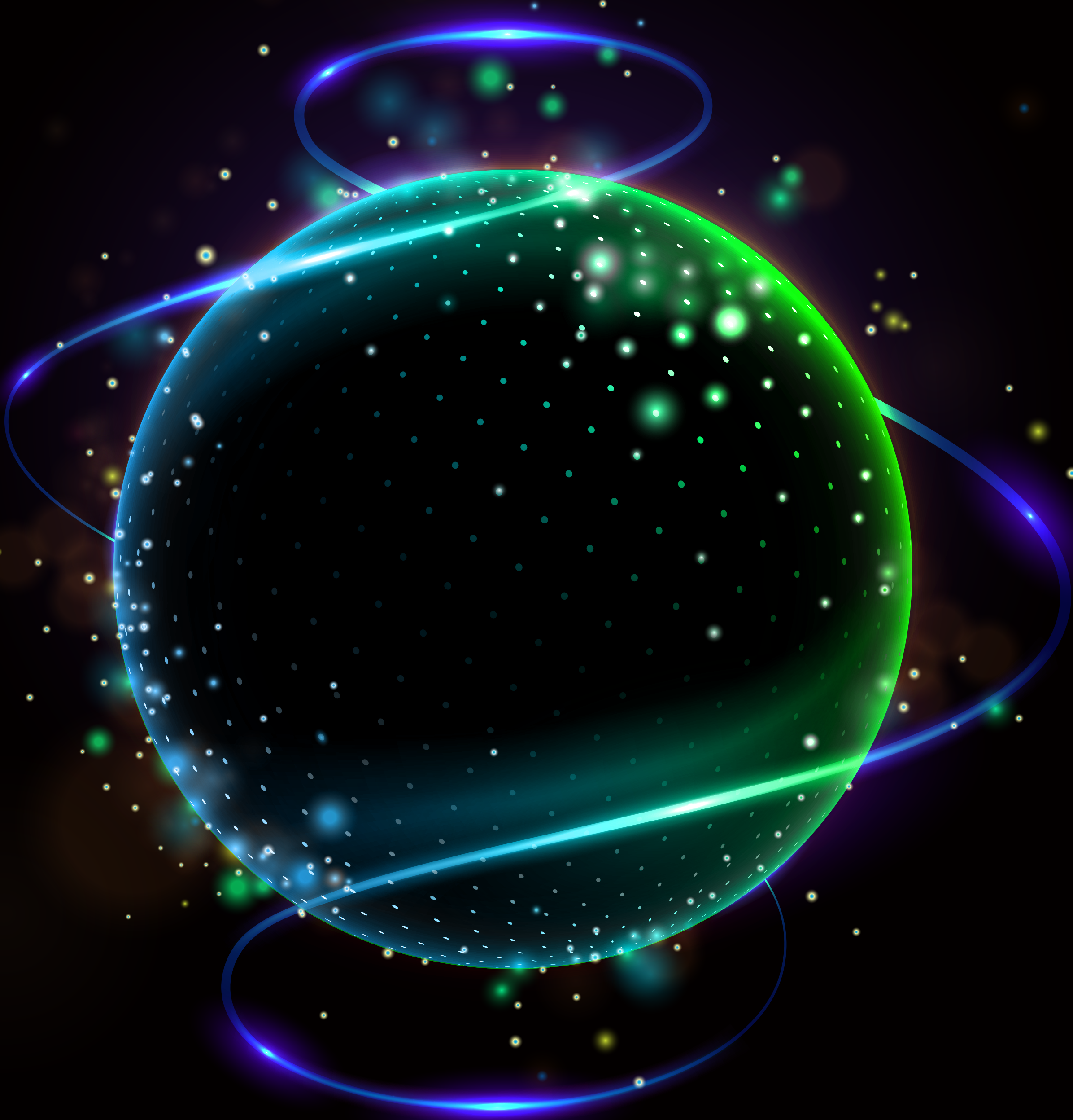
Deloitte.

FICCI



India's energy-transition pathways

A net-zero perspective

September 2023

Table of contents

Foreword by FICCI

S.K. Pathak
Secretary General
FICCI

FICCI, in collaboration with Deloitte, is happy to present this knowledge paper – "India's Energy Transition Pathways: A Net-Zero Perspective".

A good action plan on energy transition was the Prime Minister's 'Panchamrit Statement,' unveiled at the CoP26 Summit in 2021. This five-point action plan articulated the nation's climate objectives and has been the cornerstone of our commitment to sustainability.

This knowledge paper provides the steps needed to create a robust ecosystem for energy transition focusing on clean energy opportunities, signifying their impact on economic development, job creation, and environment sustainability. It provides recommendations for stimulating actions required to overcome impediments to clean energy growth in India.

With conducive policy support, steady inflow of investments and technological developments, India has seen an exponential growth in its Renewable Energy (RE) sector and especially solar power generation in the past few years. These are important for India's commitment to achieving net-zero emissions by 2070.

Each industry sector will require tailored decarbonisation strategies, based on technical feasibility, economics, and scalability. Domestic RE manufacturing capacity must be expanded significantly in critical areas, such as solar photovoltaic, battery storage, electrolysers, and green hydrogen.

I thank FICCI members, experts, and stakeholders from the industry and the government for their valuable insights incorporated in this knowledge paper.

India's energy-transition pathways

Foreword by Deloitte

Anish Mandal
Partner
Deloitte India

The 27th Conference of the Parties (COP27) is conclusive that countries need to shift from pledges to decisive actions. The forthcoming years' collective and individual endeavours will undeniably shape the trajectory of our environment and global climate.

India is the third largest energy consuming country in the world, although its per capita energy consumption is only a third of the global average. The total energy demand is conservatively estimated to double by 2070 from the 2019 level, even after the growth in energy demand is decoupled from economic growth. India is also the third largest global emitter of Greenhouse Gases (GHG) emissions, largely driven by the coal-dominated energy mix.

It has been appropriately mentioned by our Hon'ble Prime Minister, Narendra Modi, "There are no one-size-fits-all solution to energy transition". Given the different pathways countries are on, India's pathways for energy transition could be different from rest of the world. While India will continue to invest in today's energy systems, larger investments will flow into transitionary technologies.

The energy transition for a developing nation such as India would be an expensive proposition, with an estimated investment outlay of an average annual spend of ~US$ 300 billion between 2022-70, warranting significantly higher outlay in the initial years. It would also require unprecedented amounts of new technology innovations and deployment and given the scale of investments required, government and concessional funding alone would not be sufficient. Innovative financing models need to be adopted for attracting private investment into the market and bridging the funding gap.

Energy transition would require extensive collaboration between the central government, state governments, industry stakeholders, and academia. A decisive policy push and regulatory enablers are critical for adopting new technologies. The private sector's participation in this aspirational journey is an absolute must. This report discusses the nuances and describes the key pillars of India's energy transition, building blocks, the possible pathways, and recommendations to achieve our climate ambitions.

Executive summary

As the world experiences frequent and catastrophic climatic occurrences, the resounding message from the 27th Conference of the Parties (COP27) is evident: the shift from promises to pragmatic actions is imperative. The current global emphasis revolves around implementing decarbonisation strategies and planning prioritised reduction of emissions. Collective and individual endeavours are needed to shape the trajectory of our environment and global climate. About 70 nations including major economies, such as the US, China, India, and the EU, are set out to achieve carbon neutrality. This advancement is further reinforced by an increasing array of policy frameworks and legal amendments incentivising the transition to clean energy sources.

In 2022, annual global investment in energy transition technologies touched a record level of US$ 1.1 trillion, witnessing a 31 percent annual gain.[1] Renewable energy (contributing ~45 percent to investments) and transport electrification (~42 percent) have been the primary focus areas for investors. Across the globe, policymakers plan to address climate change by imposing rigorous sustainability criteria on emission-intensive industries. The European Union, the US, Japan, and Korea are frontrunners in unveiling directives, regulations, and support programmes to drive a holistic energy transition.

India is a fossil fuel dominated economy, with primary energy consumption of 880 million tonnes of oil equivalent (Mtoe).[2] The electricity, industry, and transport industries account for more than 70 percent of the primary energy demand and 85 percent of the energy-related Greenhouse Gas (GHG) emissions. India has committed to net-zero by 2070, with a target to reduce the emission intensity of its GDP and meet 50 percent of its power generation capacity based on non-fossil fuel sources by 2030.

India’s final energy demand[3] is expected to double ~1200 Mtoe by 2070 from the 2020 level. Aggressive energy efficiency measures are expected that can result in a relatively modest growth in energy demand than the business-as-usual scenario. The industry sector is likely to contribute 65-70 percent to the total energy demand. In the transport sector, passenger and freight demand is expected to increase by 3–5x by 2070. However, energy demand will remain moderate due to a high uptake of Electric Vehicles (EVs) with higher energy conversion efficiency.

India's energy transition is anchored by three fundamental pillars – 1) grid decarbonisation, 2) industrial decarbonisation, and 3) transport transition. These three pillars collectively form the foundation of India's energy transition journey and can address ~90 percent of India’s current emissions.

Enablers for grid decarbonisation (pillar 1)

The share of electricity in the final energy mix is expected to increase from 18 percent in 2020 to more than 50 percent by 2070.[4] Grid decarbonisation will hinge on a significant increase in RE penetration in the current mix. To achieve net-zero by 2070 and decarbonise grid operations, ~2000 GW of grid scale RE (wind + solar) and another ~1,000 GW of RE for green hydrogen production is required.[5] This translates into capacity addition of ~ 50 GW/year of RE in the future from a historical average of 15–20 GW annually. An accelerated pace of capacity deployment is critical to achieve energy transition and net-zero ambitions. Key recommendations include the following:

- The central government and state utilities must expedite the bidding process and quantity for renewables.
- State governments play a crucial role in ensuring faster land allocation/acquisition and statutory clearances for project development and R&R activities; states should also focus on faster grant of open access to industrial consumers.
- Domestic manufacturing capacity should be increased without any delay; the government may consider relaxing trade barriers until the domestic supply chain is established.

Hydro and nuclear will play a critical role in the supply-side transition. India may need to exploit the full technically feasible hydro potential (~140 GW) and increase nuclear capacity. **In addition, it may need to import hydro power from Nepal and Bhutan** to achieve India’s net-zero ambitions. A regional electricity market and resource sharing would be critical for South Asian countries to achieve their net-zero targets.

[1]Source: BloobergNEF
[2]India Energy Outlook 2021: IEA
[3]Primary energy demand will be higher than this
[4]Source: IEA, Deloitte analysis
[5]Estimated; Deloitte analysis

The country is likely to have limited coal-based capacity addition beyond under-construction projects. To achieve a net-zero emissions target by 2070, phasing out of coal-based capacity is expected. This would lead to the early closure of coal-based plants and coal mines, and call for the following actions:

- Devise a comprehensive framework for "just transition" that covers policy, people, cost and communities, and land and environment remediation. An innovative financing mechanism will be a crucial enabler of the just transition mechanism.
- Identify sources of funds (budgetary allocation or clean energy cess) to support the just transition and develop guidelines to use these funds.
- Encourage every state to prepare a just transition plan to mitigate economic and social risks associated with plant and mine closures.

