McKinsey Sustainability

Decarbonising India

Charting a pathway for sustainable growth

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Preface

The physical manifestations of climate change are increasingly visible across the globe, and India is not untouched. More than 75 percent of India's districts—home to 638 million people, or 1.4 times the population of the European Union (EU)—are categorised as hotspots for extreme climate events already.[1] India has acknowledged this threat in multiple forums, has set ambitious targets and is taking bold measures to address the risks.

Though India's emissions currently stand at a mere 1.8 tons CO_2e per capita (versus the United States at 14.7 and China at 7.6), it is still the world's third-largest emitter at 2.9 $GtCO_2e$ (4.9 percent of global emissions).[2] As India grows,[3] emissions will only increase without a concerted effort across multiple sectors of the Indian economy. We use external sources for GDP growth scenarios in this report and don't make projections or forecasts. These scenarios range between long term forecasts from reputed international agencies such as EIU and Oxford Economics and aspirational estimates, based on employment needs. We have used the former as a basis to develop sector growth scenarios and hence, GHG emissions. With careful planning and execution, India can meet its growth ambitions while decarbonising.

At COP26, India set out its plan to help slow down and halt global warming, with a 2070 net-zero target. While we support the global net-zero ambition of decarbonising by 2050, we have used India's stated national plan as the basis for the analysis and scenario modelling in this paper. Our analysis also shows that the transition though difficult is feasible—and could even be accelerated. However, we don't foresee India getting all the way to net zero in either of our scenarios – the last 10 percent will be particularly difficult to decarbonise.

This report presents an in-depth analysis of ways to decarbonise the six sectors which contribute to roughly 70 percent of India's overall emissions: power, automotive, aviation, steel, cement and agriculture. Additionally, we analyse four cross-cutting enablers which can help decarbonise multiple sectors: carbon-capture usage and storage (CCUS), natural climate solutions (NCS), material circularity and green hydrogen. More than 100 emission-reduction initiatives have been identified for these key sectors and themes, across two scenarios, both of which assume an orderly transition: (a) The Line of Sight (LoS) scenario with current (and announced) policies and foreseeable technology adoption, and (b) The Accelerated scenario with further reaching policies such as carbon prices and accelerated technology adoption including those of technologies like CCUS. It also includes estimates for the likely investments this transition will need and ways in which to finance it.

We started our effort with a comprehensive literature review of similar knowledge efforts conducted in this space. While there are several good reports out there, published by credentialled organisations, this report attempts to differentiate itself from others in the following ways: it is comprehensive across sectors, examines these in depth (including with customised and detailed sector models), explores implications of inter-linkages across sectors, and takes a practical, yet aspirational, view of the abatement levers. Finally, it defines a set of actions that need to be executed with urgency if this orderly transition is to get underway.

In keeping with our history of exploring environmental sustainability issues, we offer this report not to prescribe what policymakers and industry should do, but to provide a factual basis for comparing emission-reduction approaches. Further, we hope the report will help leaders in the public and private sectors launch emission-reduction projects to help secure a healthy and prosperous future for India and the world.

1 Council for energy, environment and water (CEEW).
2 As per the World Bank data, 2019.
3 India's GDP estimated to grow from $3 trillion today to $12 trillion by 2050; The Economist Intelligence Unit (EIU)-Real gross domestic product in USD at 2010 prices.

Acknowledgements

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Executive summary

In 2021, at COP26, India announced its ambition to become a net-zero emitter by 2070.[1] Despite low per-capita emissions (1.8 tons CO_2 per capita), India is the third-largest emitting country globally.[2] Therefore, if we are to win the global war on climate change, India will need to play an important role. With this in mind, India has taken several proactive steps and made commitments. For instance, its updated Nationally Determined Contribution (NDC) for 2030 commits to using half of power-installed capacity from non-fossil fuel-based energy resources and to achieving a 45 percent reduction in emissions intensity from its 2005 levels.[3]

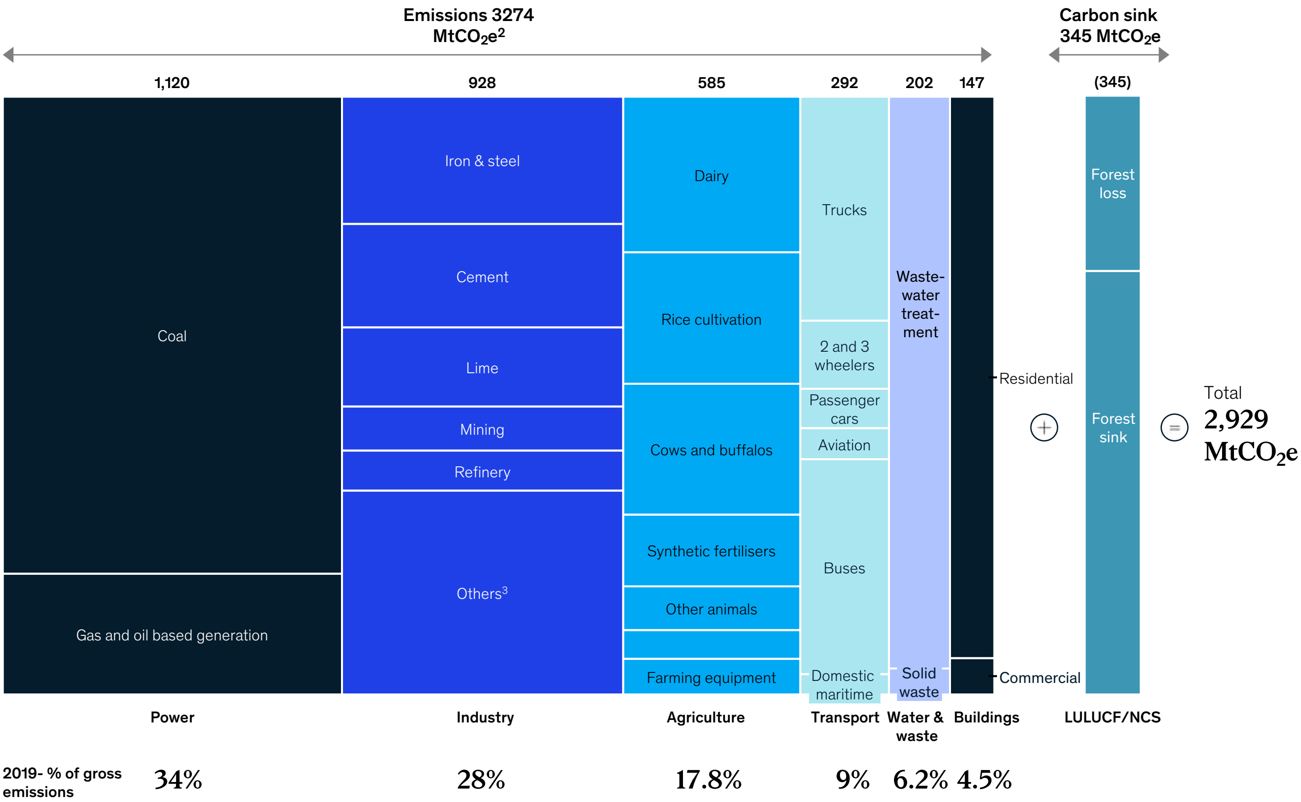
India currently emits a net of 2.9 $GtCO_2e$ every year (as of 2019). The bulk of these emissions (about 70 percent) are driven by six sectors: power, steel, automotive, aviation, cement and agriculture (Exhibit A).

1 India's NDC.
2 World Bank; Worldometer.
3 India's NDC.

Exhibit A

India's current carbon emission mix.

Baseline emissions, $MtCO_2e$[1], 2019



1. Converting GHGs into CO_2e assuming GWP-100 and AR5 methodology with India's BUR-3 reported emissions for 2016 as baseline.
2. Gross and net emissions for 2019 based on Climate Action Tracker overall emissions for India.
3. Others include: other industry oil & coal use, ammonia, aluminium, F-gases and ethylene.

Source: McKinsey India Decarbonisation Scenario Explorer

This report identifies the optimal uses of more than 100 emission-reduction levers in these sectors, across two scenarios, both of which assume an orderly transition: (a) the Line of Sight (LoS) scenario with current (and announced) policies and foreseeable technology adoption and (b) the Accelerated scenario with further reaching polices like carbon prices and accelerated technology adoption, including those of technologies like CCUS. This report attempts to be comprehensive across sectors, examining them in depth, highlighting linkages across them while taking a practical, yet aspirational, view of the abatement levers. It attempts to define two possible roadmaps for an orderly transition for India in the context of its continued expected growth. Finally, it proposes a set of actions that could be executed for an orderly transition to get underway. This report does not address physical risks and adaptation topics.

Our analysis shows that the benefits of a well-planned, orderly, accelerated transition could far outweigh the downsides for India, given its growth outlook. India must take steps within this decade to set things up. Doing so will allow it to use its growth momentum and build the country 'right' for the decades thereafter. Also, while the actions needed for India to decarbonise are challenging, most of them are 'in-the-money', and hence the journey is doable. Eight important messages emerge from this:

1. **There is an opportunity for India to create 287 Gt of carbon space for the world.** In the growth scenario assumed for this report,[4] India will likely be a $22 trillion economy in real 2010-dollar terms[5] (about seven times its current GDP) with a population of 1.7 billion by 2070. Even if its current GDP emission intensity reduction were to continue at the same rate, India's annual emissions would still rise to 11.8 $GtCO_2e$ by 2070 (from 2.9 $GtCO_2e$ in 2019).[6] Getting to the LoS scenario would create 207 $GtCO_2e$ of carbon space till 2070, while the Accelerated scenario would add a further 80 $GtCO_2e$. This is equivalent to 36 percent and 14 percent, respectively, of the remaining carbon budget for an even chance at limiting warming to 1.5 degrees Celsius. This is despite India not reaching net zero in either of our scenarios, due to the residual emissions from agriculture and select industrial sectors (remaining emissions in 2070 of 1.8 and 0.4 $GtCO_2e$ in the LoS and Accelerated scenarios, respectively). These emissions have been largely estimated with currently feasible technologies. It is to be expected that India could get to its net-zero-by-2070 commitment through the upcoming technology developments over the next decades (e.g., direct air capture {DAC}).

2. **While achieving the LoS scenario reductions will be challenging, achieving those of the Accelerated scenario will be even more so.** While there are emerging tailwinds in the form of falling costs of renewables and electrical vehicles (EVs) and some policies are beginning to be implemented (e.g., Faster Adoption and Manufacturing of {Hybrid &} Electric Vehicles in India {FAME} for EVs, an imputed \$140–240 per ton of CO_2e tax on motor fuels[7]), several other actions with significant scale up are needed. For example, renewable capacity addition has to increase from 10 GW to 40–50 GW per year, a carbon price has to be put in place to make green steel competitive, battery costs have to decline by 80 percent by 2050, hydrogen by two-thirds by 2035, a nationwide roll out of charging infrastructure has to happen, farmers have to adopt new practices for rice cultivation, targets for circularity have to be met and higher targets have to be set.

3. **If India is to have an orderly and accelerated decarbonisation, the transition has to be set up within this decade.** Over three-fourths of the India of 2050 (and 80+ percent of the India of 2070) is yet to be built. This growth could multiply demand across sectors: power (eightfold), steel (eightfold), cement (triple), automotive (triple) and food (double). If policies are set in place to create the right demand signals within this decade, then the capacities India adds in the two decades thereafter will be low carbon ones. For example, in steel, the early imposition of a carbon price could lead to 200 Mt of steel capacity being built on the low carbon hydrogen route instead of the coal route by 2050. This has happened before – policies put in place early in the decade of the 2010s have led to the explosion of renewables capacity in the recent past and will continue to enable even greater capacity expansion going forward.[8] These policies could provide a clear outlook on carbon prices in three years, as also on forward-looking blending mandates (e.g., for aviation fuels) and a national land use plan, encourage local manufacturing capabilities and gear up financial institutions to lend to green projects at scale, amongst other things. The government can also define its plans and policies

4 Real GDP growth rate assumption based on Economist Intelligence Unit (EIU) projection for 2020–30 is 5.8 percent, 2030–40 is 5.1 percent and 2040–50 is 4.7 percent. 2050–70 Real GDP growth rate has been assumed to be about 3 percent annually.

5 Based on Economist Intelligence Unit projection of $12.5 trillion by 2050 (Real GDP - USD at 2010 prices) and extrapolated to 2070 with 3 percent CAGR assumption; This GDP forecast represents a more conservative estimate compared to other estimates - we have considered the lower range of growth in our analyses to build a more robust decarbonisation pathway.

6 United Nations framework convention on climate change (UNFCC); climate action tracker; India's biennial update report.

7 Analysis discussed in Chapter 2, automotive section.

8 IEA - India Energy Outlook.

such that they are fully in concert with investment across sectors, technology development, customer-demand creation, economic viability and funding, if it is to enable an orderly transition.

4. **India would benefit from this.** India's transition from thermal power to renewables is expected to decrease the average cost of power supply from INR 6.15/kWh in FY20 to INR 5.25/kWh and INR 5.4/kWh by 2050 in the LoS and Accelerated scenarios, respectively.[9] Sustainable farming practices could help generate additional farmer income of INR 3400/hectares (ha)/annum in the LoS scenario which could increase to INR 4800/ha/annum in the Accelerated scenario. India may save a cumulative $1.7 trillion in Forex which may otherwise be spent on energy imports till 2070. In addition, India will have the opportunity to build right the first time, minimising asset stranding. Finally, if India can get manufacturing in newer technologies going, it can be a world leader in batteries, electrolysers, green steel and many other areas.

5. **There would be shifts in the energy system.** Fossil fuels, which comprise 75 percent of India's commercial energy mix today, decline to half in the LoS scenario and one-sixth in the Accelerated scenario by 2050.[10] In the Accelerated scenario, over 60 percent of India's refining capacity, 90 percent of its coal-mining capacity, 100 percent of its coal power generation would not be needed. Tax collections from automotive fuel, which at $85 billion comprise 18 percent of the annual central government income, could decline to $36 billion by 2050.[11] Scarce biomass feedstock would need to be directed to the right use. For example, the biomass currently being used by households for cooking and which in future could be used for thermal power generation might need to get directed to the hard-to-abate sectors like cement; or sugarcane-based methanol for the transport sector might need to get directed to aviation.

6. **The pressure on land systems will increase.** Growth and decarbonisation combined may require 45 million ha more land than is available (Accelerated scenario). Almost 10 million ha of this would be needed for renewable power and 8 million ha for carbon sinks and forests. Innovative land optimisation techniques such as maximising barren land use for renewable power, vertical urbanisation, improved agricultural productivity, higher forest density would all be needed to ensure there is sufficient land to use for decarbonisation.

7. **There would be a moderate impact on household spending and jobs**. A critical consideration is what impact accelerated decarbonisation would have on Indian household spending and jobs. We estimate that by 2040, the adverse income impact on people with low incomes from decarbonisation through increased housing costs would mostly be balanced by the limited impact on food costs (excluding impact on yields from direct climate change) and the decrease in the costs of energy and transport. This, of course, presumes an orderly transition – if there is a disorderly transition, the inflationary impact on people with low incomes could be adverse. This also assumes that households can mobilise financing for spends where the Capex is higher upfront even though the Opex is lower later (e.g., EVs). Without this support, their up-front capital expenditure may go up. Accelerated decarbonisation could transform over 30 million jobs (24 million new jobs could be created while six million of the existing jobs could be lost) by 2050.[12] However, this number is relatively small in the context of the macro trends affecting India's workforce (e.g., 60 million joining the workforce by 2030, 30 million needing to come off farms into non-farm jobs).[13] That said, specific communities (e.g., coal mining and associated enterprises, Eastern India) could be adversely impacted, requiring reskilling and alternative industrial development in particular areas.

