario sees the levelized cost of coal-based electricity rise by 30%, compared to the Reference Scenario in 2030 (Figure 9), when coal still occupies half the share in the electricity generation mix.

Therefore, despite its crucial role in the policy mix, a carbon pricing scheme must be carefully evaluated and designed for equitable balancing of contributions from households, businesses, and taxpayers. In December 2022, the Indian parliament passed the Energy Conservation (Amendment) Act, which, among other measures, empowers the Indian government to set up a national carbon market.[xvii] While the development of such a market may take time and is unlikely to provide economy-wide coverage of emissions, a carbon price is likely to emerge as a result over time.

In the context of a global climate club or alliance, any carbon pricing proposal should allow for a phased and differentiated – across developed and developing countries – implementation.

Figure 10: Levelized cost of coal-based electricity generation (in 2018 USD/MWh)



Conclusion

Increased electrification and green hydrogen use in industry and transport sectors supported by the decarbonisation of power supply, together with improved industrial and building energy efficiency, hold the key to achieving India's 2030 NDC targets and the net-zero 2070 goal. The sectoral shifts by 2050 entail significant additional investments of nearly 3 trillion USD over the next three decades in capital-intensive technologies like clean electricity generation, hydrogen production, electric vehicle manufacturing, and grid-scale battery storage, compared to the Reference Scenario. Most of these investments are expected to be in the private sector, in response to the enacted policies, and will depend on the availability of timely domestic and international finance to materialise. Complementary public policies– such as subsidies for nascent technologies and the creation of supporting infrastructure like EV charging stations and hydrogen distribution networks – to encourage the adoption of green technologies by consumers and the industry, will be critical in spurring private investment to make this transition happen.

While our analysis identifies the high-level strategies required for long-term decarbonisation, there are some additional factors that need to be considered for developing implementation plans for a low-carbon growth pathway. Although there are net aggregate economic gains expected in the LTD Scenario, the sectoral shifts would likely result in unequal impacts among industries, regions, and sections of population. The scale of transformation also implies increased pressures on critical natural resources such as land, water, and materials, which can potentially impact the populations dependent on these resources for a livelihood. Moreover, the implementation of measures such as the carbon tax and clean electricity mandates can, in the short run, lead to a slight increase in energy prices that can disproportionately affect low-income populations. A careful consideration of the above elements in policy planning can ensure a just and inclusive transition to India's low-carbon future.

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