The energy storage system will be critical to balance out intermittency and variability imposed by renewables. While short-duration energy storage (two- and four-hour battery storage systems, and pump storage projects) would be predominant in the initial years, subsequent years would require a significant amount of Long-Duration Energy Storage (LDES) systems. Examples of these systems are six-to-eight hours of battery storage, pump storage projects, and H2 storage (to be fired in gas turbines and used for seasonal storage solutions). Existing gas stations may be retrofitted with a hydrogen turbine that will act as a long-duration seasonal hydrogen storage.

Enablers for industrial decarbonisation (pillar 2)

Industrial decarbonisation will be crucial to abate 30 percent of energy-related emission. There is no single solution to industrial decarbonisation. Companies should exercise a broad portfolio of options to reduce carbon footprint. Within the industrial sector, steel, cement, aluminum, and fertiliser contribute ~70 percent to the total emission. This report deep dives into decarbonisation of these sectors. Each industry sector will have different levers for decarbonisation, depending on technical feasibility, economics, and scalability. For example, steel – Green Hydrogen based Direct Reduction of Iron (DRI), renewable energy, and CCUS; cement – CCUS and renewable energy; aluminum – renewable energy; and fertiliser – green hydrogen, CCUS, and renewable energy.

Green Hydrogen (GH2) is expected to find applications in fertiliser, refineries, steel production, and transport. It can also find some applications in the transport sector in the later years. A substantial amount of energy demand is expected to be met by GH2 by 2070, with total demand for GH2 reaching 50 million tons (MT).[6] Most of the new demand for hydrogen is expected to be driven by rapid adoption of hydrogen-fired direct-reduction furnaces in the steel industry.
At present, GH2 is costlier than grey hydrogen (2–2.5 times) or other alternative fuels, limiting demand increase. Therefore, bringing down GH2 cost and creating demand certainty by taking policy initiatives, developing an ecosystem and market, and adopting innovative financing, are critical.

- Policy initiatives should focus on reducing electricity cost (60–70 percent of the total cost) by partial or complete waiver of Transmission and Distribution (T&D) charges. This allows for the provision of low-cost banking of renewable electricity, waiver of cross-subsidy surcharges, waiver of electricity duty, etc.
- Market development through demand mandate and demand aggregation at a cluster level could be an important enabler to kick-start the GH2 economy. Government support in the form of subsidy or adoption of the Contract for Difference (CfD) mechanism could help create a market for GH2 and its derivatives.
- Concessional financing with risk guarantee can improve project financing viability in the initial years.

Carbon Capture, Utilisation, and Storage (CCUS) would be the most preferred option in the cement sector to capture process emissions; limited uptake is visible in the steel and fertiliser industries. Both carbon use and storage will be critical to achieve scale. Policy support, market creation through a cluster-based approach, and incentives for demonstration projects in the initial years are a crucial enabler for the uptake of CCUS technology. Key recommendations include the following:

- Fund early-stage CCUS demonstration projects in the cement and steel sectors to provide the initial thrust. The industry, financial institutions, and the government may collaborate and pledge funds to support 1–2 CCUS projects in each sector.
- Initiate a study for source-sink mapping, pore space mapping, and geological characterisation of the most promising CO_2 storage regions and basins to evaluate the storage potential and associated cost.
- Identify and select a regional cluster for CCUS deployment to drive economies of scale across the value chain – carbon capture, transportation, and disposition; new downstream value-added product facilities can be co-located in clusters/hubs

[6]BloombergNEF

India's energy-transition pathways

Enablers for transport transition (Pillar 3)

The transport sector is required to transition completely to low-emission technology, such as Battery Electric Vehicle (BEV), Fuel Cell Electric Vehicle (FCEV), Hydrogen Combustion Engine (H2-ICE), and biofuel to achieve transport transition.

Widespread deve lopment of charging infrastructure and efficient urban planning are keys to transition to low carbon transport.

Key recommendations include the following:
- Public-Private Partnership (PPP) to set up charging infrastructure and hydrogen refueling system
- Central and state governments to focus on efficient urban planning that has the potential to reduce the distance travelled and motorised travel demand
- Investment to be channelised in railways (augmentation and modernisation), freight corridors, mass public transit, etc., to drive modal shift
- The future policy endeavours to account for the potential supply chain and geo-political risks associated with import dependence of critical minerals, such as lithium and cobalt

With accelerated adoption of BEVs, an organised battery recycling market, supported by appropriate policy and incentive measures, needs to be created.

Investment and financing the transition

India's energy transition will be expensive. The country would require ~US$ 15 trillion to achieve net-zero between 2022 and 2070, equating to an average annual spend of ~US$ 300 billion warranting significantly higher outlay in the initial years.[7] On the energy supply side, investment is required to develop renewable capacity and associated evacuation infrastructure (development of hydro and nuclear capacity, and energy storage system, including pump and battery storage systems). On the demand side, investment would be required to enhance energy efficiency, and deploy GH2 and CCUS infrastructure and associated process changes in the industry sectors. On transport transition, investment would be required for transitioning to low-carbon powertrain, charging infrastructure for Electric Vehicles (EV), and building transport infrastructure to enable modal shift.

Channelising public and private finance to fund the transition capex becomes imperative for the country. Securing the necessary funds and ensuring their efficient allocation while maintaining the country's fiscal discipline remain critical hurdles on India's path to energy transition.

The government, the private sector, and Multilateral Development Banks (MDBs) will play a critical role in financing the transition. MDBs are instrumental in providing concessional finance in the initial years. In addition to concessional financing, credit enhancement schemes, such as Credit Risk Guarantee Funds, First Loss, and project aggregation, can help de-risk projects and attract capital to novel and risky projects.

The Contracts for Differences (CfDs) mechanism can play a crucial role in financing the energy transition by providing stability and incentivising investment in new energy projects. In India, CfDs can be explored in emerging technologies. In the initial years, the government may need to subsidise or create demand through mandates or introduction of carbon taxes.

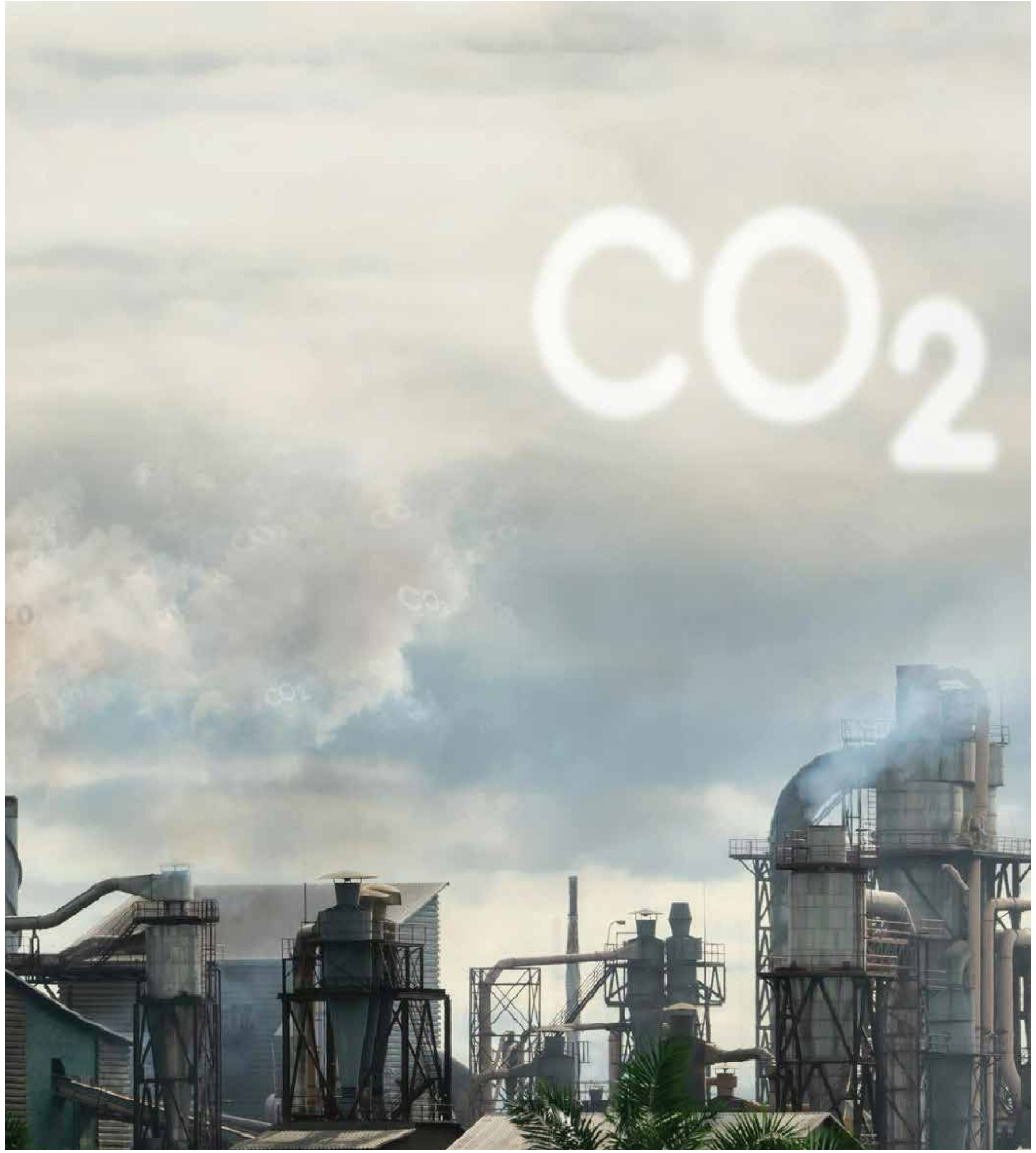
Implementation of the transition

India needs to work backward to achieve net-zero and develop decisive plans and implementation roadmaps for energy transition. Along with developing an enabling environment and formulation plans, ensuring timely implementation is critical. Long, intermediate, and short-term plans need to be developed, along with diligent follow-ups, to ensure implementation with zero tolerance for slippage.

Implementation of energy transition initiatives would require collaboration with central government, state governments, and industry experts and players. The energy transition targets need to be translated into actions for the respective state governments and sector-specific industry players. Sector-specific targets will give policy direction and timelines for emission reduction by corporates.

Indian states are important implementation actors in India's energy transition journey. States should be proactive in realising national targets, developing a conducive energy policy, participating in demand aggregation to drive economies of scale, and developing appropriate regulatory frameworks. For example, states can identify potential industrial clusters for aggregation of GH2 or CCUS that can help in market creation and cost reduction.

[7]Estimated; Deloitte analysis



Introduction

The effects of climate change are becoming prominent in the form of changing weather patterns (severe storms and draughts) and increasing global temperatures.[8] Economies across the globe are striving to reduce their carbon emissions and mitigate the ill-effects of climate change. A growing consensus around the need for green transition has helped galvanise actions designed to reduce carbon emissions. Countries across the world have embarked on an ambitious transformation of their energy sectors to avoid climate change, protect ecosystems, and improve social and environmental outcomes for their citizens.