8. **Large funding would be needed (3.5–6 percent of GDP), front loaded, but substantially in the money.** India may need an estimated $7.2 trillion of green investments until 2050 to decarbonise in the LoS scenario and an additional $4.9 trillion for the Accelerated scenario (about 3.5 percent and 2.4 percent of India's GDP through this period, respectively). 50 percent of the abatement between the LoS and the Accelerated scenarios is 'in the money', particularly across the renewable energy (RE), automotive and agriculture sectors; others would need policy support. The net spend (Capex minus Opex savings) is front loaded – the Accelerated scenario would, net of operational savings, require $1.8 trillion more in the decade of the 2030s and $0.6 trillion more in the decade of the 2040s than the LoS scenario.

9 Full system cost of power including costs (factoring reasonable returns and system losses) for generation, transmission and distribution. The corresponding cost of power generation Is INR 3.9/KwH.
10 Ministry of power annual report, 2021–22.
11 International Energy Agency (IEA) data for fossil based energy; tax value as per petroleum planning and analysis cell (PPAC) using INR 75/USD as conversion rate.
12 McKinsey Global Institute: The net-zero transition - what it would cost, what it would bring.
13 McKinsey Global Institute: India's turning point.

The decarbonisation pathway

India has reduced its emissions intensity of GDP by 1.3 percent per annum over the last decade, somewhat decoupling emissions from GDP growth.[14] However, this pace of intensity reduction is not quick enough. It will not cause India's emissions curve to bend, given the fast growth expected. India's GHG emissions would likely increase to 11.8 $GtCO_2e$ by 2070 even assuming the reduction in current GDP emissions intensity. The LoS pathway would reduce annual emissions to 1.9 $GtCO_2e$ by 2070 leading to a 90 percent reduction in economic emissions intensity versus 2019. The Accelerated pathway could further close the gap to net zero and reduce annual emissions to 0.4 $GtCO_2e$ leading to a 98 percent reduction in emissions intensity by 2070 versus 2019. The LoS scenario would lead to cumulative carbon savings of 207 $GtCO_2e$ by 2070 while the Accelerated scenario would create further savings of 80 $GtCO_2e$ cumulatively by 2070 (Exhibits B, C, D).[15]

Tackling the 0.4 $GtCO_2e$ of annual emissions in 2070, remaining in the Accelerated scenario (Exhibit D) predominantly from industry and agriculture, will require technological advancements, including improved capture technologies, newer recycling technologies and ocean-based carbon sequestration.

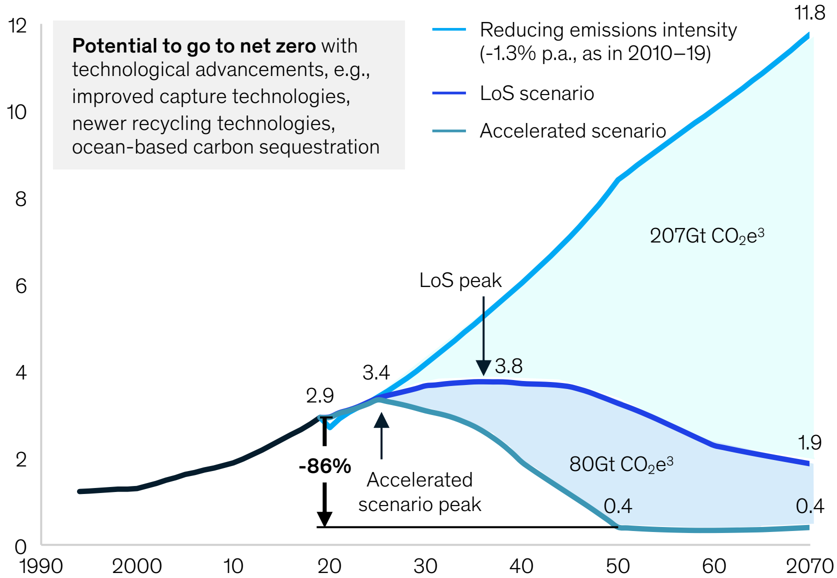
[14] UNFCCC, climate action tracker, McKinsey India DSE, EIU, India's biennial update report 3.
[15] UNFCCC, climate action tracker, India's biennial update report.

Exhibit B

Possible pathways for India to decarbonise.

India's GHG emissions[1]

$GtCO_2e$ per annum[2]



LoS scenario

- **Implementation** of India's NDC, existing and currently announced policies
- Technology advancement as per current trajectory
- Shift in demand to sustainable alternatives in selected areas, e.g., EV

Accelerated scenario

- Adoption of **new policies** such as carbon pricing
- **Technology breakthroughs,** e.g., CCUS and faster implementation of existing levers
- **Accelerated shift** to sustainable consumption, e.g., EV, alternative materials, coarse cereals, green steel

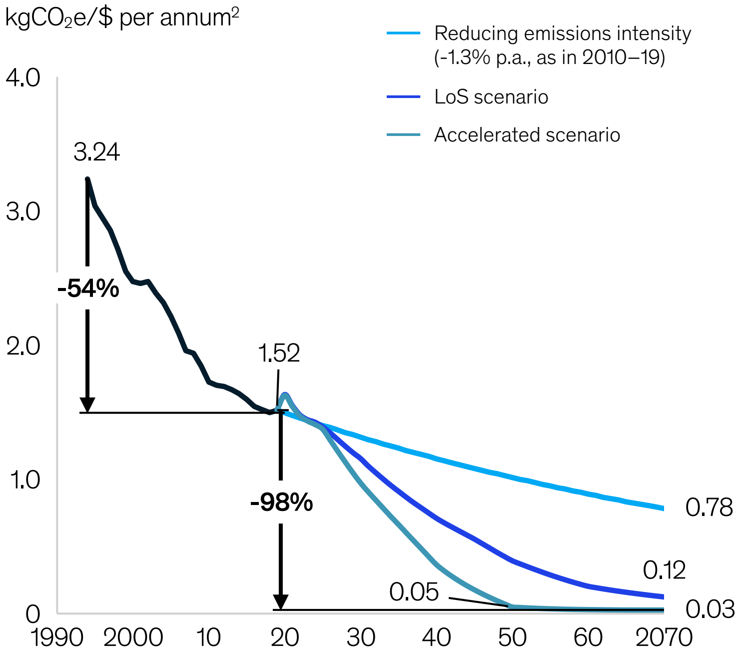
1. These emissions have been estimated with largely currently feasible technologies. It is to be expected that India could get to its net-zero-by-2070 commitment through the upcoming technology developments over the next decades (e.g., direct air capture).
2. Including LULUCF emissions and offset.
3. Global carbon budget for 1.5 degree pathway as per IPCC AR5 is 580 $GtCO_2e$.

Source: UNFCCC, climate action tracker, McKinsey India DSE, India's biennial update report 3

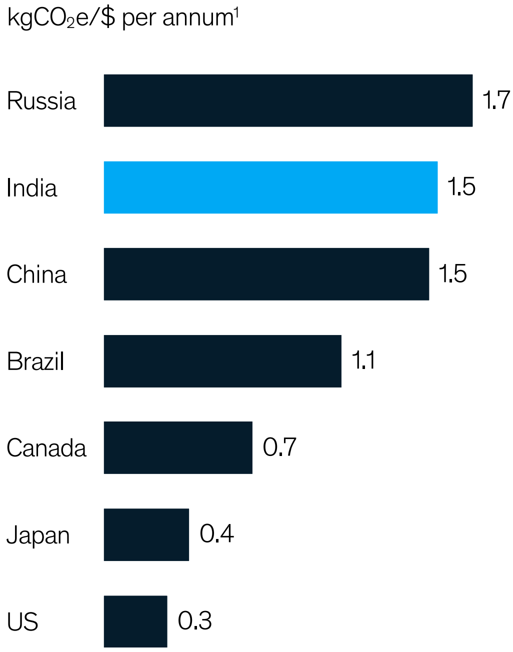
Exhibit C

Economic emission intensity reduction for India.

India's GHG economic emissions intensity[1] (volume of emissions/unit of GDP)



Current economic intensity of world's top emitter countries[3]

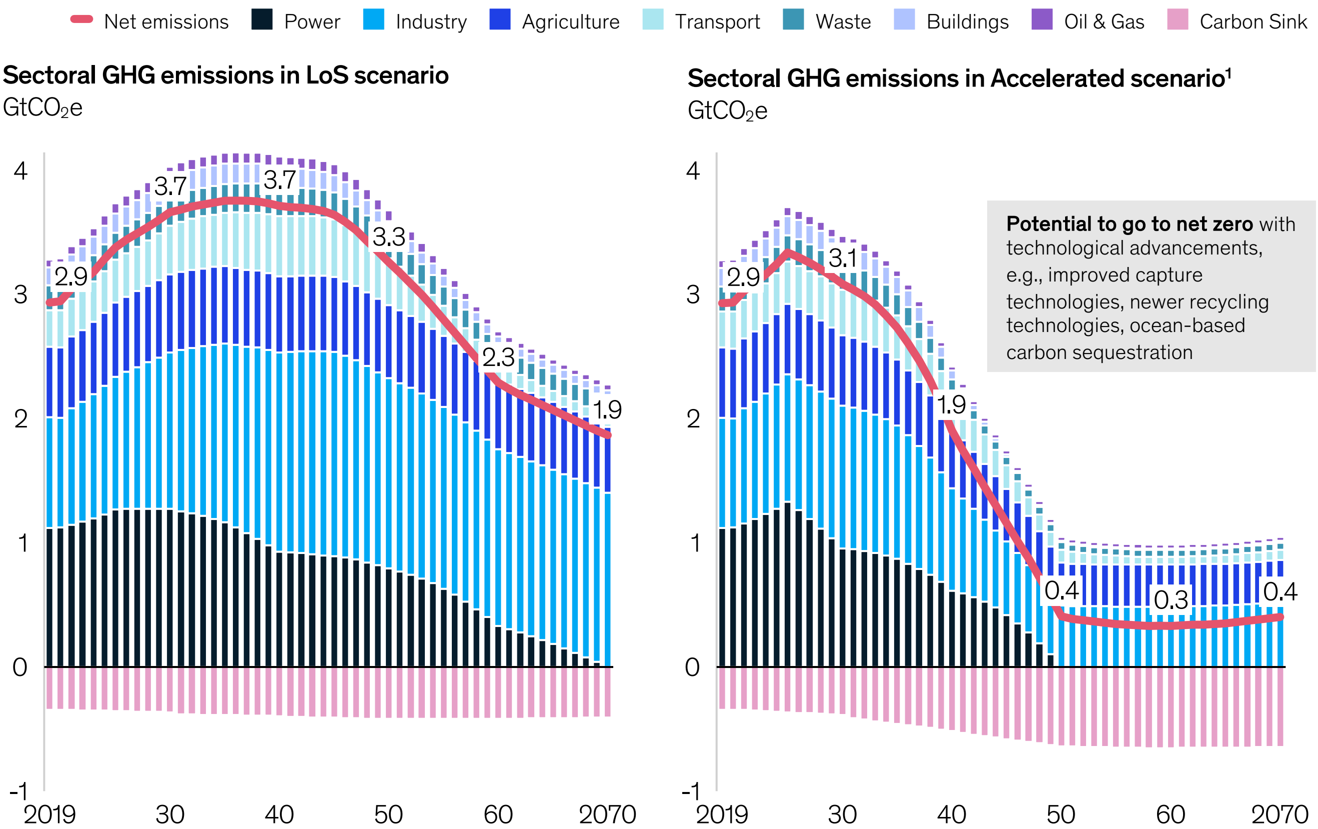


1. These emissions have been estimated with largely currently feasible technologies. It is to be expected that India could get to its net-zero-by-2070 commitment through the upcoming technology developments over the next decades (e.g., direct air capture).
2. Including LULUCF emissions and offset.
3. Economic emission intensity from annexed and non-annexed countries in UNFCCC.

Source: UNFCCC, climate action tracker, McKinsey India DSE, India's biennial update report 3

Exhibit D

Emission curves for the LoS and Accelerated scenarios.



1. These emissions have been estimated with largely currently feasible technologies. It is to be expected that India could get to its net-zero-by-2070 commitment through the upcoming technology developments over the next decades (e.g., direct air capture).

The challenge of rapid decarbonisation

Achieving the LoS reductions will be challenging, those in the Accelerated scenario even more so. India has moved in several sectors with rapid pace – renewables, energy efficiency, EVs, hydrogen. While the results are there for all to see in the continued reduction in carbon intensity of GDP, and with several sectors poised for scale up, there are also major challenges to be overcome (Exhibit E).

For example, in the Accelerated scenario, **renewable** (wind and solar) capacity addition will likely increase from 10–12 GW per year today to 50 GW per year in 2030 and 90 GW per year in 2040. Ten times as much land as is used today would need to be identified and made available. Panels and corresponding raw material manufacturing may need to be scaled up, given 80–90 percent of the solar panels are imported currently.

In automotive, 100 percent of two wheelers, three wheelers and light truck sales may need to be electric early in the next decade, all car sales would have to be electric by 2035 and trucks by 2050. For this, battery costs may need to decline by 40 percent in 2030 relative to today. Charging stations would need to increase 13 times by 2030 and 40 times by 2040 relative to today. Consumer financing, given higher, up front EV costs and raw materials for batteries, will need to be found.

Green hydrogen, which is not going to be economical versus other alternatives until 2030, would need a subsidy of $60–80/KW for electrolyser manufacturing and carbon prices (within this decade) to support uptake for its largest use case of green steelmaking. 29 GW of electrolysers may need to be installed by 2030 (relative to the current deployment of about 1.4 GW, globally[16]) and almost 400 GW by 2040.

Across other industries, steel would need growth in hydrogen green steel capacity from nil today to 152 Mt by 2040 while blast furnace–basic oxygen furnace (BF-BOF) capacity would need to see an increase from 55 Mt today to 119 Mt by 2030 and then a decrease to 85 Mt by 2040. Coal-based power generation would have to transition from 211 GW today to 120 GW by 2040 and nil by 2050. Refining capacities would need to decrease from 213 Mt per annum today to 114 Mt per annum by 2040 and 105 Mt per annum by 2050.

Additional land would be needed to meet India's land requirements. This may be needed for agriculture (12 million ha by 2040), solar plants (5 million ha by 2040), forest densification (4 million ha by 2040), etc. However, sufficient volumes of suitable land will not be readily available unless efficient land use practices are implemented.

Investment, currently at $44 billion per annum, will likely need to increase 3.6 times by 2030 and 10 times by 2040. This is doable so long as early action is taken to facilitate the transition within this decade, given that a very large proportion of the decarbonisation levers are in the money.

[16] https://www.iea.org/reports/electrolysers

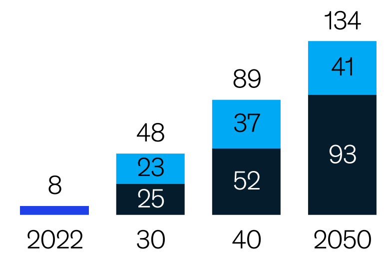
Exhibit E

Challenges for India's decarbonisation.

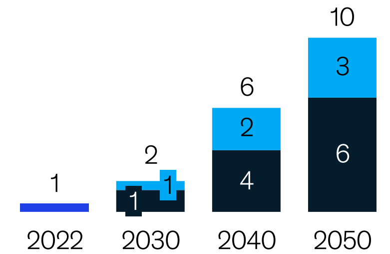
LoS scenario
Accelerated scenario
Current situation

Power

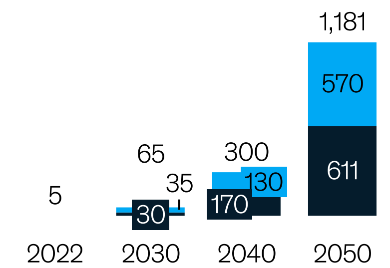
Average annual solar + wind onshore capacity addition, GW



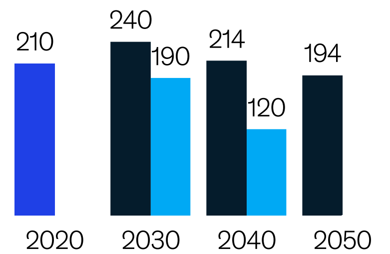
Land requirement for solar + wind onshore, Mha



Storage capacity, GW

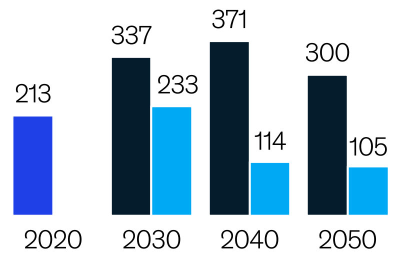


Coal power generation capacity, GW

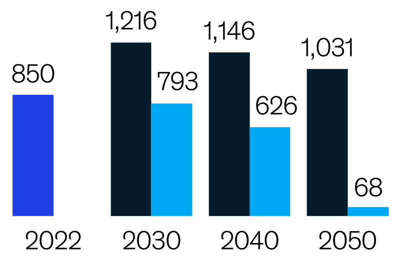


Energy & hydrogen

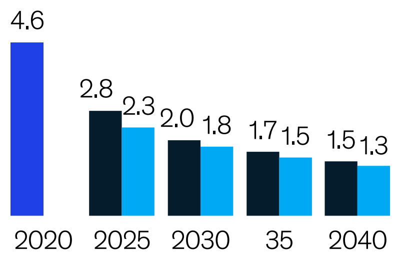
Refining capacity, MMTPA



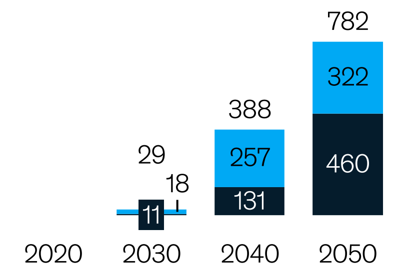
Coal consumption, MMTPA



Cost of green hydrogen, $/tonne



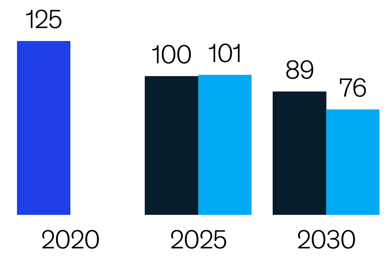
Electrolyser capacity, GW



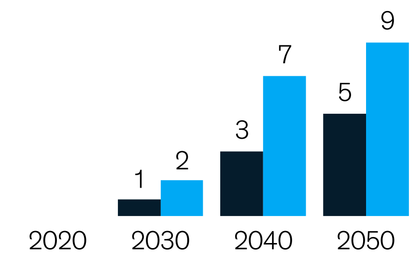
- Subsidy of \$60–\$80/KW for electrolyser manufacturing

Automotive

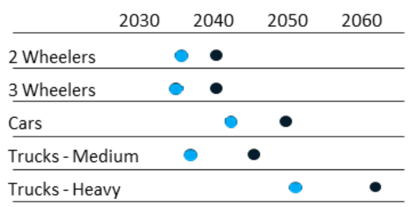
Battery costs, \$/KWh



No. of chargers, millions



Switchover to 100% EV sales



- Fame subsidies extended till 2030
- Retail fuel prices maintained
- 2022 battery spot prices hovering around \$180/KWh to \$195/KWh due to geopolitical issues and Covid impact

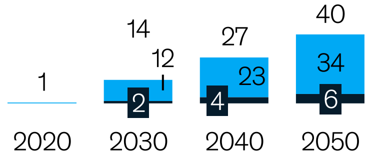
Exhibit E (Continued)

Challenges for India's decarbonisation.

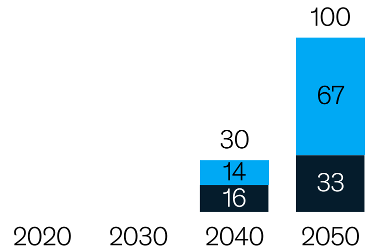
LoS scenario
Accelerated scenario
Current situation

Agriculture & NCS

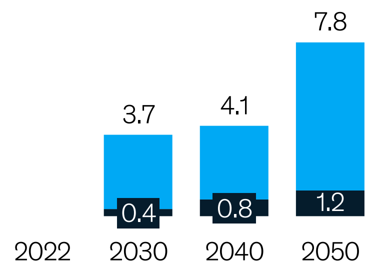
Improved rice straw management, %



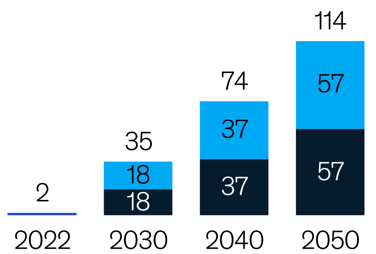
Electrification of on-farm equipment, %



Incremental land required for trees, Mha

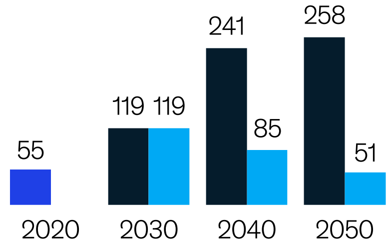


Incremental land required for regenerative agriculture, Mha

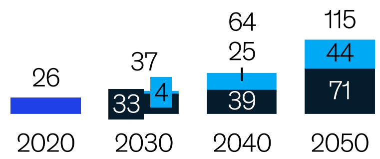


Steel and cement

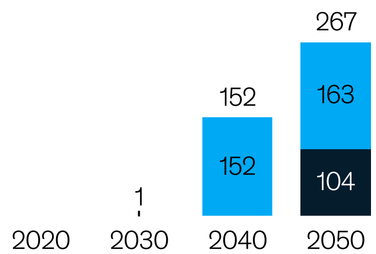
Steel - BF-BOF capacity, Mt



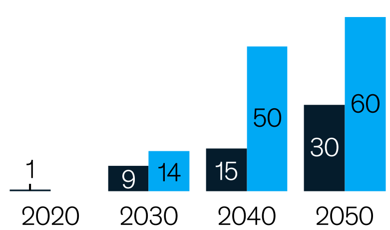
Steel - scrap based EAF-IF capacity, Mt



Steel - hydrogen green steel capacity, Mt



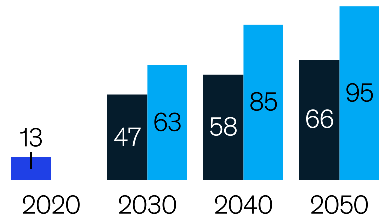
Cement - heat demand met by green fuels, %



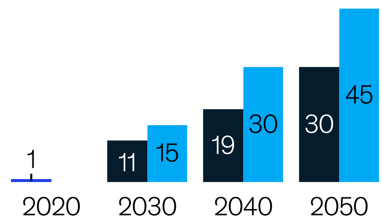
- Carbon price of $50 by 2030
- Clinker to cement ratio reduces to 60% by 2050 in Accelerated scenario (vs 65% for LoS)
- CCUS needed to capture 65% of remaining emissions from cement

Circularity & financing

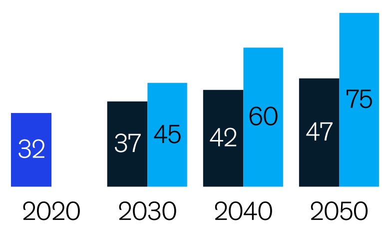
Recycling rates, plastics, %



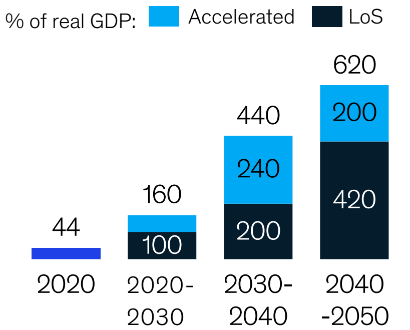
Recycling rates, construction & demolition, %



Recycling rates, municipal solid waste, %



Average annual investment, $ bn



1.6%	2.6%	3.1%	4.1%
1.6%	4.1%	6.8%	6.0%

Addressing the challenges would need to happen in concert – with stakeholders playing together in harmony. The government would need to create demand signals and the industrial sector would have to bring capacity. Equity and debt funders may have to understand the risk and bring financing at an unprecedented level. Consumers would have to adapt fast.

The risk of a disorderly transition is very high – it has been seen recently in the coal shortages India experienced post-Covid as demand bounced back. Disorderly transitions can occur in many ways. For example – under investment in fossil fuel-based capacities (e.g., coking coal-based steel), even as the demand signals don't build up quickly enough for green steel, leading to import dependence; grid instability and power shortages because of the unbalanced build up of storage capacity or inappropriate use of existing stabilisation sources like hydropower; demand compression due to increased upfront consumer prices for EVs if banks are unable to assess risks and support the higher capital costs; inflation for recycled material if blending mandates are enforced and the recycling infrastructure does not keep pace; new fossil-based capacity build up getting derailed if climate changes force sudden closure.

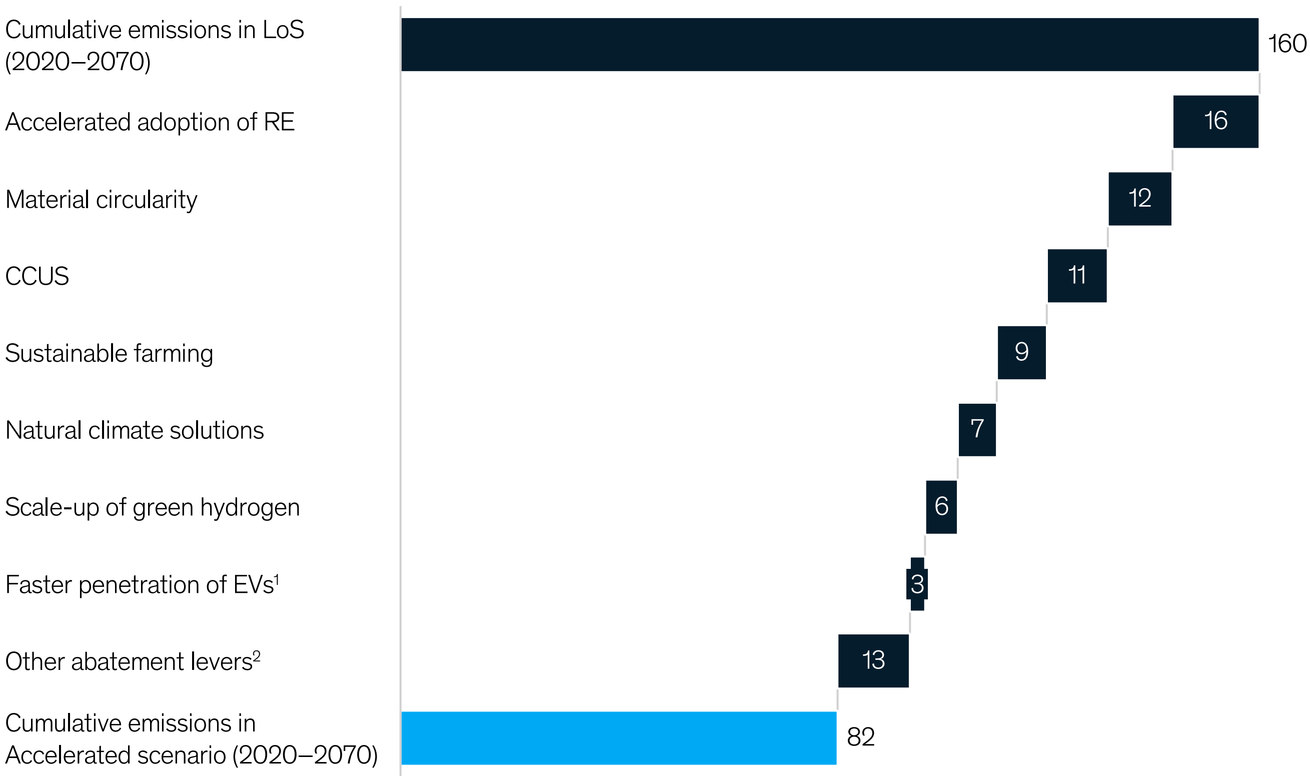
Major areas of emission reduction need urgent action for an orderly transition

The Accelerated decarbonisation scenario can cumulatively abate 80 $GtCO_2e$ more than the LoS scenario till 2070. More than 80 percent of this abatement is achievable with seven levers: renewable energy, electrification of mobility, use of hydrogen, implementation of sustainable agriculture practices, material circularity, NCS and CCUS (Exhibit F). Getting these sectors set up for an accelerated transition would need urgent action within this decade.

Exhibit F

More than 80% of abatement can be achieved through 7 key levers.

Cumulative emissions reduction between LoS and Accelerated scenarios, 2020–70, $GtCO_2e$



1. In the LoS scenario, EV penetration reaches 100% only by 2070.
2. Includes other miscellaneous abatement levers such as 100% electrification of cooking, complete treatment of wastewater, improved energy efficiency in industry, and so on.

i. **Expand renewable energy capacity:** 100 percent decarbonisation by 2050 in the Accelerated scenario as opposed to by 2070 in the LoS scenario would result in abating 16 $GtCO_2e$ by 2070. With wind-and solar-generation technologies already available at scale, power would be the quickest sector to decarbonise, potentially reaching net-zero emissions by the mid-2050s.

   India's solar and wind capacity would need to increase from its current 95 GW[17] to 2700 GW by 2050, representing a 95 percent share of generation. This would need an acceleration in the annual build to 40–50 GW from the current 10 GW a year. Ex-bus bar solar tariffs are currently in the range of INR 2.0–2.5/kWh; lower than the marginal generation cost for 60–70 percent of coal power plants.[18] This gap is likely to widen further. Transition to renewable sources of electricity would also decrease power generation costs from the current INR 3.9/kWh to INR 2.9/kWh by 2050, with lower cost renewables and grid-stabilising storage. To accelerate renewable energy production, India would have to quadruple the rate of capacity addition, resolve supply side bottlenecks (land, grid, etc.), accelerate market reforms and storage buildout (1200 GW by 2050) for integration of renewables and grid reliability, foster innovation and localise manufacturing.
   A quarter to two-fifths of the energy supply can be from infirm sources till 2030 in the LoS and Accelerated scenarios, respectively (Exhibit G). The capacity in both scenarios will likely double in the decade of the 2030s and double again in the 2040s. The basics, including capacity-inducing and investment-reducing market reform would need to be put in place now.

17 As of April 2022.
18 Ex-bus bar tariff excludes the cost of transmission and distribution. Analysis based on the unit-level coal plant variable cost; data from RE navigator and ministry of power annual reports.

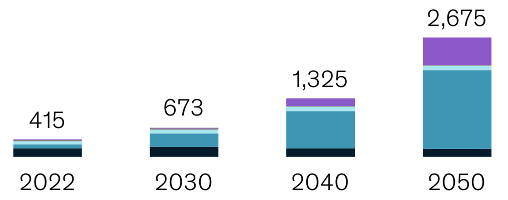
Exhibit G

Both the LoS and the Accelerated scenarios are realistic—but would likely require substantial investment.