Following a year of alarming climate events across the globe, the message from the 27th Conference of the Parties (COP27) was loud and clear – we need to move from pledges to practical actions. The focus is now on implementing decarbonisation solutions and lowering emissions. Nearly 70 countries, including large economies, such as the US, China, India, and the EU—have targets to reach net-zero carbon emissions.[9] This progress is bolstered by policy packages and legislative changes that incentivise the transition to clean energy. Moreover, countries at COP27 established a fund for "loss and damage" to aid global adaptation to climate affects, signifying an important step towards supporting communities in preparing for future damages.

The next decade will be critical, and global leaders should push for bolder climate actions. To meet the goals of Paris Climate Accord to limit the global warming "well below 2 degree C", an unprecedented level of climate action is required over the next decade.[10] This would call for accelerated adoption of clean technologies that can be enabled by favourable policies and regulations, and trillions of dollars in climate financing and protection of forests and other natural solutions.

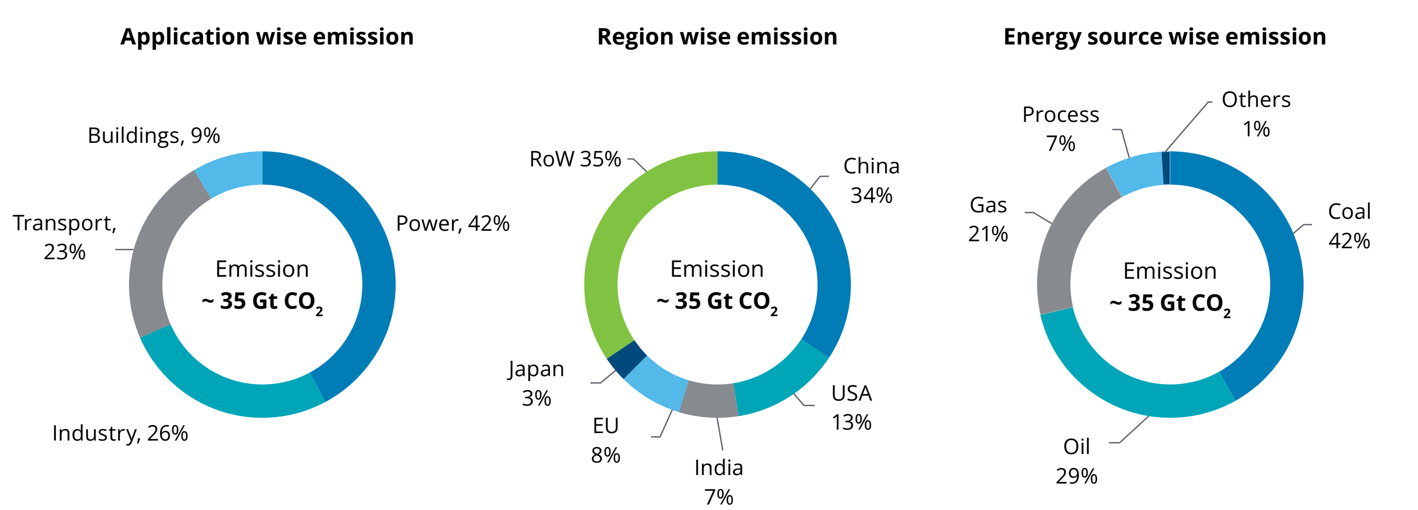
In line with global trends, India committed to meet the net-zero target by 2070. It has an intermediate target to reach about 50 percent of the cumulative electric power installed capacity from non-fossil-fuel-based energy resources by 2030. The country's low-carbon transition is already underway, driven by supportive national policies and favourable economics. Being a fossil fuel dominated economy, India finds it difficult to achieve a net-zero scenario by 2070 unless otherwise accelerated transition strategies are announced and implemented. It would require a rapidly decarbonised power system, minimum use of fossil fuel in industries, and a decarbonised transport system. This transition has to be supported with adoption of new technologies, favourable policies and support mechanisms, and a continuous source of low-cost financing.

[8] United Nations
[9] United Nationas
[10] United Nations Climate Change (UNCC), "Key aspects of the Paris Agreement"

Global trends and initiatives

Globally, China accounted for the largest share of emissions (~34 percent), followed by the US and India. Figure 1 captures the global energy related emission landscape for 2020

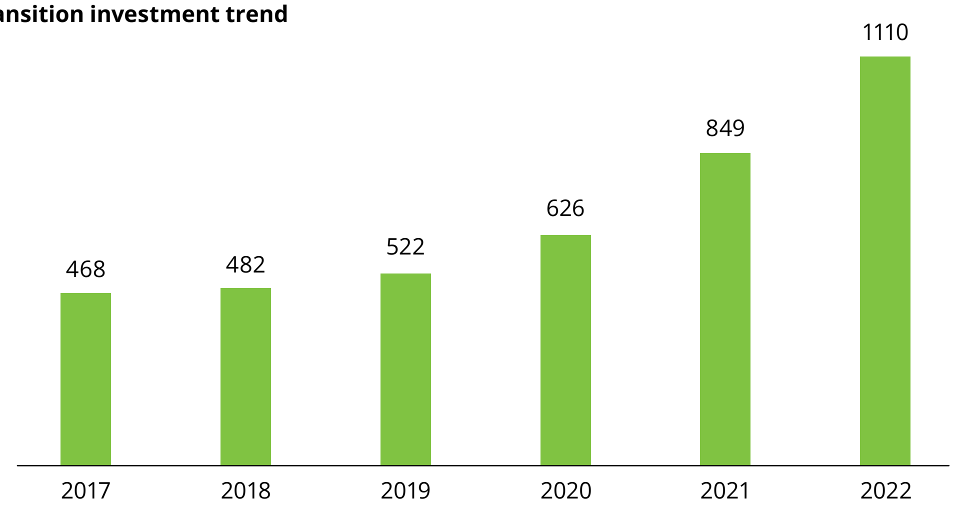
Figure 1: Global energy-related emission landscape, 2020



Source: India Energy Outlook 2021, IEA

Annual global investment in energy transition technologies has touched a record level of US$ 1.1 trillion in 2022, witnessing a 31 percent annual gain. Renewable energy, including solar and wind, had attracted highest investment of US$ 495 billion. Transport electrification (EV and charging infrastructure) came a close second with US$ 466 billion as the electric vehicle segment continued to grow globally. Other investment components included electrification of heat (US$ 64 billion), nuclear power (~US$ 40 billion), energy storage (~US$ 16 billion), carbon capture and storage (~US$ 6 billion), and hydrogen (~US$ 1 billion).[11] Favourable regulations, a conducive policy regime, and increasing competitiveness of clean technologies have accelerated the investment in energy transition.

Figure 2: Energy transition investment trend



Source: BloombergNEF

[11] Energy Transition Investment Trends 2023: BloombergNEF

Global initiatives on energy transition

Across the world, policymakers are unveiling their most ambitious plans and packages to tackle climate change, passing down stringent sustainability requirements on emission-intensive industries.

European Union

With the European Green Deal announced in 2019, Europe was the first to declare its ambition to be a climate-neutral continent by 2050. The deal was one of the main drivers and architects of the 2015 Paris Agreement and set the target of reducing its emissions by 40 percent compared with the levels in 1990 by 2030.[12] Various directives, regulations, and legislative packages have been introduced since then to fight climate change.

Table 1: Energy transition initiatives by European Union

Event	Timeline	Policy description
European Green Deal	December 2019	Goal of making Europe the first climate-neutral continent by 2050
European Industrial Strategy	March 2020	Foundation for an industrial policy to support the transition to a green and digital economy, making the EU industry globally competitive
Just transition facility	June 2020	Expected to mobilise ~€55 billion between 2021 and 2027. The plan aims to ensure a just transition towards a climate-neutral economy, providing targeted support to alleviate the socio-economic impact.
Fit for 55 packages	July 2021	This legislative proposal intends to reduce net GHG emissions by 55 percent by 2030 (vs 1990 base). The programme included plans for an updated EU emissions trading system (ETS) and the creation of a €65 billion social climate fund.
REPowerEU	May 2022	Launched in response to the global energy market disruption caused by the Ukraine crisis, this policy was intended to reduce Europe's dependence on Russian oil and gas and tackle the climate crisis. This plan targets 45 percent penetration of RE in Europe by 2030. For GH2, the target is to produce 10 million MT and import 10 million MT by 2030. The plan is also mulling over to deploy a Carbon Contracts for Difference (CCfD) to create a green hydrogen market.
Renewable (Green) hydrogen initiatives	2022-23	Multiple initiatives have been announced to promote renewable hydrogen in the EU: **Important Projects of Common European Interest ('IPCEI'):** This involves public funding support for two important large-scale hydrogen projects. **European hydrogen bank:** This is a market-making mechanism. The pilot phase of the bank will start in 2023 with a direct subsidy scheme that aims to close the market price gap between renewable green hydrogen and its fossil-derived grey counterpart through the €3 billion European Hydrogen Bank (EHB). Funding support will be provided for 10 years **H2 Global (Germany):** In the double-sided, auction-based mechanism, the difference between supply prices (production and transport) and demand prices will be compensated using grant funding from the German government. The auction process is ongoing.

Source: Council of the European Union

[12] European Commission

"Fit for 55 packages" were central to Europe's energy transition. The plan aims to reduce GHG emissions by at least 55 percent by 2030 compared with the 1990 level. It contains a set of proposals to revise, tighten, and update existing EU legislation and introduce new initiatives to ensure the EU's policies are in line with the 2030 climate goal.

United States

The US has announced its targets to achieve a 50 percent reduction in emission by 2030 (from the 2005 level), 100 percent carbon-free electricity by 2035, and net-zero by 2050.[13] The Inflation Reduction Act of 2022 (IRA) and Bipartisan Infrastructure Law of 2021 (BIL) are two most ambitious legislative actions that the US has ever taken on climate. They together represent more than US$ 430 billion[14] towards modernising and decarbonising the American energy system. Table 2 captures energy transition initiatives by the US.

Table 2: Energy transition initiatives by the US

Event	Timeline	Policy description
Bipartisan Infrastructure Law	December 2019	• Allocates ~US$ 10 billion for clean hydrogen over five years • Establishes the DOE hubs programme and competition for US$ 8B in funding • "Low-carbon hubs" to serve as an important starting point to kickstart the overall hydrogen economy
Inflation Reduction Act (IRA)	August 2022	Estimated US$ 369 billion[15] investment to target mature clean technology manufacturing and deployment, and support emerging solutions; IRA includes the following: • Wind, solar, and storage tax credit • Up to US$ 3/kg hydrogen production credit • Interest tax credit for fuel cells and hydrogen storage • CCUS tax credit • Clean vehicles tax credit • Nuclear tax credit

Source: US Department of Energy

The Inflation Reduction Act and Bipartisan Infrastructure Law together provide a historic level of funding for clean energy and energy security. They are expected to unlock large-scale investment in the areas of producing green hydrogen, developing a low-carbon hub, and manufacturing clean technologies, such as electrolyser and battery storage. Several countries have also announced national strategies on GH, energy efficiency, transport decarbonisation, industrial decarbonisation, etc.