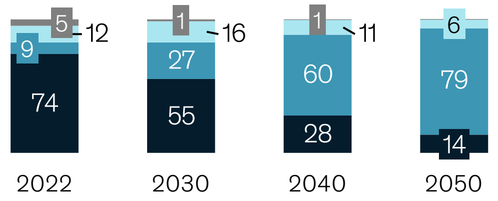
Transmission & distribution | Coal | Other fossil[1] | Solar and wind | Other non-fossil | Storage[2]

LoS scenario

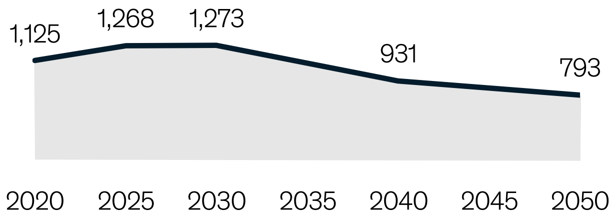
Non-fossil capacity at 400 GW by 2030
Capacity evolution until 2050, GW



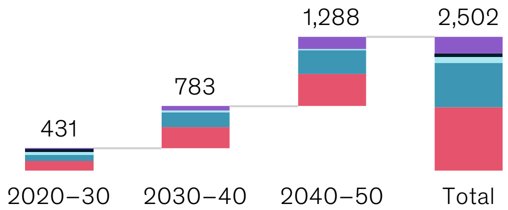
Coal reaches net zero by 2070
Generation mix, %



Emission peaks in the early 2030s
CO_2e emissions until 2050, Mt



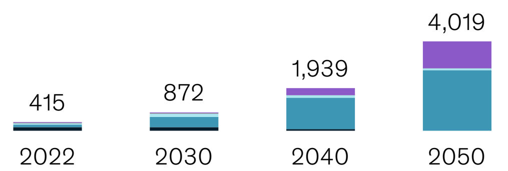
$2.5 trillion investment required by 2050
Investments in RE and storage until 2050, $ billions



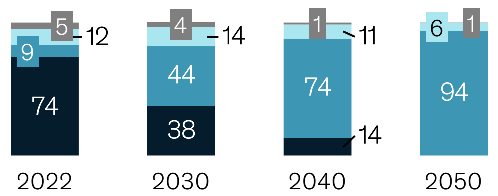
Capacities by 2050: Solar – 1372 GW; Wind onshore – 364 GW; Hydro – 51 GW; Nuclear – 22 GW, Capacities by 2030: Solar – 204 GW; Wind onshore – 86 GW; Hydro – 69 GW; Nuclear – 16 GW.

Accelerated scenario

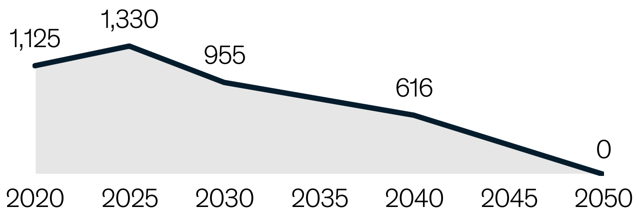
Non-fossil capacity at 600 GW by 2030
Capacity evolution until 2050, GW



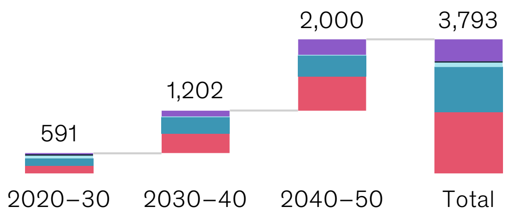
Coal reaches net zero by 2050
Generation mix, %



Emission peaks in mid-2020s
CO_2e emissions until 2050, Mt



$3.8 trillion investment required by 2050
Investments in RE and storage until 2050, $ billions



Capacities by 2030: Solar – 376 GW; Wind onshore – 102 GW; Hydro – 71 GW; Nuclear – 24 GW; Capacities by 2050: Solar – 2172 GW; Wind onshore – 536 GW; Hydro – 54 GW; Nuclear – 22 GW.

1. Other fossil includes gas and oil; other non-fossil includes hydro, biomass and nuclear.
2. Storage includes battery, pumped hydro, LDES 8–24h, LDES 24h+ and hydrogen.

Source: McKinsey Power Model

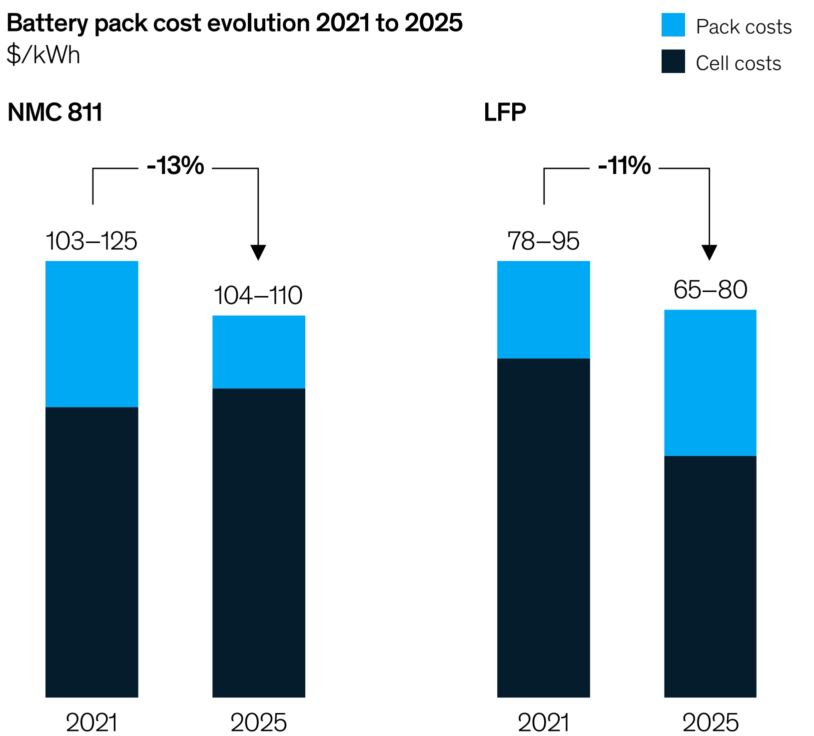
ii. **Increase penetration of EVs across vehicle types.** Electrification of mobility would likely deliver 7 $GtCO_2e$ of cumulative abatement from now till 2070 between the LoS and Accelerated scenarios. This is underway due to advances in battery technology (storage capacity up two times, cost reduction of 17 percent every year over the last 10 years). It enjoys explicit support from the government (GST benefit of five percent for EVs versus 28–51 percent for internal combustion engine {ICE} vehicles; FAME, production-linked incentives {PLI}).[19] Perhaps the most important factor is an implicit carbon tax on transportation fuels of $140 to 240/ tCO_2e (Exhibit H, I).

In the Accelerated scenario, all new vehicle sales are assumed to shift to EVs fully around 2030 for two wheelers, around 2040 for cars and 2040–2050 for CVs. These assumptions are based on total cost of ownership (TCO) parity which needs to be balanced out by market maturity considerations. Typical maturity bottlenecks, which need to be solved, include adequate availability of EV models, charging and swapping infrastructure maturity as well as incentive/dis-incentive schemes as proposed by the government. The infrastructure bottlenecks need decadal Capex investments to the tune of $3 trillion for which the green financing needs to be sorted out. This transition would be enabled by a) further reducing battery costs and fuel cells through at-scale localisation; b) continuing government support through GST and FAME benefits and fossil fuel taxation; c) achieving the target modal mix of 45 percent for rail freight by 2040; and d) targeting affirmative action on select transitions, e.g., commercial fleets, especially heavy commercial vehicles (HCVs).

[19] FAME; ministry of heavy industries

Exhibit H

Battery costs declining rapidly, powering the EV revolution.



Main drivers of scale effect

- Increase in EV demand
- Improvement in learning & yield rates
- Increase in average plant size from 9 GWh in 2021 to 18 GWh in 2025
- Spread of direct & indirect cell production costs such as labour, SG&A, logistics, R&D costs and PPE & depreciation

Main drivers of technology effect

- Energy density increase (impact on direct material and fixed costs) as well as component technology of cathode, anode and electrolyte
- Gains from next-generation cathode (advanced NMC 811)
- Reduction in the cost of cell components such as separator, copper foil, aluminium foil, etc.

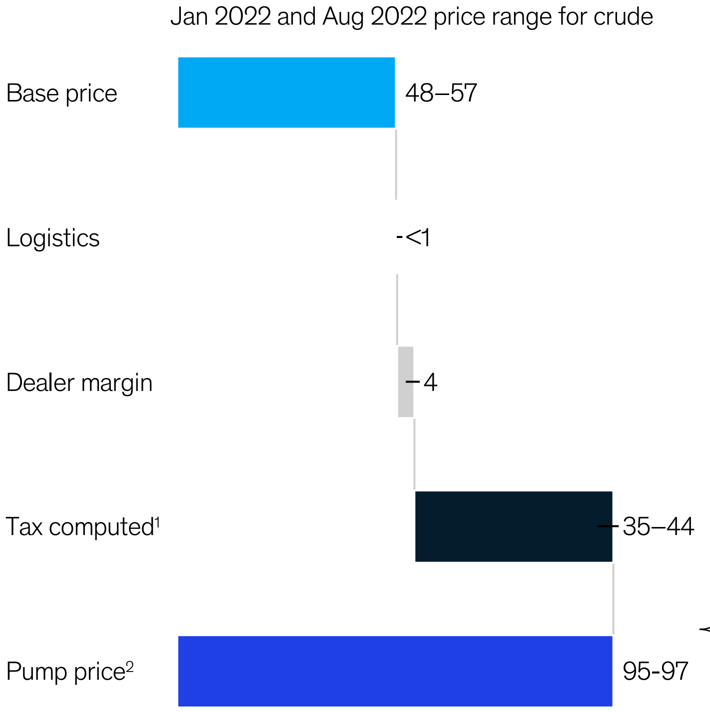
Note: Cost+ at 10 GWh plant in China, excluding the LFP royalties; LFP Export VAT 13%.

Source: McKinsey Battery insights – Battery Cost model

Exhibit I

Substantial implicit carbon tax on automotive fossil fuels.

Fuel price breakdown (Delhi example), INR/lit



Fair taxation	Implicit carbon tax (INR/lit)	Implicit carbon tax (USD/tCO_2e)
At 5%[3] of product cost[4]	**33–41**	**190–240**
At 18% of product cost[4]	**25–34**	**140–200**

Assumptions
1. Includes excise duty and VAT; ignores OMC losses or absorbed costs.
2. Gross sale price at the pump without any fair taxation at Delhi is INR 96.72 in Aug 22, INR 95.41 in Jan 22.
3. Current average electricity tax rate.
4. Product costs are a summation of base price and logistics costs and dealer margins.
5. Per litre consumption of petrol produces 2.3 kg of CO_2; i.e., 435 litres of petrol produces 1-ton CO_2.

Source: Press, McKinsey analysis

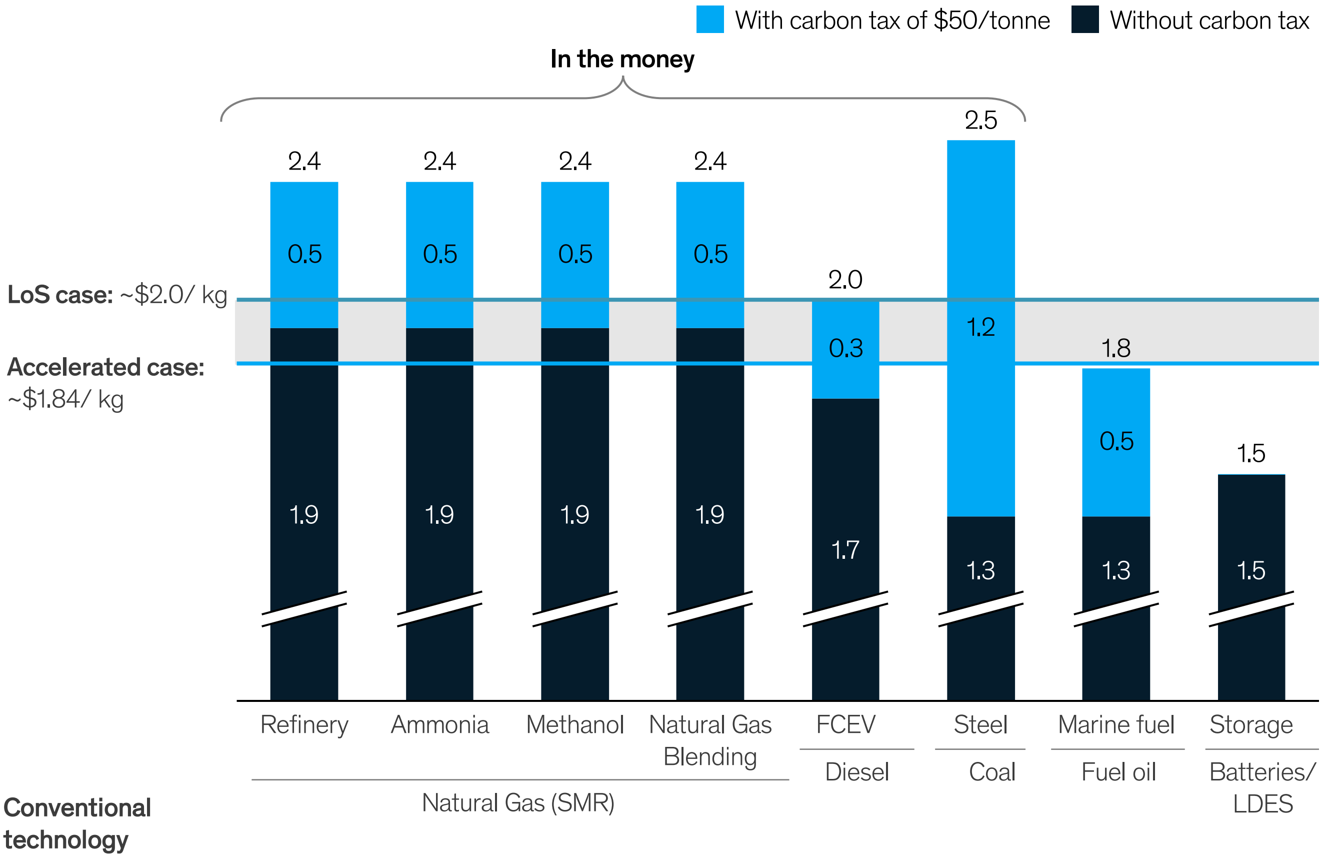
iii. **Ramp up green hydrogen as fuel or feedstock:** Hydrogen is a versatile energy source and chemical reductant. Adoption of green hydrogen could enable an annual abatement of 900 $MtCO_2e$ for India by 2050. This is subject to the evolution of the cost competitiveness of green hydrogen against alternative energy sources, which can be accelerated by faster R&D, adopting technology and ensuring early demand that drives down costs. Green hydrogen demand would first emerge as a replacement for grey hydrogen in use cases like refining, urea, methanol as it becomes more competitive versus grey hydrogen by 2030. In our LoS scenario, hard-to-abate sectors such as steel, automotive and power would drive demand only in the decade of the 2040s. These sectors have the potential to drive a disproportionate portion of the demand for green hydrogen in the decade of the 2030s and 2040s with blending mandates and a carbon price of $50 per tonne (Exhibits J, K).

Exhibit J

Green hydrogen could become competitive for a majority of the use-cases by 2030.