Key takeaways

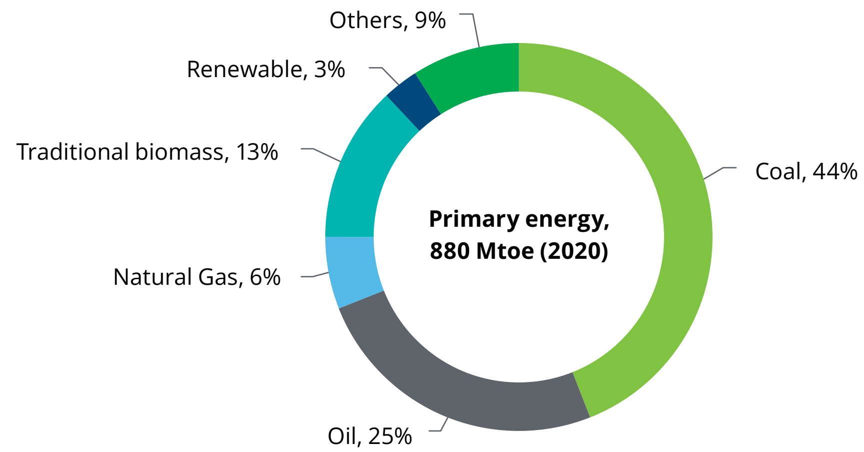
- The EU and the US have been leaders in allocating large-scale government funding in driving energy transition initiatives.
- The policy measures and initiatives are conceptualised as grant or subsidy schemes. However, mode of transferring subsidy is region specific (e.g., direct subsidy, capex support, and tax incentive).

[13] The White House
[14] Investing in American Energy: US DoE
[15] US$ 369 billion figure for the IRA is not a "target" or a "ceiling," but rather an estimate from the Congressional Budget Office (CBO)

India’s energy landscape

India is the world's third-largest energy-consuming country, although its per capita energy consumption is only a third of the world’s average. In 2020, the total primary energy demand was 880 million tons of oil equivalent (Mtoe). The country is also the third-largest global emitter of GHG emissions (2.6 billion tons in 2022), largely driven by a coal-dominated energy mix. At present, coal meets 44 percent of the primary energy demand in the country, but accounts for nearly 75 percent of India’s energy sector emissions. [16] The second-largest contributor to emissions is oil, primarily driven by the transport sector. The power, industry, and transport sectors account for more than 70 percent of the energy demand and 85 percent of the energy-related GHG emissions. [17] Figure 3 captures India’s primary energy mix for 2020.

Figure 3: India's primary energy mix, 2020



Source: India Energy Outlook 2021, IEA

India’s emission landscape

India’s power sector is the largest contributor to CO_2 emissions, primarily due to its heavy reliance on coal (more than 70 percent of electricity generated in 2020 was from coal).[18] In addition to ensuring energy security, fossil-fuel-based plants provide grid stability to balance the intermittent generation from wind and solar sources. The carbon intensity of India’s power sector is 725 g CO_2/kWh, compared with a global average of 510 g CO_2/kWh,[19] underlining the predominant role of GHG emitting coal-based generation.

The industrial sector is the second-highest contributor to India’s CO_2 emissions (~30 percent). The iron and steel industry is the largest industrial subsector in terms of emissions. Indian steel production primarily relies on blast furnaces (using coal) compared with gas-based direct reduction and electric-arc furnaces (using recycled scrap), making it more emission-intensive than other countries. The cement industry is the second-largest industrial subsector in terms of emissions, with coal and oil as the primary fuels used. Other major industries contributing to industrial emissions are aluminum, fertiliser, and petrochemical. India’s macroeconomic growth and increasing focus on domestic manufacturing are expected to drive the increase in industrial output. However, the increase in industrial activity will require commensurate uptake of energy resources. The total energy consumption by the industrial sector is expected to grow multifold in the next few decades.

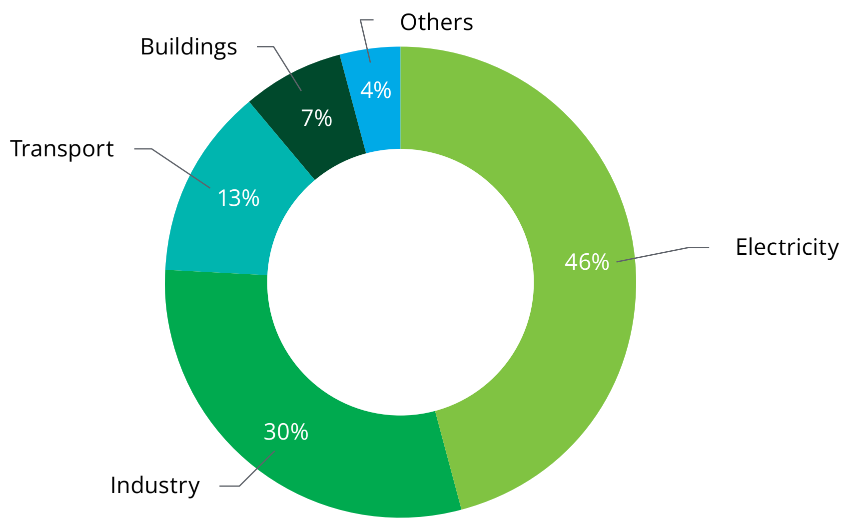
The transport sector is responsible for ~13 percent of India’s CO_2 emissions. The sector accounts for more than 80 percent of the total oil demand in India. Oil demand for road freight transport in India tripled since the 2000 (the highest after China), with trucks contributing more than 45 percent to emissions. In terms of the passenger vehicle fleet, India has a much larger share of two- and three-wheelers compared with other developed countries. The rapid growth of mobility has been enabled by the expanding road network in India and improvement in the overall infrastructure.

Energy demand in the buildings sector (over the second half of 2000s) has been driven by an increase in a building floor area in rural and urban areas, rise in levels of basic appliance ownership, and an increase in the use of refrigerators and air conditioners in urban areas. With rising disposable incomes and urban dwellings, appliance ownership is expected to further increase.

[16] India energy outlook 2022: IEA
[17] India energy outlook 2022: IEA
[18] Source: Central Electricity Authority (CEA)
[19] India Energy Outlook, 2021

Figure 4 captures India's emission landscape by sector for 2020.

Figure 4: India's emission landscape by sector, 2020



Source: India Energy Outlook 2021, IEA

Outlook of energy growth and transition

To contain the emissions increase, the Government of India has committed to decouple the economic growth with energy growth through launching a slew of policy and regulatory initiatives across the emitting sectors. In addition to setting an ambitious target to reach net-zero by 2070, India has committed to reducing the emissions intensity of its GDP by 33-35 percent by 2030 and meeting 50 percent of its installed electricity generation capacity by non-fossil fuel sources.[20]

Achieving net-zero emissions by 2070 would mean the emission curve could peak about 2040. After that, it will follow an accelerated declining trajectory with 5-10 percent balance emissions to be offset through carbon sequestration (with the help of afforestation).

Outlook of energy demand

India's final energy demand is expected to double by 2070 with a steady year-on-year increase of 5-6 percent for the next one or two decades. Rising incomes and improving standard of living (driven by economic growth, rapid urbanisation, and industrialisation) are expected to lead to increasing energy consumption. Aggressive energy efficiency measures are expected, which can result in a modest growth in energy demand, and more efficient and sustainable energy use. A targeted set of initiatives, including policy and regulatory, investment, and research and development, are required to contain the increase in final energy demand. The industry sector will likely to be the major energy consumer, driven by growth in the steel, cement, and aluminium sectors. In the transport sector, the increase in energy demand is likely to remain moderated despite a significant increase in passenger and freight demand because of modal shift measures; increase in electrification is expected to induce higher energy efficiency in vehicles (25-30 percent in combustion engine vehicle vis-à-vis 70-80 percent in battery electric vehicle).

Efficiency increase will also be visible in the building and cooking sector. The building sector currently accounts for 6 percent of the total energy demand. The demand is expected to go up to more than 10 percent by 2070, driven by urbanisation, replacement of existing building stock with new construction, and increasing appliance ownership (especially air conditioners) to address the cooling load. The building sector's energy efficiency will be driven by adoption of energy-efficient appliances and thermally efficient building. Energy demand from cooking currently accounts for ~14 percent of the total energy demand. However, it is expected to reduce to ~5 percent by 2070 due to fuel switching and efficiency improvements.

Outlook of supply side transition

To meet the primary energy demand, cleaner sources of energy, especially solar and wind electricity, will need a substantial uptake. The demand for electricity is expected to increase more rapidly than the overall energy demand due to electrification of transport and industries. The share of electricity in the final energy consumption is expected to rise from 18 percent in 2020 to more than 50 percent by 2070. Most of the electricity will be supplied through non-fossil-fuel-based electricity sources. Integration of RE will be supported by deployment of long duration and seasonal energy storage solutions.

Construction of new coal-based power plants is expected to gradually slow due to an increased climate focus and favourable economics of renewables. Early decommissioning of coal-based power plants, along with just transition of coal mines, must be explored, keeping energy security in consideration in the medium to long-term to achieve net-zero emissions. Further, GH2 is expected to find applications in fertiliser, refineries, steel production, and gas distribution network. The transport sector can also adopt GH2 in the later years. CCUS is another critical element of India's energy transition. A few industrial sectors (e.g., cement) where processes cannot be electrified or fuel substitution is not feasible, deployment of CCUS is expected.

Key takeaways

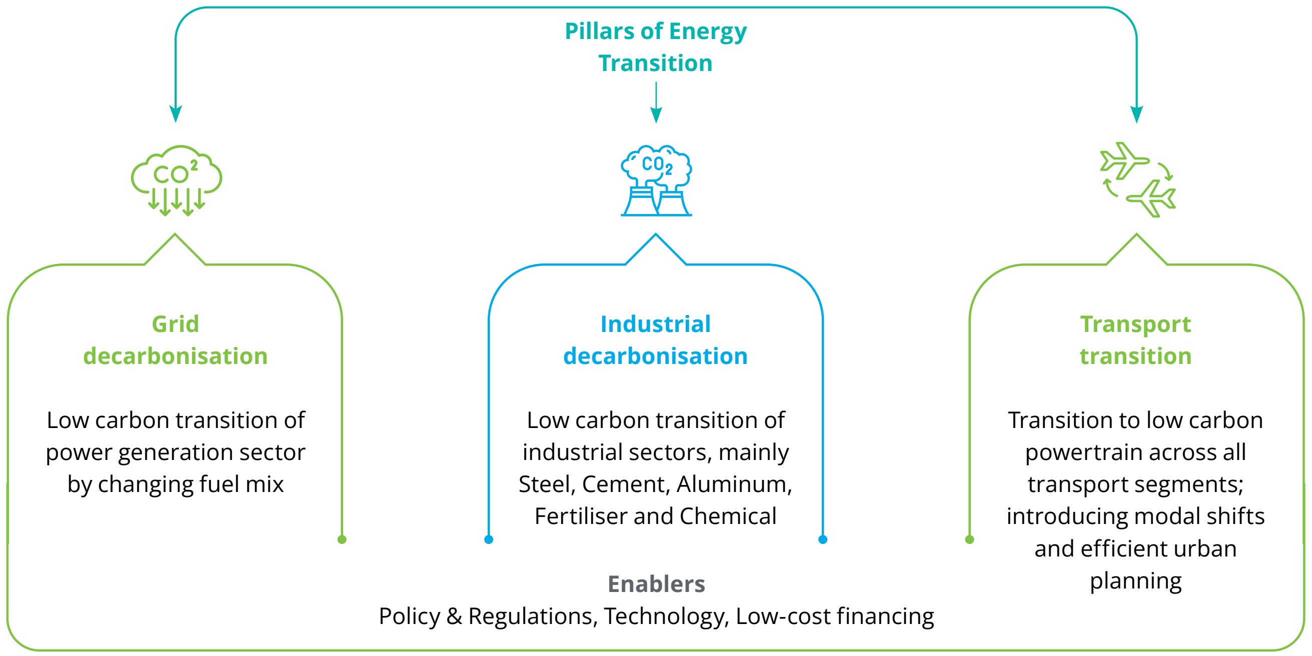
- India's total energy demand is expected to double by 2070 from the 2020 level, considering aggressive energy efficiency and adoption of new technologies.
- The industry sector is likely to contribute 65-70 percent to the total energy demand. In the transport sector, passenger and freight demand in Billion Passenger Kilometres (BPKM) is expected to increase by 3–5x by 2070; corresponding energy demand from the transport sector will remain moderate due to a higher uptake of EVs and FCVs, which have higher energy conversion efficiency.
- Share of electricity in the energy mix to meet the demand is expected to increase from 18 percent in 2020 to more than 50 percent by 2070. Most of this electricity will be supplied through non-fossil source.

[20] India's NDC committment

The three pillars of India's energy transition

India's energy transition is anchored by three fundamental pillars. First is grid decarbonisation that signifies the shift towards cleaner power sources and emphasis on renewable energy integration, such as solar and wind into the national grid. Second is industrial decarbonisation that focuses on reducing emissions from the energy-intensive and hard-to-abate industries through efficient technologies and practices. Last is the transport transition that emphasises on adoption of EVs and sustainable transportation solutions, aiming to curtail the carbon footprint of the transportation sector. These three pillars collectively form the foundation of India's energy transition journey and can address ~90 percent of India's current emissions.

Figure 5: Pillars of India's energy transition



Source: India Energy Outlook 2021, IEA

Grid decarbonisation

The last decade was remarkable for India's power sector as India achieved almost 100 percent electrification, and nationwide synchronisation of grid was attained in 2013. Despite significant growth in the renewable sector, coal remains the dominant fuel for the sector, with more than 40 percent contribution to India's energy-related emissions. Therefore, decarbonising the grid is an important energy transition lever. This would require accelerated growth of RE and gradual phasing out of coal-based plants.

In the past few years, barring Covid-19 affected years, the growth of RE (solar and wind) has been phenomenal. The growth of RE was propelled by multiple policy measures, such as fiscal incentives, large-scale procurement mechanisms through solar parks, waiving of inter-state transmission charges and losses, must-run status for RE generating stations, proposed manufacturing-linked solar power projects, reverse auctions, and renewable purchase obligations. Improvements in the network infrastructure and deepening of power markets have aided in the integration of RE. The introduction of the Green Day Ahead Market and Term Ahead Market segments on the power exchange has improved the liquidity of RE and provided transparency on prices.

To achieve the 500 GW target and achieve grid decarbonisation for net-zero ambitions, the growth of RE addition in the next few decades would have to be significantly steeper. Historically, India has added 15-20 GW renewable annually.[21] The future pace of capacity addition is expected to be significantly higher. The country would need an average of 40-50 GW of RE capacity addition every year for the next few decades, with an assumption that coal-based power will be transitionally phased out by 2060.

[21] Based on India's historical capacity addition

Share of electricity in the final energy consumption is expected to rise from 18 percent in 2020 to more than 50 percent by 2070. Non-fossil-fuel-based electricity supply would be met through a mix of energy sources – solar, onshore wind, offshore wind, hydro and nuclear. Inclusion of hydro and nuclear capacity in the future generation mix will be crucial to supplement variable RE. Most of the technical potential of hydro is expected to be exploited, and regional grid inter-connection should be explored to import hydro from Nepal and Bhutan. Figure 6 below captures the pathways for grid decarbonisation:

Figure 6: Pathways for grid decarbonisation

Pathways for Grid decarbonisation	2022-30	2031-50	2051-70
Coal based TPP	Capacity addition through under-construction projects; very few new order finalization	Gradual decommissioning; 160 – 170 GW by 2050	No coal based TPP by 2070
Gas based TPP	No new addition	No new addition	No new addition
Solar	230 – 300 GW by 2030; 30 – 35 GW/year	700 – 800 GW by 2050; 25 – 30 GW/year	1300 – 1500 GW by 2050; 25 – 30 GW/year
Wind Onshore	150 – 160 GW by 2030; 10 – 15 GW/year	Gradual decommissioning; 160 – 170 GW by 2050	450 – 550 GW by 2070; 8 – 10 GW/year
Wind offshore	<5 GW	70 – 100 GW by 2050	120 – 150 GW by 2070
Nuclear	15 – 20 GW by 2030	50 – 60 GW by 2050; ramping up of nuclear capacity	80 – 90 GW by 2070
Import	Minimum import	80 – 100 TWh import from Nepal and Bhutan	130 – 150 TWh import from Nepal and Bhutan
BESS	Limited adoption of short duration BESS to enable round-the-clock renewable	Long-duration BESS (8 hours) kicks in; BESS becomes commercially feasible. 150 – 200 GW 8 hours BESS	400 – 500 GW 8 hours BESS 150 – 200 GW 4 hours BESS
Pump Storage	10 – 15 GW	15 – 20 GW	20 – 25 GW
H2 Turbine	NIL	H2 Turbine (seasonal storage) kicks in	40 – 50 GW H2 Turbine storage

Source: Pathways assessment by Deloitte

Key takeaways

- Power sector decarbonisation will be mostly driven by renewables.
- About 40–50 GW of annual RE capacity addition is required for grid decarbonisation.
- Hydro and nuclear power will also play a crucial role in grid decarbonisation.

Industrial decarbonisation

While grid decarbonisation can address ~46 percent of India's emission from the electricity sector, industrial decarbonisation can address another ~30 percent of the country's energy-related emission. There is no single solution to industrial decarbonisation; a broad portfolio of options is being exercised or explored by industrial companies to reduce emission.

Figure 7: Decarbonisation levers for industrial companies

Decarbonization levers

Energy efficiency
Adapt production equipment to lower energy use per produced volume

Renewable Energy
Replacement of fossil-based or grid electricity with RE

Direct electrification
Replace fossil fuel for heating with electricity powered by renewables, such as electric furnace, electric kiln etc.

Low-carbon Hydrogen
Replace feedstock or fuel with low-carbon hydrogen, e.g., in fertilizer or steel production

Biomass as a feedstock or fuel
Replace feedstock or fuel with sustainably produced biomass to reduce CO_2 emissions

Carbon Capture, utilisation & Storage
Capture the emitted CO_2 and store or use the same

This report has outlined transition pathways for four key emission-intensive sectors, which contribute ~21 percent to the total emission and ~70 percent to the total industrial emissions.

[22] Ministry of Steel
[23] Iron and Steel technology roadmap: IEA

Steel

The iron and steel industry is a major energy consumer within the industry sector, with a share of ~12 percent in the total emission. India extensively uses coal-based DRI as opposed to natural gas-based DRI, which is more common across the world. Main crude steel production routes in India are BOF (45 percent of total), EAF (26 percent), and induction furnace (29 percent).[22] However, of the large steel plants in India, 70 percent are Blast Furnaces and Basic Oxygen Furnaces (BF-BOF).

India's steel industry is more energy and emissions intensive than international benchmarks due to the following factors

- Presence of many small production facilities
- Heavy reliance on coal for DRI furnaces
- Low quality of domestic coal
- Relatively old stock of blast furnaces in the country
- A low proportion of scrap in the total metallic input

According to the IEA,[23] the Indian steel sector's emission intensity is 2.2–2.4t of CO_2 per tonne of crude steel produced; this is higher than the international benchmark. Of the direct emissions, coal forms 90 percent of the total emissions mainly because of its use in coke ovens, blast furnaces, and coal-based direct reduction furnaces. Decarbonisation pathways for the Indian steel sector are captured below:

Figure 8: Pathways for the steel sector decarbonisation

Pathways	Decarbonization potential	Pathways for Grid decarbonisation: 2022-30	2031-50	2051-70
Energy efficiency in BF-BOF and DRI	Low	Energy efficiency is a continuous process; Specific energy consumption per ton of steel can be reduced up to 20% by use of energy efficient drives, waste heat recovery, increasing oxygen injection into BF-BOF etc.		
Renewable Electricity	Medium	• Shift from fossil-based captive electricity to hybrid/round-the-clock renewables	• Shift from fossil-based captive electricity to hybrid/round-the-clock renewables	• Shift from fossil-based captive electricity to hybrid/round-the-clock renewables
Change in production mix	High	• Through BF-BOF and Coal DRI route; • pilot scale demonstration of H2-DRI and injection of H2 into blast furnace	• H2-DRI route becomes more prevalent from 2035; existing BF-BOF and DRI units continue to operate	• Entire capacity addition through H2-DRI; closure of all BF-BOF and coal DRI plants by 2070
Carbon capture	Low	• Pilot scale demonstration	• Selective adoption in the younger fleet of BF-BOF; adoption rate will vary depending on geography and availability of large-scale storage basin availability	• Selective adoption

Source: Pathways assessment by Deloitte

[24]IEA India Energy Outlook
[25]Industry inputs; Secondary research

Cement

The cement sector accounts for ~8 percent of India's total emission and ~27 percent of the industry sector emission.[24] The calcination or clinker production process (decarbonisation of limestone) accounts for about 60 percent of CO_2 emission from a cement plant. The remaining comes from combustion of fuel and electricity use. Indian cement players emitted 570-600kg of CO_2 for each ton of cement manufactured in FY22,[25] which is in line with the global benchmark. The major challenge of the cement sector is that ~60 percent of the total emission is "process emission". This cannot be abated through a change in fuel mix. Decarbonisation pathways for the cement sector include adoption of several initiatives and technologies, including CCUS, clinker substitution, renewable energy, and kiln electrification.