Required hydrogen production costs for breakeven against conventional technologies

$/ kg in 2030

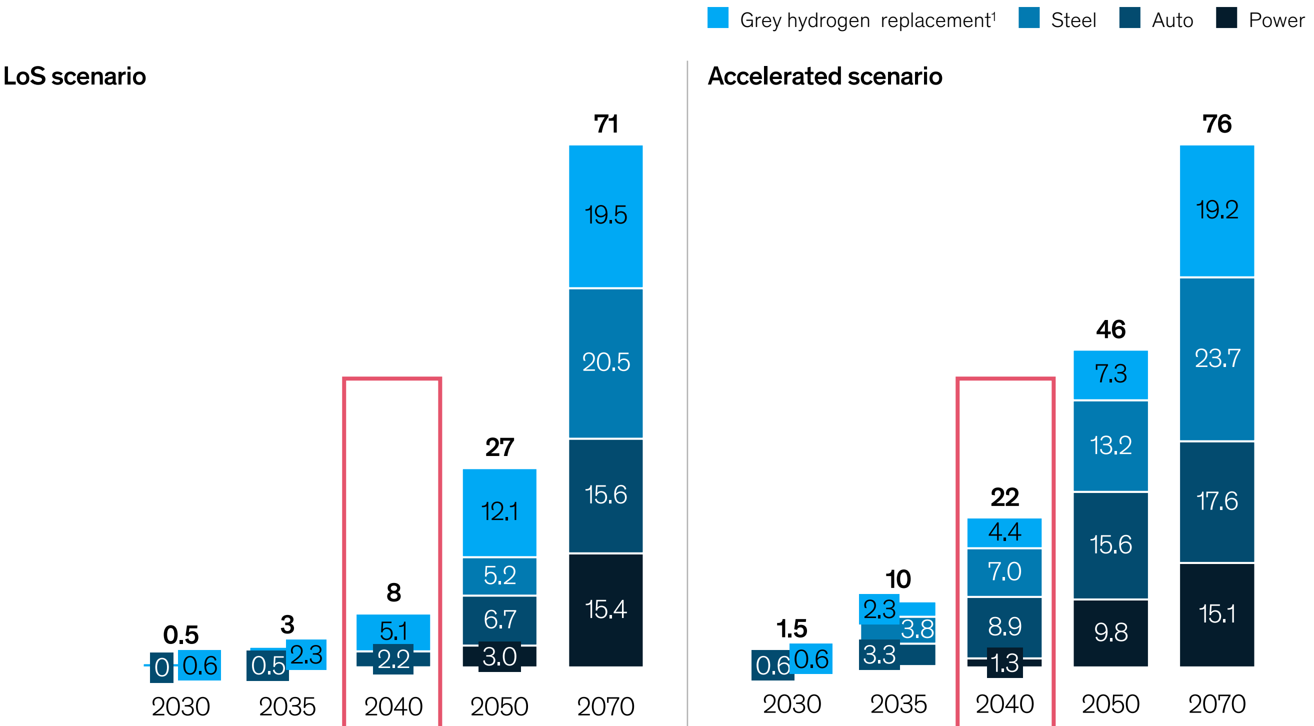


Source: McKinsey Hydrogen Insights: Breakeven Analysis

Exhibit K

Hard-to-abate sectors drive disproportionate demand for hydrogen in the Accelerated scenario.

Green H2 Demand, MMTPA bottom-up sector wise projections



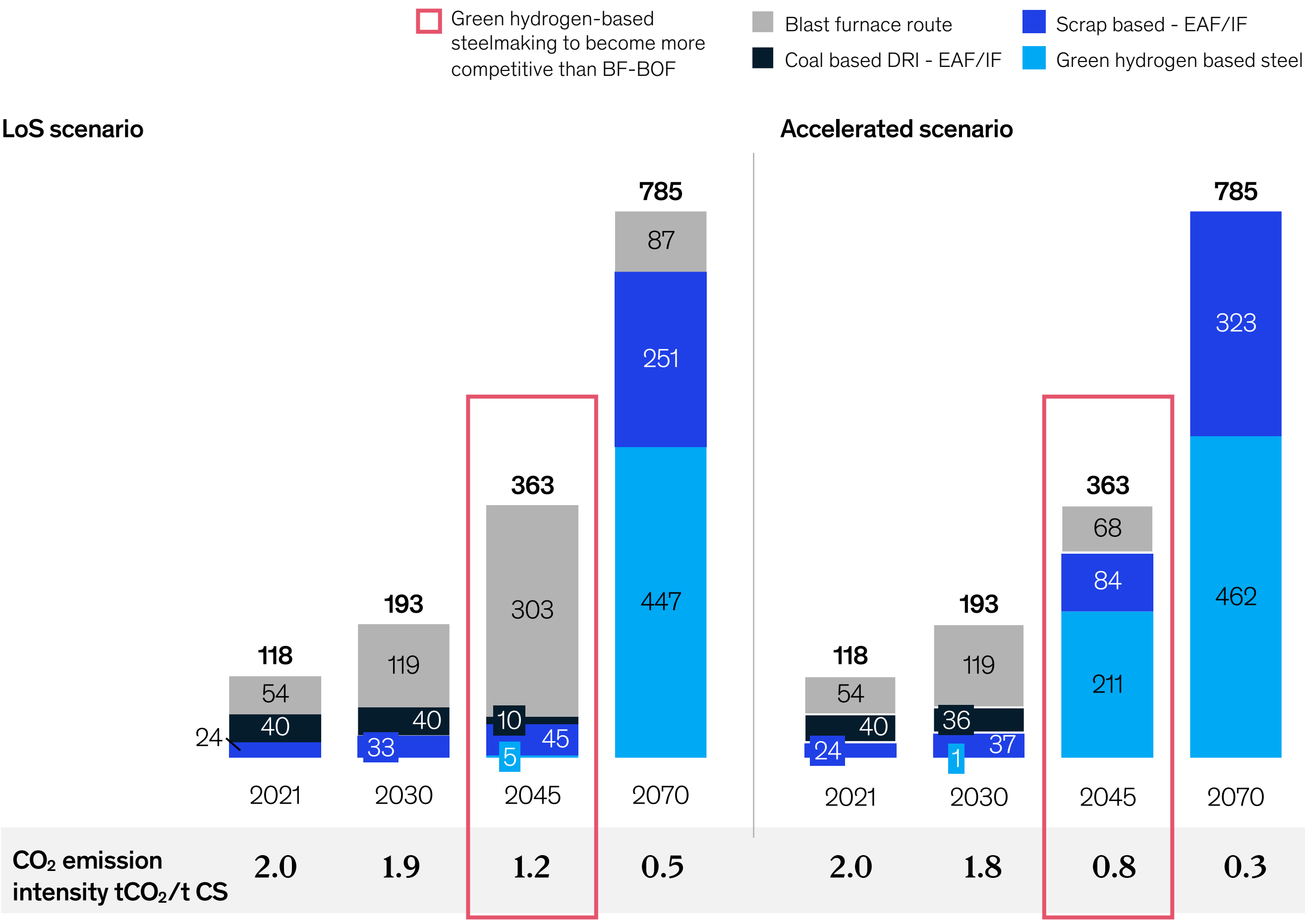
	LoS 2030	LoS 2035	LoS 2040	LoS 2050	LoS 2070	Accelerated 2030	Accelerated 2035	Accelerated 2040	Accelerated 2050	Accelerated 2070
CO_2 abated MMTPA	5	27	71	302	810	20	155	310	535	903
$ billion	1.2	4.8	10.6	33.0	64.1	3.1	16.2	31.5	56.0	68.3

1. Includes refineries, methanol production, fertiliser production and city gas blending.

Exhibit L

Crude steel production by route.

MMTPA



Note: Assumes scrap rate increasing from 10% currently to 20% in BF-BOF by 2040; scrap rate in green hydrogen-based EAF at 10%; DRI usage in EAF scrap at 10% of total metallic mix.

Source: McKinsey decarbonisation TCO model v14, Metal Bulletin

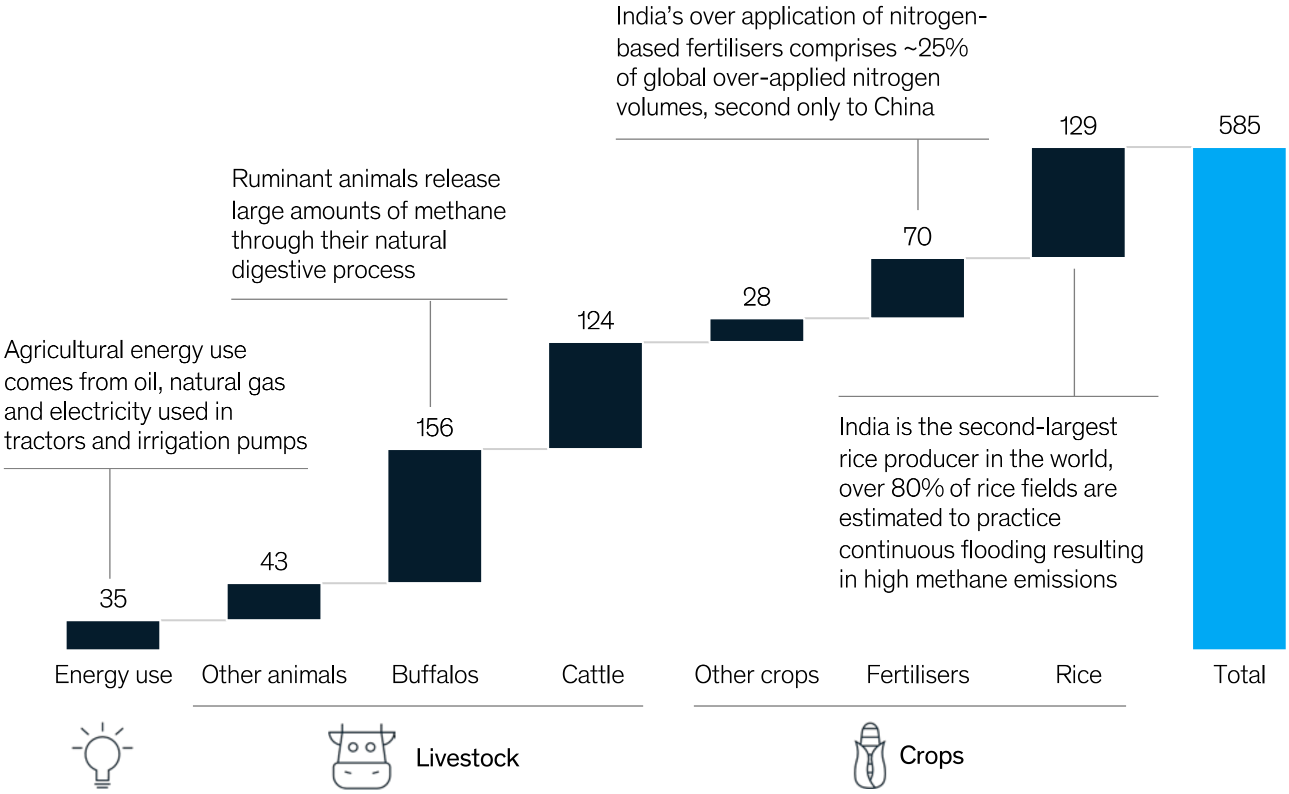
Accelerating hydrogen adoption in steel-making will help India build sustainable assets that could help India in its decarbonisation journey. The steel industry will likely make an investment of about $265 billion over the next 30 years in the new BF-BOF capacity installation, which could run the risk of getting stranded in case of climate shock or early closure, even with India's 2070 net-zero NDC. Indian steelmakers could avoid this risk by investing early in green hydrogen-based steelmaking instead of going down the conventional blast furnace route to the tune of 200 Mt starting from 2030 (Exhibit L). This would need to be enabled by the right policies including a carbon price of $50/t, plans for which would have to be in place within two or three years for steelmakers to plan their investments. This would create additional carbon space of 5.7 $GtCO_2e$, and result in cumulative Forex savings of $280 billion on coking coal imports by 2050. Early adoption of hydrogen also enables Forex savings of $420 billion on oil & gas imports.

iv. **Reform agriculture and dietary systems:** Decarbonisation in the agriculture sector can lead to annual carbon abatement of 292 $MtCO_2e$ by 2050, or nearly half of all expected annual emissions from agriculture. This would mainly be driven by cultivating rice sustainably (20 percent of abatement), reducing nitrate fertilisers (16 percent) and shifting towards sustainable consumer alternatives such as plant-based protein (15 percent) and millets (7 percent).

Exhibit M

Agriculture is one of the largest emitters of GHG in India.

GHG emissions from agriculture in 2019 by category
$MtCO_2e$



1. Includes goats, sheep and swine.

Source: Food and Agricultural Organisation; UNFCCC; McKinsey India Decarbonisation Model

Paddy farming and livestock account for 70 percent of agricultural emissions (Exhibit M).[20] Reducing paddy farming emissions by practicing rice-straw upcycling, dry seeding and rice intensification (SRI) over half of India's rice cultivated area and reducing livestock emissions by adopting efficient feeding and manure management practices for half the livestock population would be critical for decarbonising agriculture.

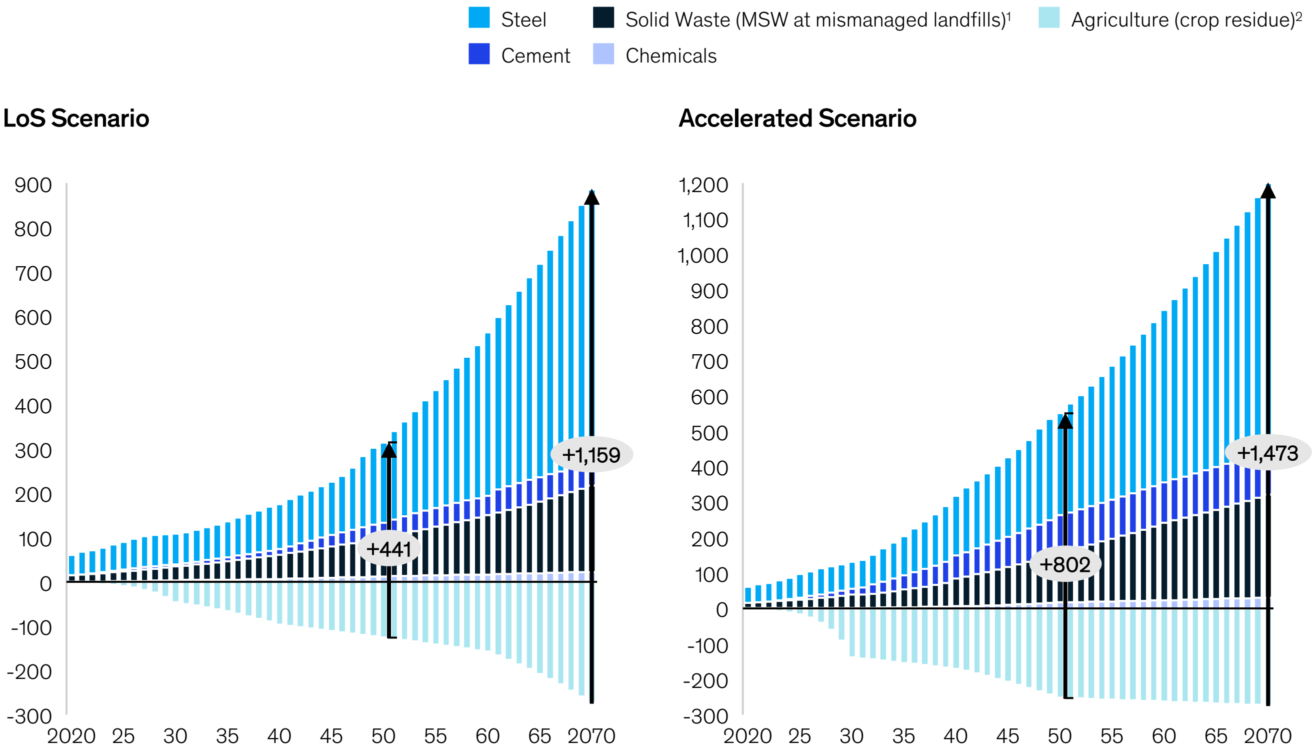
v. **Drive material circularity:** India currently generates 750–800 million tonnes of waste across waste streams with recycling rates of 13 percent for non-agricultural waste streams.[21] Improvement in recycling rates to 80 percent could provide significant recycled raw material and help abate up to 34 $GtCO_2e$ by 2070 in the Accelerated scenario (12 $GtCO_2e$ more than in the LoS scenario which assumes recycling rates increasing to 55 percent). Recycled raw materials help save 50–95 percent emissions in material production across steel (scrap-based electric arc furnace {EAF} steel production), cement (recycled concrete, biomass fuels), plastic (recycled feedstock, recycled plastics), aluminium and other materials.[22] While most technologies for recycling various waste streams already exist, driving material circularity would require investment in recycling infrastructure as well as enforcement of waste management and extended producer responsibility regulations. Demand signals would need to be created through recycled material use mandates.