Figure 9: Pathways for cement sector decarbonisation

Pathways	Decarbonization potential	Pathways for Cement sector decarbonisation: 2022-30	2031-50	2051-70
Change in fuel mix	Medium	• Shift from fossil-based captive electricity to hybrid/round-the-clock renewables; • 15 – 20% thermal substitution rate with biomass, waste	• Shift from fossil-based captive electricity to hybrid/round-the-clock renewables; • 30 – 40% thermal substitution rate with biomass, waste;	• Shift from fossil-based captive electricity to hybrid/round-the-clock renewables; • >50% thermal substitution rate with biomass, waste
Use of Hydrogen as a heating fuel	Low	• Not likely	• Maximum 5% with necessary process modification	• Maximum 5% with necessary process modification
Clinker substitution	Medium	• Clinker factor 70 – 75%; clinker substitution through fly ash, slag, waste gypsum etc.	• Clinker factor 60 - 65%; clinker substitution through fly ash, slag, waste gypsum etc.	• Clinker factor 60 - 65%;
Carbon capture	High	• Pilot scale demonstration	• Commercial scale adoption expected from 2035-40	• Entire process emission to be captured with CCUS

Source: Pathways assessment by Deloitte

Aluminum

Aluminum production is an energy-intensive process. In India, carbon intensity of primary aluminum production is 17–19 MT CO_2 per ton of production, due to the significant use of coal in generating captive power. In the primary production process, alumina refining and smelting are the most energy-intensive processes, accounting for more than 90 percent of direct emission. Decarbonisation of aluminum production will be driven by adoption of renewable energy for the smelting process, fuel switch in the alumina refining process, and adoption of novel technologies, such as "inert anode technology"

Figure 10: Pathways for the aluminum sector decarbonisation

Pathways for Aluminum sector decarbonisation

Pathways	Decarbonization potential	2022-30	2031-50	2051-70
Renewable energy	High	• Partial substitution of fossil power/grid power with renewable Round-the-clock power	• Complete substitution of fossil power/grid power with renewable Round-the-clock power by 2050 • Gradual closure of coal based captive power plants	• Complete substitution of fossil power with renewable Round-the-clock power
Change in heating fuel mix	Low	• Biomass co-firing for process heat generation in alumina refining	• Complete shift to biomass, industrial waste for process heat generation in alumina refining • Selective use of hydrogen as heating fuel	• Complete shift to biomass, industrial waste for process heat generation in alumina refining • Selective use of hydrogen as heating fuel
Novel technology	Low	• Pilot of "Inert Anode Technology"	• Commercial scale adoption of "Inert Anode Technology"	• Commercial scale adoption of "Inert Anode Technology"

Source: Pathways assessment by Deloitte

[26]Industry input; Secondary research

India's energy-transition pathways

Fertiliser and ammonia

Ammonia is a major ingredient in manufacturing nitrogenous fertilisers. The ammonia production process is emission intensive as it uses natural gas as the feedstock to produce hydrogen. Theoretically, each ton of ammonia produced from gas emits 2.0–2.2 ton of CO_2 into the atmosphere. In India, total consumption of ammonia is 18–19 million tons; ~95 percent of this is used in the fertiliser industry.[26]

Figure 11: Pathways for the fertiliser sector decarbonisation

Pathways for Fertiliser sector decarbonisation

Pathways	Decarbonization potential	2022-30	2031-50	2051-70
Green Hydrogen	High	• Pilot of green hydrogen/ ammonia plant to substitute grey hydrogen	• 100% substitution of grey hydrogen with green hydrogen for DAP and NPK fertilisers • 15 – 20% substitution for Urea fertiliser	• 100% substitution of grey hydrogen with green hydrogen for DAP and NPK fertilisers • 100% substitution for Urea fertilizer
CCUS	Low	• Not likely	• Selective adoption based on technical and commercial viability	• Selective adoption based on technical and commercial viability
Renewable Energy	Medium	• Partial substitution of grid/captive electricity with renewable electricity	• Complete substitution of grid/captive electricity with renewable electricity	• Complete substitution of grid/captive electricity with renewable electricity

Source: Pathways assessment by Deloitte

GH2 can decarbonise 100 percent ammonia required for DAP and complex fertilizers (NPK) production. In case of urea, decarbonisation potential is likely to be limited to 15–20 percent, due to process challenges. Apart from using hydrogen, 1 ton of ammonia requires ~0.3 MWh of electricity, which is currently sourced either from grid or captive generation unit. This electricity can be decarbonised by shifting to renewables.

Key takeaways

- Industrial decarbonisation will be crucial to abate 30 percent of the energy-related emission.
- Each industry sector will have different levers for decarbonisation, depending on technical feasibility, economics, and scalability. For example, steel – GH2 DRI, renewable energy and CCUS; cement – CCUS and renewable energy; aluminium – renewable energy; and fertiliser – GH2, CCUS, and renewable energy.
- Emission reduction potential from energy efficiency measures is 10–15 percent. Energy efficiency is a continuous process; matured industries have already adopted most energy-efficient measures.
- Industrial companies are shifting to renewable energy, driven by both sustainability targets and cost advantages offered by renewables.
- GH2 is expected to find applications in fertiliser, refineries, steel production, and transport; some adoption is expected in the transport sector in the later years. Overall 25-30 percent of energy demand is expected to be met by GH2 by 2070, with total demand reaching 50–60 million tons.
- Carbon Capture, Utilisation, and Storage (CCUS) is expected to be the most preferred option in the cement sector to capture the process emission; limited uptake is visible in the steel and fertiliser industries. To achieve net-zero by 2070, total deployment of CCUS is expected to be 400–500 million tons.

India's energy-transition pathways

Transport transition

After power and industries, the transport sector is the third-largest carbon emitter (12–13 percent) in India, making it an important pillar for the energy transition. A high dependence on oil to meet this demand presents major roadblocks to achieving India's decarbonisation aspirations. With increasing demand, disposable income, and industrial and commercial activity, India is expected to witness a rapid rise in both passenger and freight transport demand. Therefore, the country must take an integrated approach towards decarbonising the transport sector, focusing on three major areas covered below.

Transition to low-carbon powertrain

Transition to low-carbon powertrain refers to four key technologies - Battery Electric Vehicle (BEV), Fuel Cell Electric Vehicle (FCEV), Hydrogen Internal Combustion Engine (H2-ICE), and biofuel blending with conventional fuel. Despite significant advancements in BEV in the past few years, FCEV, H2-ICE, and biofuel blending are still in nascent stages.

Innovative urban planning and modal shift

Apart from adopting low-carbon powertrain, transformative urban planning and modal shift could be key to India's transport decarbonisation.

- **Innovative urban planning:** Efficient urban planning through innovative concepts, such as integrated transport and spatial planning, logistics optimisation, and travel demand management, can reduce the need for distance travelled. With regard to freight transport demand, developing a dedicated freight corridor can help in the efficient management of freight by lowering freight volume.
- **Driving modal shift:** Modal shift can be considered along two areas – from private to public/shared modes of transport and from road to railways or even waterways (more carbon-efficient mode). A shift away from personal transport modes to public transport has the potential to limit the number of private vehicles on road. This in turn will decrease traffic congestion and subsequently contribute to emission reductions.

Figure 12: Pathways for transport transition

Pathways for Transport transition

	Decarbonization potential	2022-30	2031-50	2051-70
Passenger transport	Car	• Moderate uptake of BEVs; 15 - 20% penetration by 2030	• Gradual increase of BEV and FCEV • Last sale of ICE vehicle between 2045 – 50	• Complete transition to BEV (80 – 90%) and FCEV (10 -20%)
	2W/3W	• Moderate uptake of Electric 2W/3W; 20 - 50% penetration by 2030	• Rapid increase of Electric 2W/3W • Last sale of ICE vehicle between 2035 – 40	• 100% electrification to achieve by 2050 - 55
	Bus	• Slow uptake of BEVs; 6 – 8% penetration by 2030	• Gradual increase of BEV and FCEV • Last sale of ICE vehicle around 2050	• Complete transition to BEV (70 – 80%) and FCEV (20 – 30%)
	Rail	• 100% electrification by 2030	• 100% electrified	• 100% electrified
	Aviation	• Blending of green aviation fuel in low quantity	• ~50% use of green fuel	• Near 100% transition to green fuel
Freight transport	Heavy Commercial Vehicle (HCV)	• Diesel to continue as the dominant fuel	• 70 - 75% fleet to convert to BEV and FCEV • LNG and Diesel to form rest 30%	• Complete phase out of fossil fuel by 2070 • BEV: 70-80%, FCEV: 20 – 30%
	Light Commercial Vehicle (LCV)	• CNG to emerge as the transition fuel	• 70 – 80% fleet to be electrified	• 100% BEV by 2060-65

Source: Pathways assessment by Deloitte

Blending of biofuels in the Internal Combustion Engine (ICE) vehicles and the emergence of H2-ICE vehicles are expected in the transition period.

Key takeaways

- The BEV technology is expected to dominate the vehicle mix, with some adoption of FCEVs in certain segments (bus and HCV).
- In addition, initiatives should be taken for efficient urban planning and facilitating the modal shift to reduce travel demand.

Challenges of energy transition

India's ambition to transform the energy landscape requires planning and concerted efforts. The country grapples with a burgeoning energy demand driven by rapid economic growth and a large population. Heavy reliance on coal and oil poses a hurdle in the shift towards cleaner energy sources. Moreover, substantial infrastructure investments and advancements in energy storage technologies are also vital to support integration of variable renewables. Clear policy frameworks, attracting investments, managing social and economic implications, and ensuring energy access for everyone remain pivotal amidst the broader goals of reducing carbon emissions and promoting sustainability in the energy sector. Figure 13 captures below the challenges in energy transition.

Figure 13: Challenges in energy transition

Economic challenges

- As estimated, India would require USD 14 – 17 trillion to achieve net zero between 2022-2070 for India's energy transition.
- This large transition capex is a meaningful cost to the economy. There could be reasonable front-loading of these investments, with the 2030-2050 decades seeing substantially higher investment intensity. Securing the necessary funds and ensuring their efficient allocation while maintaining the country's fiscal discipline remain critical hurdles on India's path to an energy transition.
- Operating expenditure of end-users is also likely to increase in most of the sectors, at least in the initial years of adoption. Many new technologies, such as green hydrogen, battery storage, CCUS etc., have not yet reached maturity, and they are costlier than the available conventional technologies

Technological challenges

- Availability of resource rich sites and land to deploy more than 2000 GW of grid scale RE and additional ~1000 GW for green hydrogen is a major concern. Associated challenges are likely to emerge in relation to land acquisition.
- Successful transition will depend on the pace of adoption of new technologies, such as green hydrogen, CCUS, long duration storage etc. For example, transition of cement and steel sectors will depend on commercial scale adoption of CCUS. Likewise, transitioning to electric vehicles demands a robust charging infrastructure and battery technology advancements. Slower pace of technology innovation may derail the transition trajectory
- In addition, upgrading the energy sector's digital infrastructure to enable smart grids, real-time monitoring, and data analytics presents its own set of complexities.

Policy & Regulatory challenges

- The country is yet to chart out a clear roadmap for phasing out coal based power stations and adding RE at a rate of 30-35 GW/year, without which, attaining net-zero target will be difficult.
- India doesn't have a carbon tax imposed, which would enable the transition faster. Still, many of the end-use sectors are reliant on subsidies in the fossil-based energy sources.
- RE and new energy policies are state specific, which vary significantly. While some states have progressive policy and regulations, there need to be more focus towards easy allocation of open access and energy banking, incentives in the initial years, land allocation, setting up charging infrastructures etc.
- Demand obligations or mandates are not available

Enablers of energy transition in India

Renewable energy

To meet India's climate ambition, non-fossil capacity has to grow multifold compared with the existing installed base, especially solar and wind. The pace of capacity addition through 2023–70 will be 2–3 times of the historical pace of capacity addition. Renewable capacity will be required for both grid decarbonisation and GH2 generation.