[20] McKinsey analysis on data from FAOSTAT.
[21] World consumer research report; United Nations development programme (UNDP) plastic waste management programme; Central pollution control board (CPCB) solid waste management reports, Indian textile journal; Indian council for agricultural research; ministry of steel; Building material promotion council; FAO; Ministry of Steel – Steel Scrap recycling policy; National Policy on Crop Residue Management by Ministry of Agriculture.
[22] Material economics – the circular economy report.

Exhibit N

Emissions reduction by driving material circularity across sectors.

Annual emissions reduction, $MtCO_2e$



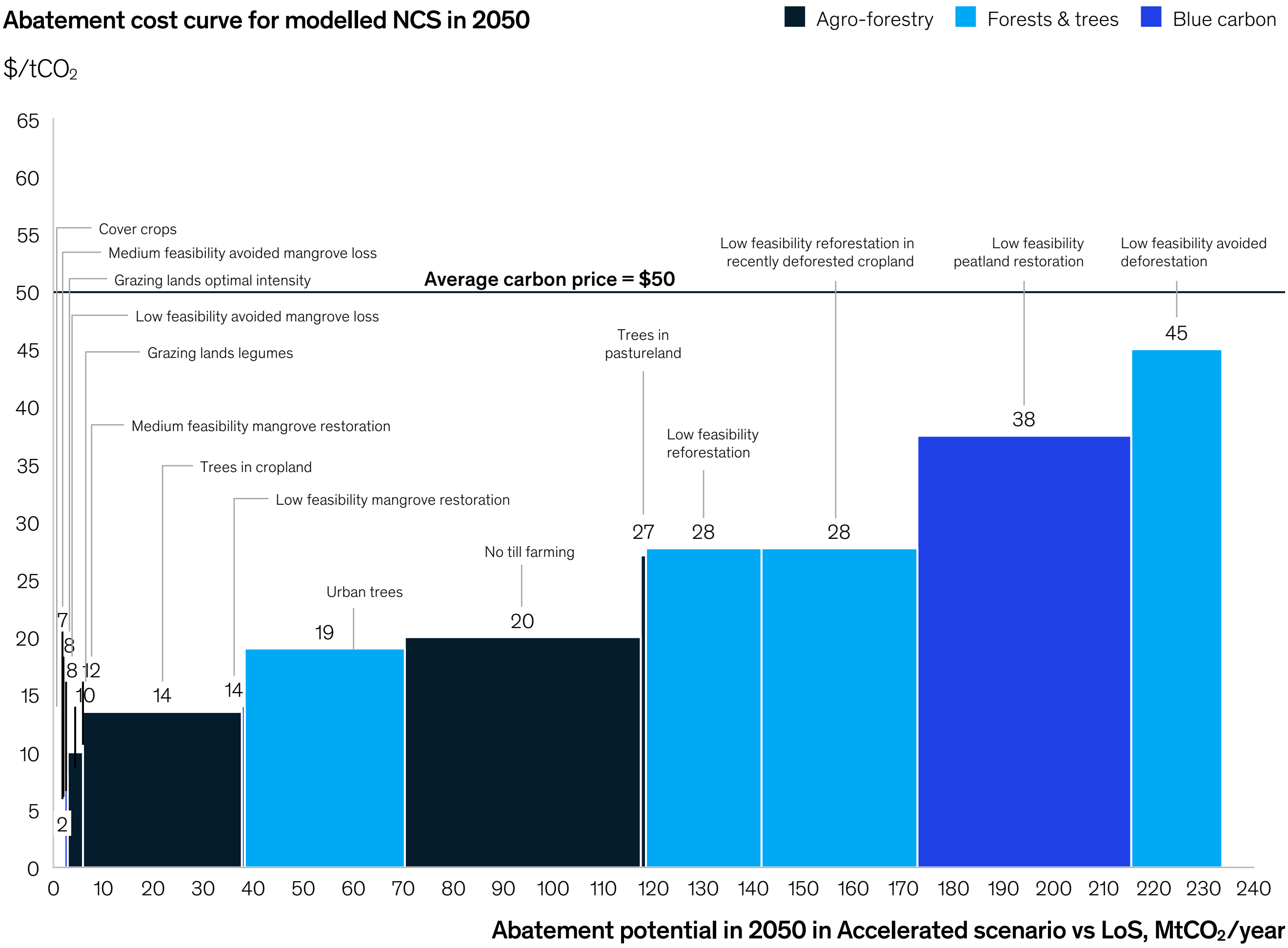
1. Emissions from mismanaged landfills from MSW (Municipal Solid Waste) containing organic and inorganic waste including paper, plastic, textiles among others
2. Sequestration through non-incineration-based uses of crop residue (e.g., paddy straw).

Source: World Consumer research report; UNDP Plastic Waste Management Program, CPCB Solid Waste Management Reports, Indian Textile Journal, Indian Council for Agricultural Research, Ministry of Steel, Building Material Promotion Council, FAO, Steel recycling, Ministry of Steel – Steel Scrap recycling policy, National Policy on Crop Residue Management by Ministry of Agriculture.

vi. **Sequester using natural climate solutions (NCS):** NCS can help remove or sequester emissions through the conservation and restoration of nature. In the Accelerated scenario, India's natural resources can sequester 640 $MtCO_2e$ annually by 2050, nearly 300 $MtCO_2e$ higher than the 2019 levels and 230 $MtCO_2e$ more than the LoS scenario. This translates to additional sequestration of 3 $GtCO_2e$ between 2020 and 2050, and 7 $GtCO_2e$ by 2070 compared to the LoS scenario. Nearly 85 percent of sequestration would come from forests (avoiding deforestation, reforestation), agroforestry (trees in cropland, regenerative agriculture) and urban tree plantation. This would involve restoring an additional eight million hectares of forest (over 10 percent of current forest cover) and practicing regenerative agriculture (such as low-till farming) in at least half of India's croplands, as opposed to 20–25 percent adoption in an LoS scenario. A \$50 per tCO_2e carbon price will enable this sequestration (Exhibit O).

Exhibit O

CO_2 abatement through NCS can be achieved below a carbon price of \$50/tCO_2e.



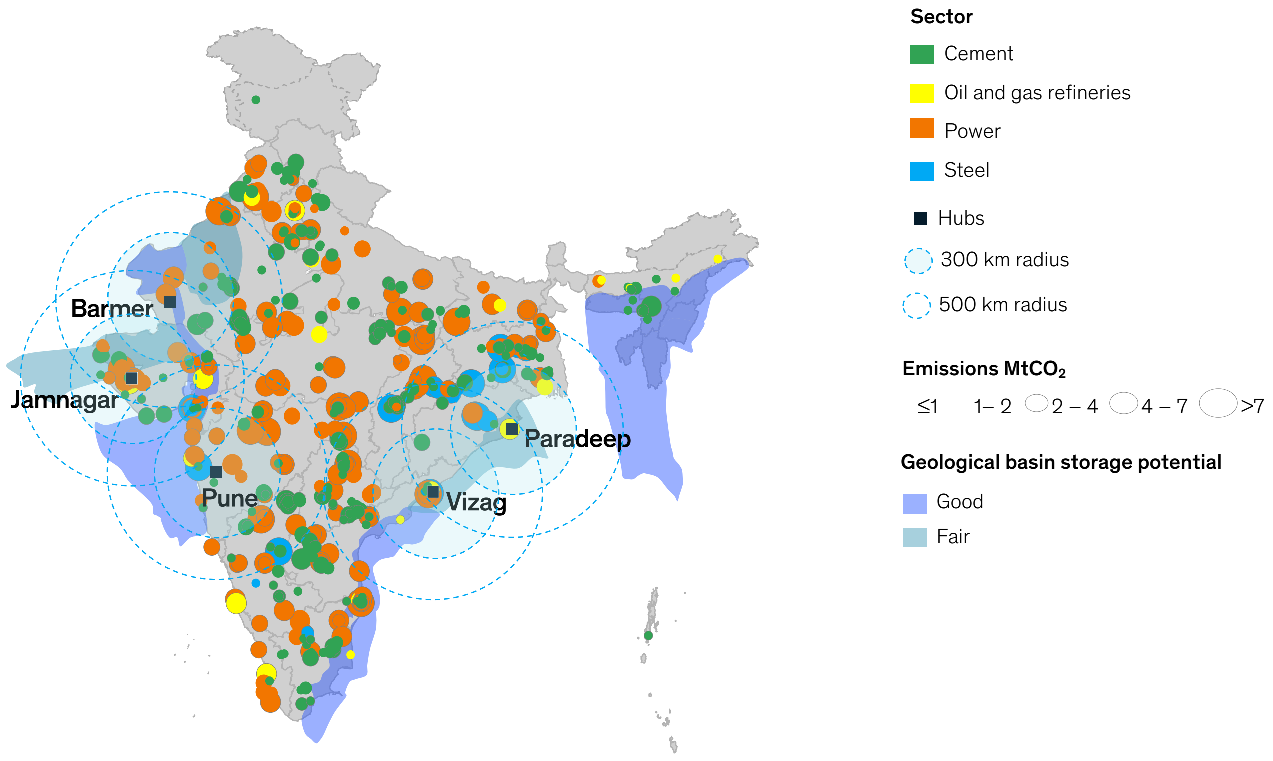
Source: McKinsey Nature Analytics

vii. Scale CCUS across industries: Adoption of new carbon-capture technologies could help reduce industrial emissions further, particularly for hard-to-abate sectors like cement, oil and gas and chemicals. CCUS could help capture 11.4 $GtCO_2e$ across these sectors cumulatively by 2070 for utilisation or storage. A hub model set-up for CCUS could be a cost-effective approach and five hubs in India located close to storage could address 70 percent of point source emissions with a transportation radius of up to 500 kilometres (Exhibit P). There could also be a potential for utilising the captured carbon in applications like chemicals production, artificial limestone and construction blocks. CCUS is expensive and would require significant investment and R&D to scale and become cost-effective, and is likely to be a small abatement lever.

Exhibit P

Around 25–30 percent of point source emissions could be captured within 300 km and 65–70 percent within 500 km of five hubs.

Possible CCUS hubs in India



Source: Global Greenhouse Gas Emissions, EDGAR; Joint Research Centre, European Commission; Netherlands Environmental Assessment Agency

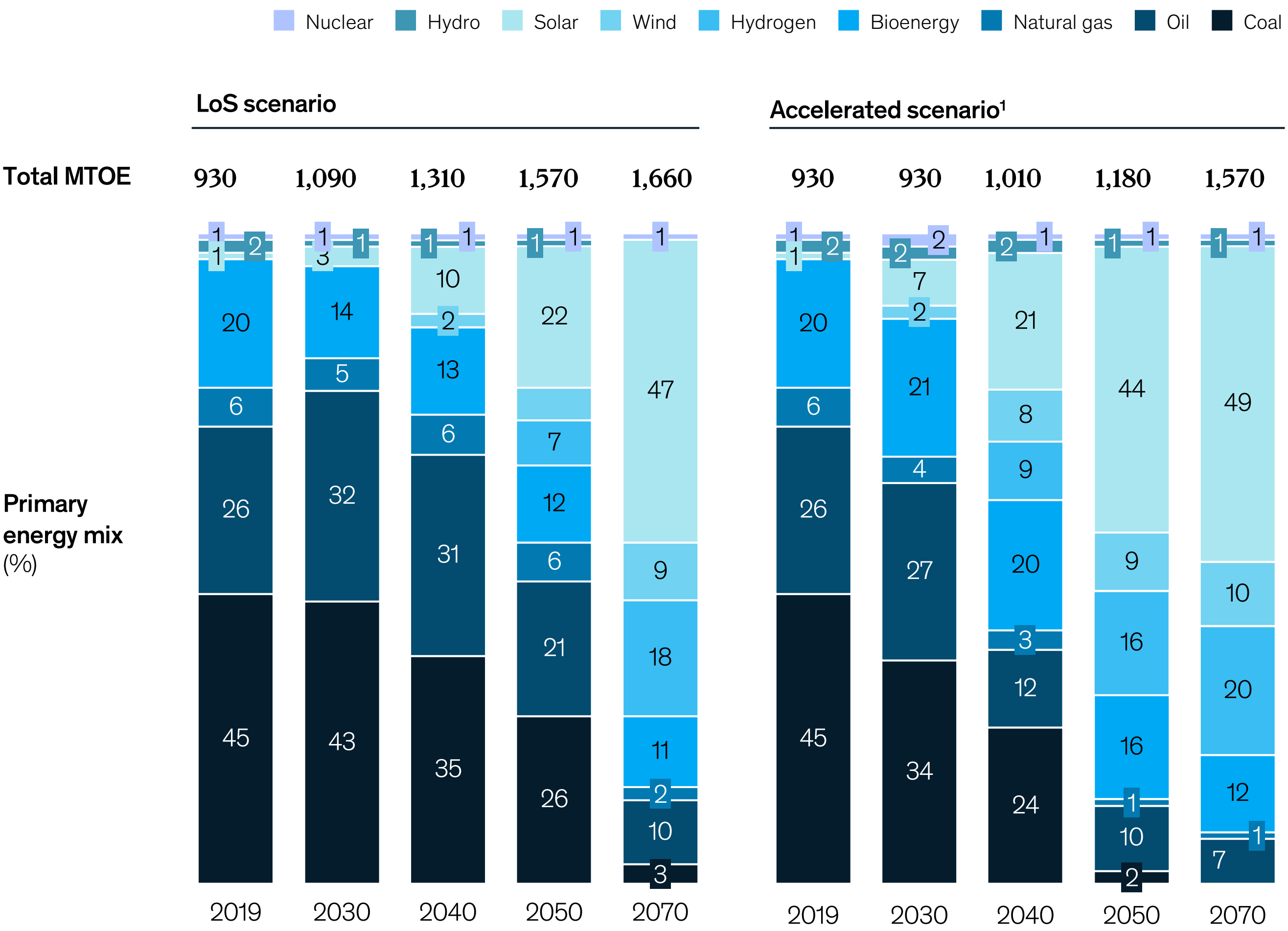
Implications for energy systems

India depends on fossil fuels to meet approximately 75 percent of its current energy demand.[23] This declines rapidly in both the scenarios (Exhibit Q). For example, decarbonisation in the transportation sector would require shifting from petroleum-fuel cars to EVs. The industry sector would shift from a reliance on fossil fuels to a mix of electricity, hydrogen and biomass for its manufacturing processes. In agriculture, farm equipment would become electric. And, as India moves away from coal-based power generation to renewables such as solar and wind, thermal coal demand would reduce drastically. Primary energy demand in the Accelerated scenario would be lower by 18 to 24 percent between 2030 and 2050 driven by higher energy efficiency, circularity and shifts in material use.