Given the scale of energy requirement, India may need to import clean energy (hydro power) from neighbouring countries, such as Nepal and Bhutan.

Enabling recommendations

Achieving the renewable energy transition at this massive scale would require concerted efforts from the centre, state, and private sectors. Table 3 captures the key recommendations for different stakeholders:

Figure 13: Challenges in energy transition

S. no.	Recommendations	Responsible stakeholder(s)
1	**Capacity increase:** A minimum annual capacity addition of 40-50 GW is required for net-zero transition. To enable such capacity addition, state utilities need to undertake scientific studies, such as resource adequacy and integrated resource planning, to meet their demand and plan for electricity procurement to optimise system cost. Unless utilities increase their procurement, such demand for RE power would be absent; investments and ecosystem would not support such addition.	Goal of making Europe the first climate-neutral continent by 2050
2	**Developing a domestic manufacturing ecosystem:** Enhancing domestic manufacturing ecosystem across the renewable value chain is critical. For example, polysilicon, wafer, solar cell and module, inverter, and wind turbine.	Private sector players
3	**Relaxation of trade barriers:** The government may consider relaxing duties and other trade barriers on import of solar cell and module until the domestic ecosystem is developed.	Central government
4	**Increasing hydro and nuclear capacity** • Ensure the timely completion of under-developed hydro and nuclear projects. • Create a framework to enable private-sector participation in the nuclear power sector. • Promote new technologies, such as Small Modular Reactor (SMR).	Hydro PSUs, NPCIL NITI Aayog, MOP, DAE
5	**Strengthening transmission grid and regional grid interconnections** • Adequate planning and investment are required to support transmission infrastructure to enable evacuation of power and prevent congestions in the network as large amounts of variable energy is integrated into the grid. • India may have to look for avenues to import RE (mainly hydro from Nepal and Bhutan) from the neighbouring regions. The regional interconnection potential will have to be explored to ensure that the country accommodates the desired level of RE in its overall energy mix.	Central government
6	**Facilitating low-cost financing:** Channelling public and private investment in the RE sector will be crucial to enable large-scale capacity addition.	Central government multilateral development banks
7	**Facilitate faster land acquisition and clearances:** Ensure faster land allocation/acquisition and statutory clearances for project development and R&R activities.	State governments
8	**Ensuring a robust legal framework for Renewable Energy credits:** Development of comprehensive and transparent regulations for RE procurement is essential to attract investment, stimulate renewable energy development, ensure clear claim of RE procurement, avoid double issuance of certificates in the carbon market and provide clarity for businesses seeking to engage in long-term contracts for renewable energy supply.	Central government

Considering the large capacity of RE required to achieve net-zero by 2070, the country should re-assess and identify the renewable potential. This necessitates establishing regional interconnections for the import of RE power from neighboring countries and developing long-duration energy storage systems for integration of such high variable renewables.

Energy Storage System (ESS) for grid stability

TEnergy storage technologies and devices are a must for a high renewable energy world. The government introduced multiple interventions to enable a more conducive environment for ESS adoption in India.[27]The government and utilities are committed to providing reliable supply to their consumers. The increased inclination of utilities towards procuring Round-the-Clock (RTC) and peak power solutions holds potential for bundling energy storage solutions with renewable supply. Both pumped hydro storage and battery energy storage solutions would gain prominence in the Indian electricity system with the former being a preferred choice but restricted by its potential. Battery Storage Energy Systems (BESS) could be scalable and flexible with use cases across the value chain. In the long run, BESS can outweigh PSP in India. The uptake in BESS largely depends on the projected price reduction and establishment of a global supply chain. Long-duration energy storages (four-, six-, and eight-hour storage) would be critical to have a RE transition in the grid.

Enabling recommendations

To achieve net-zero by 2070, ESS deployment is expected to grow multifold with new long-duration energy storage technology gaining maturity. Energy storage systems for stationary grid applications must evolve beyond lithium-ion technologies to achieve affordable long-duration storage capabilities (sodium ion technology, GH2-based storage solutions for seasonal storages, etc.). Table 4 captures the key recommendations for different stakeholders:

Table 4: Key recommendations to ramp-up energy storage solutions

S. no.	Recommendations	Responsible stakeholder(s)
1	**Capacity increase:** Deployment should be increased in line with RE addition through the bidding process. Innovative business models have emerged globally for the grid and off-grid applications of battery storage. This can be explored in India to enable faster adoption.	Central government, state utilities
2	**Developing a domestic manufacturing ecosystem:** The government has notified a Production-linked Incentive (PLI) scheme for domestic manufacturing of battery storage. Enabling domestic manufacturing ecosystem for the components and battery recycling industry would be necessary for the success of the PLI.	Central government, private-sector players
3	**Promoting new technologies:** There may be geological and supply chain constraints for large-scale deployment of PSP and Li-ion BESS. Therefore, industries and the government must focus on creating a roadmap for commercial scale deployment of new ESS technologies (at present with low technology readiness level), such as flow battery, sodium-ion battery, and H2 storage.	Industry players, research institutes, etc.

Short-duration energy storage systems would be sufficient in the next decade. Later years would require a significant amount of Long-duration Energy Storage (LDES) systems, such as eight hours of battery storage, and H2 storage (to be fired in the gas turbine).

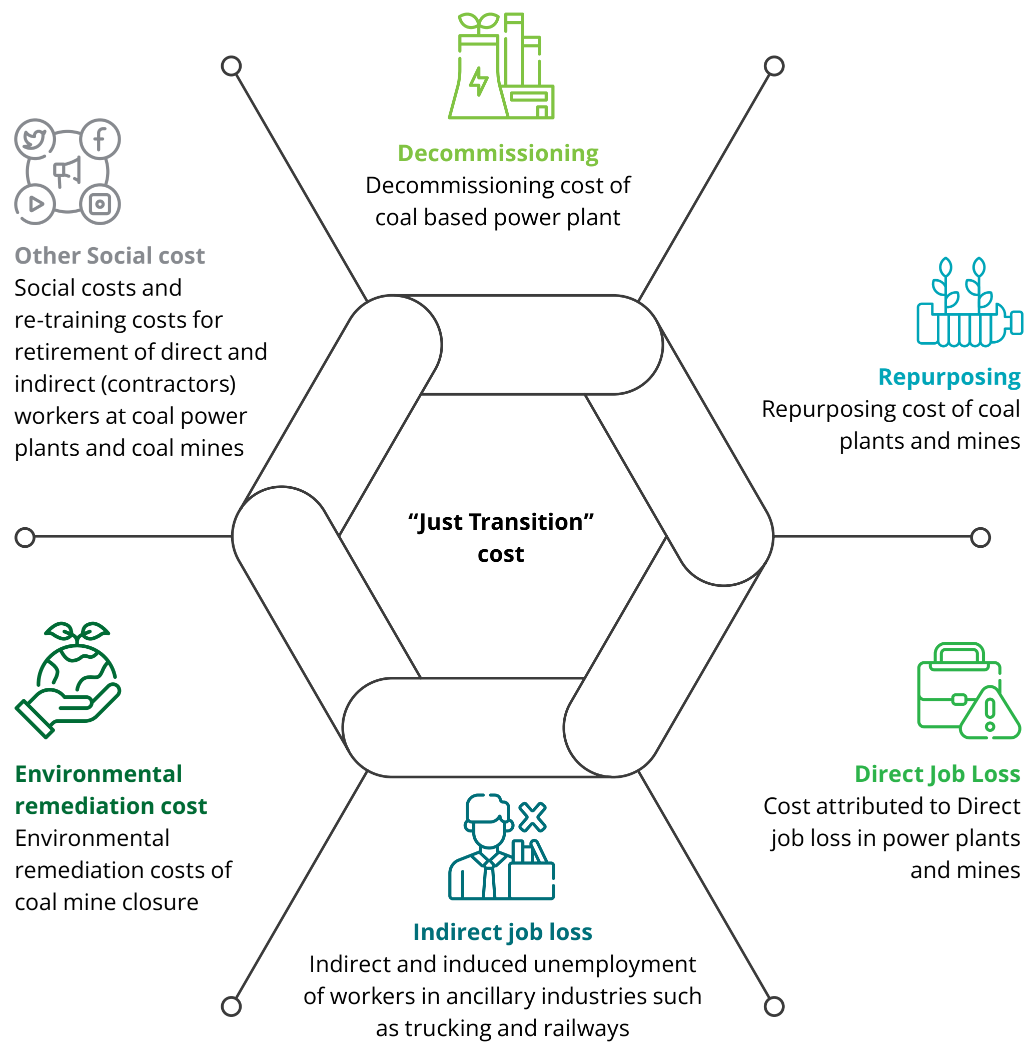
[27]For example, Energy storage purchase obligation, PLI scheme, National Framework for promoting ESS

Early closure of fossil-based plants and driving a "just transition"

India's clean energy transition will drive the early closure of coal-based power stations and reduced use of fossil fuel. At present, India operates ~220 GW of coal-based power stations[28] and consumes ~700 million tons of coal annually only in the power sector (total consumption is ~1 billion tons per annum). To achieve net-zero emissions, India would have to gradually phase out coal-based power stations after appropriate diligence on energy security has been established. Such decommissioning of thermal power plants and gradual phasing out could result in the closure of mines and subsequent loss of employment in the power, mining, and allied sectors (for example, logistics, trucking, and other informal sectors).

The coal sector is deeply interconnected to the local communities. This has led to heavy economic and social dependence of communities on the coal sector. In addition, coal belts in India are situated in many socially and economically backward regions of the country. Understanding and addressing the social dimensions of the energy transition is critical to ensure that communities, workers, and their families are not affected or left behind. The Indian coal sector employs ~1.2 million workforce. This, however, does not include employment related to coal logistics (includes both road and railway transportation) and allied sectors.[29] About 3–10 additional jobs/ livelihoods depend on every formal job in coal in coal mining districts. Driving a just transition to achieve net-zero emissions in India may cost more than ~US$ 200 billion. Figure 14 captures the cost components of this transition.