23 IEA world energy balances

Exhibit Q

The primary energy mix would likely shift to renewable sources of energy.



1. Total primary energy supply is lower in Accelerated scenario than in LoS scenario because of how renewables are accounted for

Implications for the Accelerated scenario:

- **Shrinkage in refining capacity**: The current refining capacity of 250 Mt per annum would increase to 298 Mt per annum by 2030 but then 182 Mt per annum of refining capacity would need to be repurposed or abandoned by 2040. Refiners can repurpose some of the existing refinery assets to produce petrochemicals, green hydrogen, ammonia, synthetic fuels, etc.
- **Reduction in tax revenues:** The total contribution of the petroleum sector to the exchequer is $103 billion, of which $85 billion is tax collection. In the Accelerated scenario, the tax collection may drop to $35 billion by 2050.[24]
- **Reduction in coal mining and closure of coal-based power plants:** By 2050, coal consumption for power would be reduced to a tenth of current consumption and all current coal-based power capacity (211 GW) would need to be decommissioned. Most of this decline would be driven by the power sector's shift to renewable energy sources. The remaining coal used to make steel and generate heat in cement production would also be phased out over time, as the consumption of green fuels such as electricity, hydrogen and bioenergy increased.
- **Corrected use of biomass and agri-based fuels.** Today, the bulk of bioenergy demand is in the form of biomass usage in residential buildings for cooking purposes. The remaining demand, which amounts to less than a quarter of total demand, comes from the power sector. Going forward, scarce feedstock would need to be directed to be used correctly. For example, the biomass currently being used for the power sector and agri-based fuels for the transport sector will need to get directed to the hard-to-abate sectors like cement and aviation, respectively. The bio-fuels usage envisaged for the future could fundamentally transform how agriculture residue will be used in the future versus how it is directly burnt today.

[24] IEA data for fossil based energy; tax value as per PPAC using INR 75/USD as conversion rate

Implications for land use

India has a total land area of 329 million hectare, out of which 21 million ha consists of inland waters, leaving a total of 308 million ha of available land. Today, 23 percent of this available land is forest area, 59 percent is agricultural land and the remaining 18 percent is used for non-agricultural purposes, grazing pastures and barren land.[25] As India grows in a sustainable fashion in the Accelerated scenario, it will need land not only for urbanisation, industrial capacity and increasing agricultural output but also for renewable power, carbon sinks and biomass feedstock for decarbonisation.

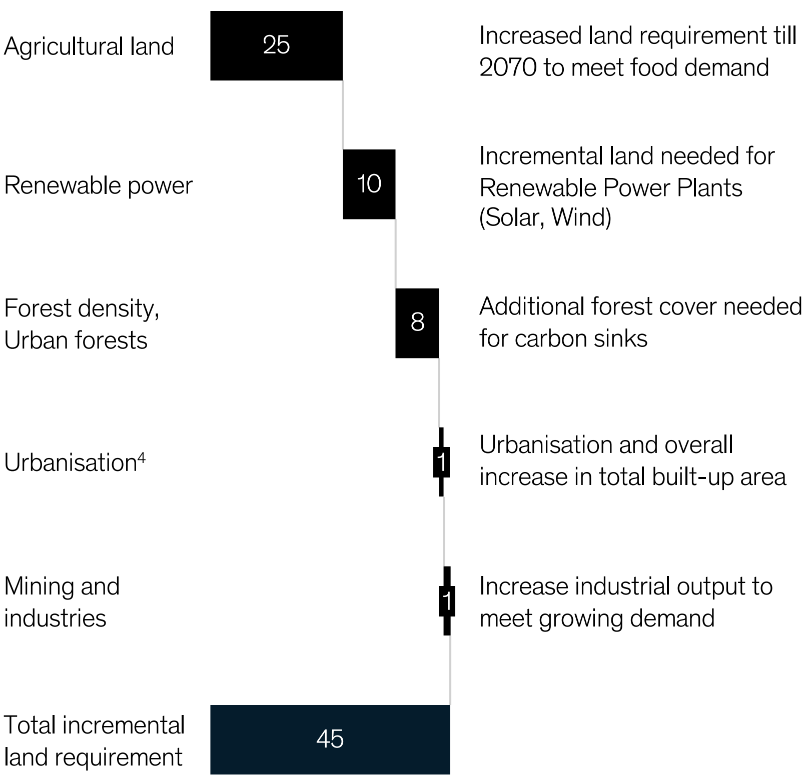
Based on current land usage practices, we estimate that the total increased land area requirement would be 45 million ha in 2050 versus today (Exhibit R). However, this land is not readily available, and India will have to implement efficient land use practices to ensure that necessary land can be made available. These measures would need to be innovative and could include increasing agricultural productivity by adopting sustainable and higher-yield farming practices, using barren land for installing solar and wind power plants, increasing the density of forests to meet carbon sink goals and using vertical urbanisation to create higher population densities in towns and cities, instead of increasing the overall built-up area. However, these measures will likely free up only 34 million ha, leaving a further 11 million ha unsolved for.

25 Land use statistics at a glance, Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture & Farmers Welfare, Directorate of Economics & Statistics, November 2021

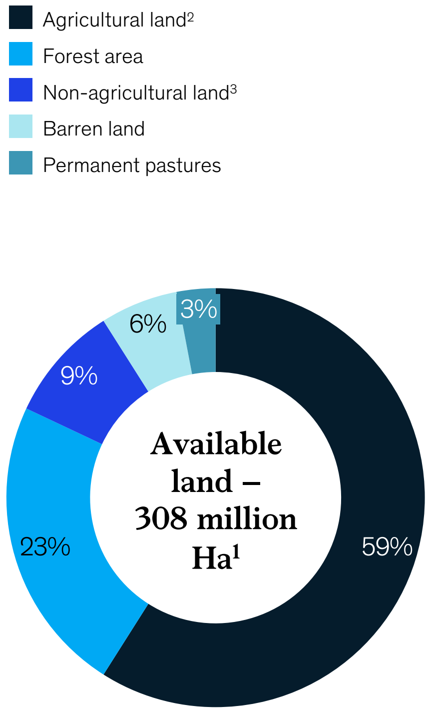
Exhibit R

45 million ha incremental land would likely be required in the Accelerated scenario by 2070.

Incremental land requirement in 2070 versus today
Mn Hectares



India's current land use, Percentage of available land



1. Total land 329 mn ha less Inland waters of 21 mn ha.
2. Agricultural land includes croplands, culturable wastelands, land under miscellaneous tree crops and fallow lands.
3. Non-agricultural land includes built up urban and rural areas, mining land and land used for other industrial purposes like railways, irrigation, etc.
4. Urbanisation requirement includes a need to increase built up urban area by 3.7 mn ha, which is offset by a decrease in rural built-up area by 2.8 mn ha.

Impact on people – spending and jobs

A critical consideration for accelerated decarbonisation is the impact it will have on the average Indian household's spending. Our estimate suggests that there will be minimal inflationary impact on households below the Empowerment Line[26] by 2040 (Exhibit S). Food spending sees no major impact (expenditure in agriculture may be offset by cost savings from sustainable practices and improved productivity), whereas energy and transport spending are reduced due to lower power generation costs with renewables and operational savings due to the shift from ICE vehicles to EVs. Housing could become somewhat more expensive due to the increase in steel and cement prices. This is a preliminary viewing that could bear more precise analysis. Also, this assumes that higher upfront costs of EVs would be addressed by financing, paid for by operating cost savings. If the financing does not come, this would impact affordability and demand.

26 https://www.mckinsey.com/featured-insights/asia-pacific/indias-path-from-poverty-to-empowerment

Exhibit S

Decarbonisation-driven household spending impact for households on the Empowerment Line[1] (in year 2040).

⇔ No major impact ↓ Decrease in spending ↑ Increase in spending

	Normative spend for household FY20 (INR/month)	**Impact in Accelerated scenario in 2040**	**Factors not considered**
Food	3,840	⇔ Incremental agri capex offset by savings from sustainable practices, improved productivity, and income from crop residue and agroforestry (carbon credits)	Climate impact on agriculture yields and hence food prices
Housing	543	↑ Increase in cost of cement (impact of 1-1.5%) and steel (impact of 0.5–1%) increases housing costs	Land price increases caused by land demand for decarbonisation
Energy	847	⇔ Decrease in average supply cost from 6.15 kWh to 5.4 kWh. Increase in T&D costs offset by decrease in generation costs due to shift to RE and reduction in AT&C losses	Land driven increases, increase in raw material prices
Transport and others[2]	1,463	↓ ICE to EV shift leads to reduced costs	Financing assumed to be available for higher upfront cost of EVs; fuel related tax losses not compensated for through auto and power taxes
Health and social security[3]	1,450	⇔ Increased cost of building infrastructure, lower spends on transportation and power costs, not impacting the overall spend	Adaptation costs
Education[4]	702	⇔ No major impact	
Total	**8,845**	⇔	

1. MGI 2014 Report: From poverty to empowerment. Data adjusted for inflation and household of four people assumed.
2. Includes clothing, footwear, entertainment, communication and domestic appliances.
3. Adjustment for value of subsidies in sanitation and drinking water is included under health.
4. Includes elementary and secondary education.

Source: McKinsey Global Institute analysis

The accelerated decarbonisation is expected to impact jobs and skills requirements across sectors as they decarbonise. India's coal mines are estimated to employ around 0.35 million workers currently. Additionally, more than 1.7 million people are indirectly dependent on the coal sector.[27] The phasing out of coal as India decarbonises would need to be supported by new businesses that support the transition for this workforce. Similarly, as two-thirds of the 2030 refining capacity could be closed by 2050 in the Accelerated scenario, the workforce in this sector would also be impacted. However, the power sector would likely see an uptick in employment with jobs moving from non-renewable energy plants to jobs in solar and wind projects. The automobile industry would see a restructuring from ICE manufacturing to EV manufacturing roles. The steel and cement sectors would also see restructuring from BF-BOF to hydrogen-based green steel and adoption of new raw materials for clinker development, respectively.

Overall, the Accelerated decarbonisation of India could transform more than 30 million jobs (24 million new jobs could be created while six million existing jobs could be lost) by 2050.[28] While important, the scale of workforce reallocation may be smaller than that from other macro trends (e.g., 60 million new workers entering the workforce by 2030). Displaced workers will nonetheless need support, training and reskilling through the transition.[29]

Reduced energy import dependence and opportunity to build export competitive new industries

While the primary benefit of decarbonisation would be the ability to arrest climate change, this transition offers other benefits, too. It would result in localising India's energy requirement with the shift from coking coal, oil and gas to renewable energy, green hydrogen and biomass strengthening energy security. This could result in Forex savings of $2.4–3.0 trillion by 2070. Further, India could also aspire to becoming a global manufacturing hub for green hydrogen, solar panels electrolysers and batteries.

27 TERI.
28 McKinsey Global Institute: The net-zero transition - what it would cost, what it would bring.
29 McKinsey Global Institute – India's turning point.

Accelerating decarbonisation would require investments to be scaled up

Our bottom-up models estimate that financing this decarbonisation would need an estimated $7.2 trillion in green investments until 2050 to decarbonise in the LoS scenario and an additional $4.9 trillion (Exhibit T) for the Accelerated scenario (about 3.5 percent and an additional 2.4 percent of India's GDP through this period, respectively). This would translate to an average annual investment of $240 billion in LoS, with an additional $160 billion in the Accelerated scenario.

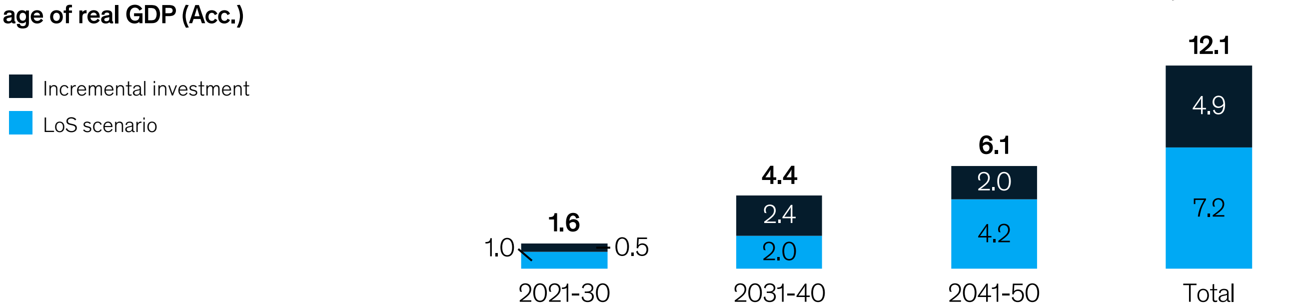
About 70 percent of the funding would be needed for Capex investment in the power and automotive sectors in both the scenarios, primarily driving an expansion of RE capacity and electrification of the automotive sector (Exhibit U).

Exhibit T

Investment is required for India's decarbonisation in the LoS scenario; and to accelerate the transition.

Decade-wise investment[2]
($ trillion)

	2021-30	2031-40	2041-50	Cumulative
Total investments as % age of real GDP (LoS)	2.6%	3.1%	4.1%	3.5%
Total investments as % age of real GDP (Acc.)	4.1%	6.8%	6.0%	5.9%

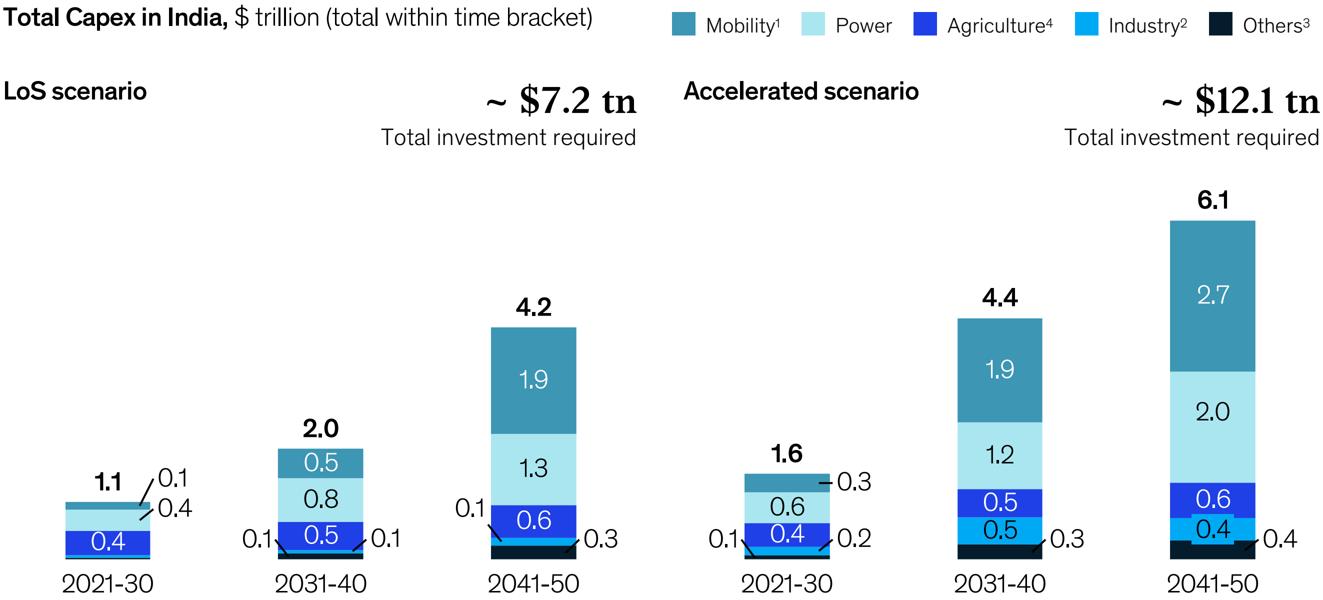


Average annual investment		2021-30	2031-40	2041-50
	LoS, $ trillion	0.10	0.20	0.42
	Accelerated, $ trillion	0.16	0.44	0.61

1. EUI data used for GDP forecast.
2. The investment numbers are based on bottom-up investment analysis for abatement and supporting infrastructure, built granular, sector by sector. High-emission ongoing capex has not been considered; Capex calculations derived from bottom-up models for power, steel, cement, other industries, transport, agriculture, NBS, CCUS, hydrogen and material circularity.
3. Estimated cumulative GDP: 2021–30: $38.7 tn; 2031–40: $64.6 tn; 2041–50: $101.6 tn.

Exhibit U

70% of total investment would likely be required to decarbonise the power and mobility sectors.



1. Automotive and aviation sectors combined under mobility header.
2. Industry includes steel ($113 bn), cement ($81 bn), aluminium, ammonia and waste management in LoS, includes CCUS in Accelerated scenario ($325 bn).
3. Others includes cross-cutting themes, i.e., hydrogen ($189 bn) and circular economy ($185 bn) in LoS.
4. Total production capex involved in agriculture, including factor costs and green levers.

Source: Bottom-up models for sectors

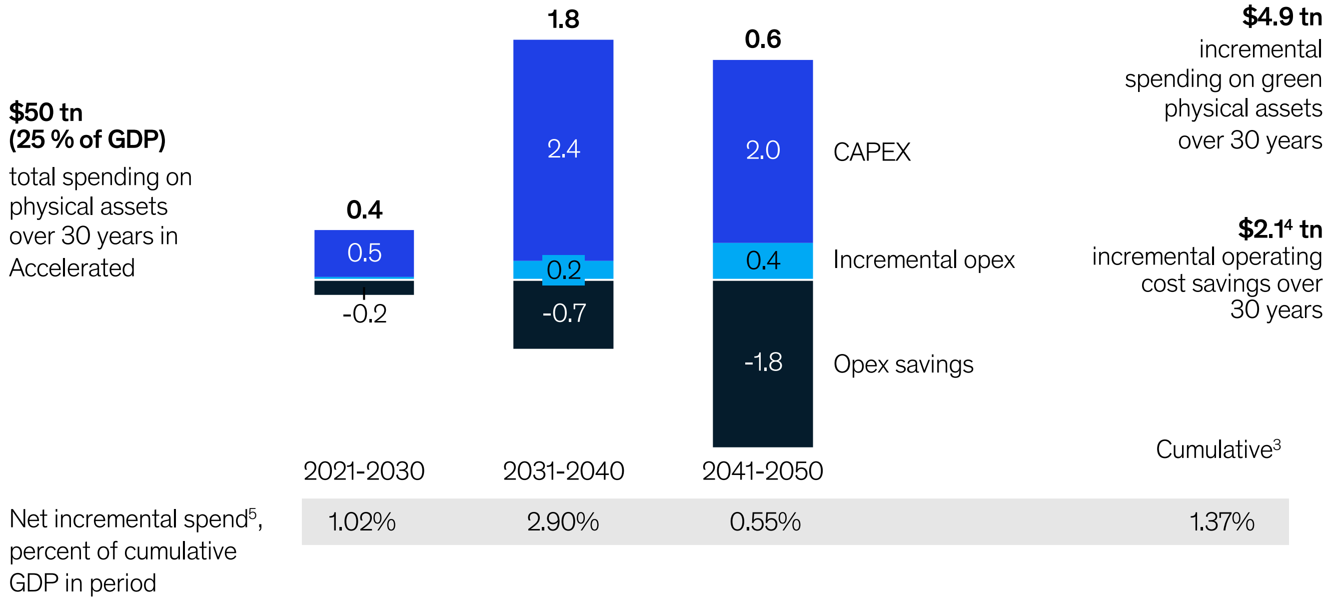
Accelerated decarbonisation will likely create operational cost savings, such as lowering the cost of power generation due to the increased penetration of renewables. As a result, some portion of the additional investment could be recuperated through operating cost savings. The investments required are front-loaded; India would have a runway till 2040 to orchestrate half of the total $12.1 trillion requirement. The balance half of investments would be required from 2040–2050. From now until 2050, operating costs would lead to overall savings of $2.1 trillion, offsetting about 45 percent of the capital investment required over the same period (Exhibit V).

However, the cost savings are not balanced across sectors. The domestic transportation, power and agriculture sectors would derive most of the operating cost savings, while sectors like steel and cement would see an increase in operating costs, in addition to the capital investments.

Exhibit V

In the Accelerated scenario, decarbonisation could offset 45% of incremental capital investments.

Incremental[1] decade wise spend[2] for accelerating Decarbonisation, $ trillion



1. Spending on physical assets in accelerated scenario, minus those in LoS scenario for capex and vice versa for opex; excluding opex reduction in refining sector (which is mainly due to reduction of the refining activity).
2. Estimation of capex includes spending on physical assets in power, mobility, steel, cement, agriculture, CCUS, hydrogen, circular economy and other industries. Estimation of opex includes spend for physical assets across various forms of energy supply (e.g., power systems, hydrogen, and fuel supply), energy demand (e.g., for vehicles, alternate methods of steel and cement production), and various forms of land use (e.g., GHG-efficient farming practices).
3. Calculated as spending on physical assets net of operating costs in that period, divided by GDP in the period. GDP is for the cumulative GDP from 2021–2050 is taken directly from IHS-Markit.
4. Savings from one sector may not directly compensate for capex requirement of other sectors and numbers shown present a macro-economic view for the nation.
5. Potential revenue from levers has not been captured.

Current annual investments toward decarbonisation and other green projects are about $44 billion (heavily skewed toward the power sector), accounting for 10–12 percent of the future investment required.[30] The Accelerated scenario optimises net system-level costs at country level. However, most businesses and consumers are unlikely to take decisions based on total cost of ownership. Without intervention, these stakeholders may well make decisions different from those laid out here, basing their spending decisions on factors like upfront capital costs. Thus, financing the transition will require targeted demand- and supply-side interventions.

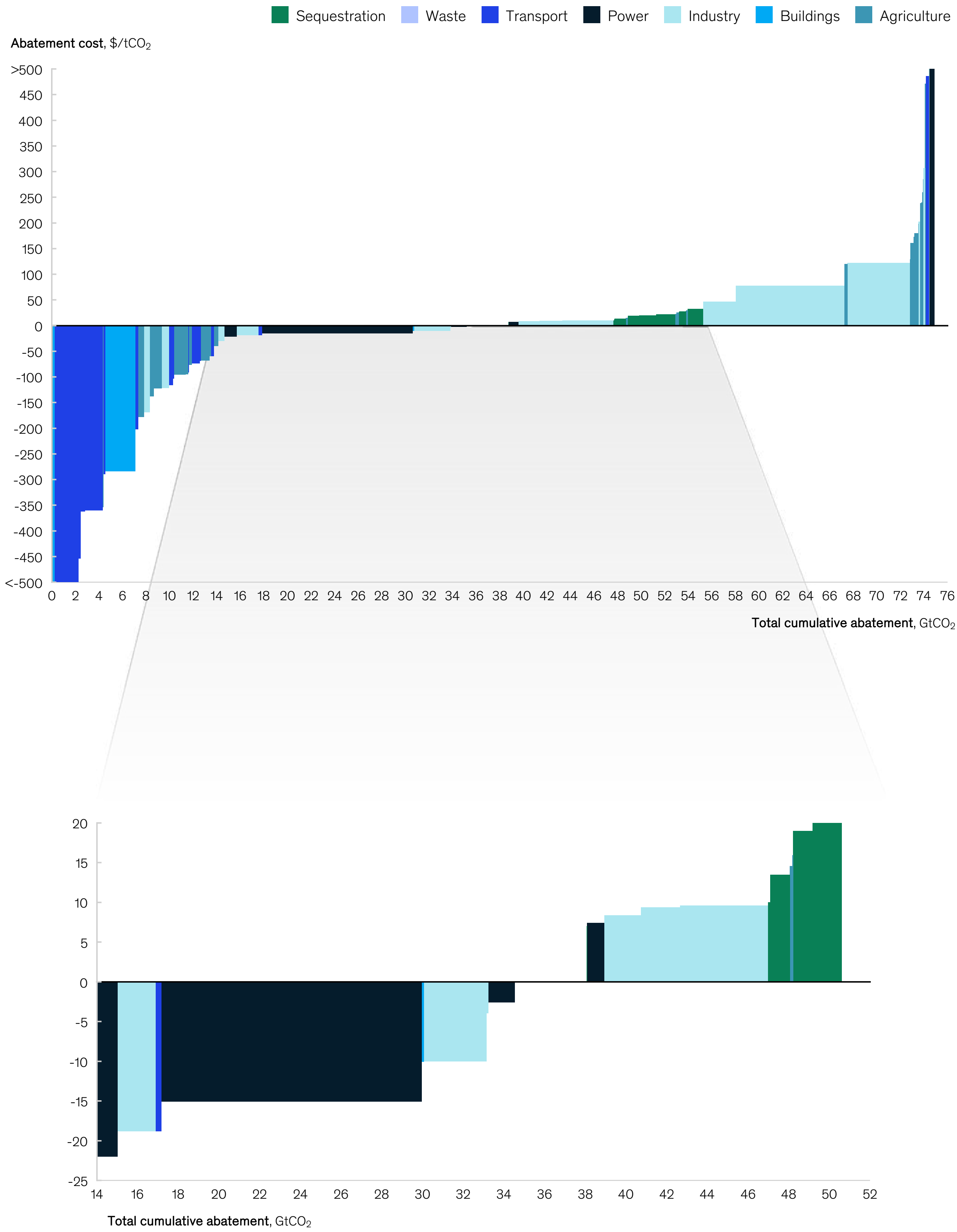
The cost of decarbonisation is expected to decline as technologies mature – even in a high growth economy, as innovation and economies of scale lower technology costs over time. As a result, between the Accelerated and LoS scenarios, two-thirds of the emissions could be abated at negative or low cost (<$10/t$CO_2$e) and 50 percent of the emissions could be abated through in-the-money levers (Exhibit W). Solar energy, wind power and EVs, comprising the first quintile of the abatement potential, present a positive investment case. The levers in the last quintile are the high-cost ones, comprising some advanced agriculture practices, offshore wind, CCUS, etc. which would cost more than $60/t$CO_2$e. Hydrogen-based steel would cost $47/t$CO_2$e till 2040. From 2040–2070, it would cost $9.6/t$CO_2$e. An estimated carbon price of $40–50 /t$CO_2$e could potentially drive domestic carbon credits generation by making all sequestration levers cost competitive.

[30] Landscape of green finance in India, Climate Policy initiative

Exhibit W

Two-thirds of the emissions can be abated at a low or negative cost (<10 $/t$CO_2$).

Cost curve displays the cumulative abated emissions wrt LoS scenario



Ten urgent actions could accelerate India's decarbonisation and ensure it is orderly

From our analysis, it appears that benefits to India could outweigh the downsides of a well-planned, orderly, accelerated transition given its growth outlook. But it requires that India take action within this decade to set things up. If it does so, India can use its growth momentum to build itself right in the decades thereafter.

It is vital for all stakeholders — government, corporates, consumers, civil society — to come together and act now and in concert to accelerate India's decarbonisation and ensure it is orderly. The government can provide policy and regulatory support to make projects across sectors economically viable. These could include but are not limited to incentivising the usage of EVs and fuel cell electric vehicles (FCEVs) by balancing taxation schemes, simplifying regulations for authorising and installing new power and grid installations, creating demand signals for higher-cost green materials like steel and generating support for localising electrolyser manufacturing. Support would also be required to ensure a just transition that minimises impact on low-income households. These actions would need to work together and happen in the right sequence otherwise they would result in shortages, price rise and will be at risk of disorderliness.

Achieving the necessary technological breakthroughs to reduce emissions in hard-to-abate sectors, and accelerating their progress to market, would require consistent public and private investment. It would also require greater willingness among business leaders and policy makers to adopt new technologies. These would include longer duration storage technologies to capture the seasonality of renewable sources, advancement in fuel cell technology, improvements in recycling technologies.

This report proposes ten actions needed today within the context highlighted to accelerate India's decarbonisation:

1. **Lay out a detailed, medium-term (5 - 15 - 25-year) decarbonisation plan** with sector-specific priorities and policy frameworks that provides demand signals and guides corporates to invest. The plan will need to be implemented through an accountable nodal agency so as to ensure coordination across ministries and external stakeholders in delivering net-zero. The governance mechanism employed must include compensating mechanisms to address socioeconomic impact. Delays in doing this or quality gaps (e.g., inconsistent policies across sectors, too many changes) would lead to the wrong investment decisions worth several hundreds of billions of dollars, or reduced investment, thus leading to a less than ideal transition.

2. **Accelerate implementation of a compliance carbon market (within three years)**. This would also require the creation of demand signals to accelerate decarbonisation, especially in the hard-to-abate sectors, and incentivise investments in the newer technologies like CCUS. Policy makers could take a strategic (as opposed to a compliance-oriented) view of this and work across ministries. Getting this right, fast, can enable both domestic and foreign investment.

3. **Enabling banks to support the transition, catalysed by a green transition bank.** Banks could be asked to come up with their investment glide paths within a year or two and build the necessary capability for assessing risks in these new spaces. The regulator could assist with the necessary taxonomy, disclosure guidelines, actions to reduce risks. A green transition bank with a clearly defined set of green financing norms can act as the catalyst for change.

4. **Accelerate renewable adoption in the power sector** to scale up capacity addition 4X, and to deepen market reforms with a 30-year outlook in a manner that ensures a stable grid fed predominantly by infirm power. These market reforms can reduce the investment requirements by $150–200 billion by 2050.

5. **Empower a nodal authority to define a national land use plan,** lay clear land-use guidelines and mandates for optimised use across urbanisation, industrial needs, carbon sinks, agriculture and renewables.

6. **Create a resilient indigenous manufacturing capability and increase investment in cleantech R&D.** Efforts would be needed to develop local raw material resources (e.g., rare earths), secure materials from elsewhere in the world and produce equipment locally through mechanisms like the PLI. This would need to be supported by a green innovation mission which increases the investments in R&D across a number of the technologies that will drive decarbonisation.
7. **Evaluate five CCS hubs** in Gujarat (Jamnagar), Odisha (Paradeep), Rajasthan (Barmer), Maharashtra (Pune) and Andhra Pradesh (Vizag) potentially in public-private partnership for utilisation and storage of captured carbon.
8. **Create a national circularity mission** with recycling hubs in the top 20 Indian cities (contributing 35 percent of municipal solid waste), mandated targets on recycling rates, recycled raw material use (e.g., blending norms) and landfill levies.
9. **Enhance the National Hydrogen Mission,** where government could play a key role in accelerating demand through blending mandates, boosting cost competitiveness via capital subsidies and R&D investments and enabling export opportunities via international trade agreements.
10. **Companies can aim to play on the front foot,** evaluating investment opportunities that this green trend would unlock, aligned with India's national plans or opportunities opened up by decarbonisation of other countries (e.g., green hydrogen derivative exports). Heavy emitters could immediately set five- to-ten-year decarbonisation targets, and use these to mobilise their organisations, looking for the value-creating opportunities, in addition to investing right for the future.

These actions would need to be supported wholeheartedly by consumers such that we see a behavioural shift in their approach. The government has announced the Accelerate Lifestyle for Environment (LiFE) mission at CoP26. This would be a crucial component for India's transition.

In closing, India needs thoughtful action now for setting itself up for an accelerated and orderly transition. Looking beyond the short term and laying the foundation for this transformation within this next decade is absolutely imperative.

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This report has been updated to provide additional context and new data (March 2023)

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