Figure 14: Cost components of "just transition"



[28]This figure doesn't include captive power plants; that will be additional ~40 GW
[29] Coal dependence and need of just transition: TERI

Enabling recommendations

Table 5 captures the key recommendations for different stakeholders:

Table 5: Recommendations for driving a just transition

S. no.	Recommendations	Responsible stakeholder(s)
1	**Just transition framework:** Developing a framework for the early decommissioning of coal-based power plants, along with just transition of coal mines, will be critical to achieve the energy transition. The framework should focus on policy, people and communities, land, and environment remediation, and evaluating the cost. The framework should also facilitate close collaboration amongst key stakeholders (governments, financial institutes, private organisations, NGOs, affected communities, etc.).	Central government, state utilities
2	**Framework for compensating developers:** A buyout of investors for the remaining term of Power Purchase Agreements (PPA) would serve the dual purpose of unlocking capital that would otherwise be locked into stranded power plants, while also greening the electricity grid.	Central government
3	**Allocation of funds:** Identify sources of funds (budgetary allocation or clean energy cess) to support the just transition, and developing guidelines for utilisation of such funds.	Central government state government for fund disbursal
4	**Creation of an empowered taskforce:** Create an empowered task force to oversee and govern the progress on just transition. This includes physical progress, allocation of funds, utilisation of funds, and actual impact delivered on ground.	Central government
5	**Retrofitting of gas-based power plants:** Retrofitting gas-based plants with hydrogen turbine can act as a long-duration seasonal storage. This is a medium-to-long-term intervention.	NITI Aayog, central government, industry players

To implement these recommendations, a comprehensive framework covering policy, people and communities, and land and environment remediation, needs to be devised. An innovative financing mechanism is a crucial enabler of the just transition mechanism.

Green hydrogen and derivatives

GH2 is expected to play an important role in this energy transition, particularly in decarbonising the "hard-to-abate" sectors that cannot be electrified easily. In 2021, the Government of India launched the National Hydrogen Mission (NHM), which was followed by the release of the National Green Hydrogen Policy. The government approved the provisions of NHM by sanctioning INR 19,744 crore outlay in January 2023. The mission aims to take annual green hydrogen production to a minimum of 5 MMTPA by 2030 and capture 10 percent of the global demand (expected to become 100 MMTPA by 2030).[30] In July 2023, the government announced a methodology to disburse subsidies for electrolyser and GH2 production. The announcement of incentives, along with the aspirational production target, positions India as one of the attractive destinations globally for GH2 production.

Enabling recommendations

Table 6 captures the targeted measures required to decrease cost and drive the adoption of GH2 in the energy system.

[30]Source: India National Hydrogen Mission document

Table 6: Key recommendations for GH2 ecosystem

S. No.	Recommendations	Responsible stakeholder(s)
1	**Electricity cost reduction interventions:** Electricity accounts for 60–70 percent of the total production cost. Key policy imperatives that could reduce the LCOE include the following: • Partial or complete waiver of Transmission and Distribution (T&D) charges • Provision of low-cost banking of renewable electricity to facilitate low-cost RTC renewable power • Waiver of cross-subsidy surcharges • Waiver of electricity duty	State governments, central government for ISTS waiver
2	**Demand aggregation and Contracts for Difference (CfD) mechanism:** The market for hydrogen can be created by aggregating demand at a regional level (cluster level) and using a CfD fund. Regional level demand aggregation is the most preferred option to obviate the need of hydrogen transportation. Based on the aggregated demand (through a combination of multiple contracts of different quantities and tenure), the aggregator can sign "hydrogen purchase agreement" with domestic producers and "hydrogen supply agreement" with consumers.	Central government (MNRE, MoF, SECI, etc.)
4	**Demand creation through mandates:** Domestic demand could be created through industry-level mandates for hydrogen consumption. The fertiliser and refining sectors have a high transition readiness as they have existing application of grey hydrogen. New applications, such as steel, mobility, and blending in natural gas network, may witness gradual adoption. Investments on GH2 supply projects based on 100 percent export contracts may not be an easy workout for investors.	Central government
5	**Ecosystem development through creating a domestic supply chain and hydrogen infrastructure** While the PLI scheme for electrolyser is expected to give the initial boost to domestic supply chain development, equal focus may be given to manufacturing BOP equipment, such as compressors, dispensers, and electricals. Per an analysis, the alkaline electrolyser system has the potential for 100 percent indigenisation, while the PEM system can be indigenised up to 70–80 percent.[31] The government (central or state) may encourage manufacturers to set-up indigenous facilities for BOP equipment and ancillaries. At present, the infrastructure required to transport and store hydrogen is non-existent. Beyond manufacturing electrolyser and generating hydrogen, policies should enable capital flows to develop hydrogen infrastructure, expand the network, and retrofit existing gas infrastructure. As the NHM lays emphasis on hydrogen exports, assessing ports' readiness to export green ammonia or other hydrogen carrier is important.	Industry players, central government for any policy
6	**International collaboration on harmonising standards, certifications, and safety protocol:** Developing and harmonising standards, certification, and safety protocols for hydrogen use and infrastructure are critical for the faster uptake of GH2 applications. Government-to-Government (G2G) collaboration must be used to develop frameworks and harmonise standards and certification requirements around GH2 and embedded products.	Central government, think tanks, such as NITI Aayog

[31]Deloitte analysis

Achieving a full-blown industrial decarbonisation, without large-scale adoption of GH2, is difficult. GH2 development is still in the nascent stage and largely limited to feasibility studies and proposed pilot projects. The cost gap between GH2 and other alternatives (such as grey hydrogen, natural gas, and coal) can be bridged through policy initiatives, ecosystem development, and innovative financing. Creating the market through demand mandate or aggregation at a cluster level could be an important enabler to kickstart the GH2 economy in the initial years.

Carbon Capture, Utilisation, and Storage (CCUS)

Carbon Capture, Utilisation, and Storage (CCUS) has a critical role to play in decarbonising industrial sectors that are hard to electrify, due to their high energy and process-related emissions. In a net-zero scenario, India may require 400–500 million tons of annual CCUS capacity by 2070.[32] A majority of this is likely to be deployed to capture process emission from the cement industry.

The following key sectors are expected to see the adoption of CCUS:

- **Cement:** The cement sector is considered the most viable sector for the adoption of CCUS. In this sector, CO_2 is emitted as a result of the clinker production process. About 60 percent of the total emissions from cement production are process emissions,[33] and they can only be eliminated by technologies, such as CCUS. Globally, cement producers are relying heavily on CCUS to achieve their net-zero target.
- **Steel:** While electrification and use of GH2 have a great potential to decarbonise the steel industry (hydrogen-based direct reduction followed by an electric arc furnace for steel melting), India is expected to continue with significant conventional blast furnace-based steel production until the alternative technologies mature. The country is expected to produce 400–450 MTPA steel by 2050,[34] and CCUS will be critical to achieve sustainability and export competitiveness.
- **Power:** About 60 percent of India's current coal-based fleet is less than 15 years old.[35] Therefore, to avoid any stranded assets and meet the baseload demand, India is expected to continue with a coal-based power plant (share in power generation mix will reduce) for the next few decades. As the largest emitter of CO_2, CCUS in the power sector may be explored to achieve meaningful decarbonisation and ensuring energy security in India.

CCUS is not yet a commercially mature technology in the present day, with only pilot and small-scale projects implemented so far. In the absence of any carbon pricing, the current cost structure is prohibitive and varies significantly across applications and industries. In addition, ideal sites for CO_2 storage are not yet established. Initial theoretical assessments have determined that India has a large potential (400–600 Gt) for storage in saline aquifers and basalt.[36] These technologies are still in the development stage and must reach commercialisation before large-scale deployment.

[32] BloombergNEF; Deloitte analysis
[33] OECD report on Low and zero emissions in the steel and cement industries
[34] Iron and Steel technology roadmap, IEA
[35] Derived; 135 GW capacity out of 210 GW capacity was installed after 2008
[36] Study by British Geological Society and IIT Bombay; NITI Aayog report on CCUS

Table 7 captures below CCUS adoption potential and timeline for India

Table 7: CCUS adoption potential and timeline

Sector	Timing		
	2025 -30	2030-40	Rationale and challenges
Cement	✓	✓	About 50–55 percent emissions from cement plants are process emissions (decomposition of calcium carbonate to CO_2 and calcium oxide) that cannot be abated through a change in fuel mix or electrification. CCUS may be the only option for cement decarbonisation.
Ammonia/ fertiliser and refining	✗	✓	With CCUS, existing plants can be retrofitted. In addition, certain percentage of captured CO_2 can be used for downstream fertiliser production (e.g., urea). With low-cost CO_2 storage options, CCUS could be more affordable than shifting to other options, such as GH2.
Steel	✗	✓	With CCUS, existing plants can be retrofitted. However, transportation and storage of CO_2 could be a challenge and cost prohibitive for steel manufacturers.

Commercial scale adoption of CCUS is expected only after 2030. However, availability of storage and downstream applications of captured carbon are critical to achieve scale.

Enabling recommendations

The government must enact a policy framework that supports creating sustainable and viable markets for CCUS projects. In the initial years, funding and supporting demonstration scale projects in different industries is important. The cost structure of demonstration projects for different sectors can be quite different, depending on the source and quality of the gas stream and the extent of CO_2 capture targeted.[37]

Table 8: Recommendations for CCUS adoption

S. no.	Recommendations	Responsible stakeholder(s)
1	**Funding support for sizeable demonstration projects:** Funding early-stage CCUS demonstration projects in the cement and steel sectors can provide the initial thrust. A few projects can be funded through budget. The industry, financial institutions, and the government may collaborate and pledge funds to support 1–2 CCUS projects in each sector.	Central government, industry players, financial institutes, including MDBs
2	**Mapping of carbon storage sites:** A study needs to be initiated for source-sink and pore space mapping, and geological characterisation of the most promising CO_2 storage regions and basins to evaluate the storage potential and associated cost.	Central government, think tanks, such as NITI Aayog
3	**Promoting regional CCUS cluster/hubs:** Identify and select regional clusters for CCUS deployment to drive economies of scale across the value chain – carbon capture, transportation, and disposition; new downstream value-added product facilities can be co-located in clusters/hubs	State governments, industry player

While electrification and adoption of GH2 can address industrial decarbonisation to a large extent, certain industrial sectors (cement, urea, etc.) call for the adoption of CCUS as a solution. Providing policy support, creating the market through a cluster-based approach, and incentivising demonstration projects in the initial years are crucial enablers for the uptake of CCUS technology. However, cost-effectiveness should be considered while selecting CCUS (e.g. vis-à-vis green hydrogen) as a decarbonization solution

India's energy-transition pathways

Zero emission transport

Two critical enablers for transport transition are a) low-carbon powertrain and b) efficient urban planning, along with the modal shift. These two enablers will help reduce emission and contain energy demand by introducing higher "well-to-wheel" efficiency and reducing the distance travelled.

Enabling recommendations

Table 9: Recommendations for transport decarbonisation

S. No.	Recommendations	Responsible stakeholder(s)
1	**Continue with EV-related incentives:** Continue with existing incentives to lower upfront purchase cost of EVs.	State governments, central government for ISTS waiver
2	**Driving efficient urban planning:** The government at different levels (central and state) should focus on efficient urban planning that has the potential to reduce the distance travelled and decrease motorised travel demand.	Central government (MNRE, MoF, SECI, etc.)
4	**Driving modal shifts:** Channelise investments in railways (augmentation and modernisation), freight corridors, mass public transit, etc. Focus should be on increasing public transport share over private transport.	Central government
5	**Improving fuel efficiency:** In the transition period, the government should continuously focus on making fuel standards more stringent, introduce fuel efficiency standards for different kinds of vehicles, and devise a mechanism for maximum compliance.	Industry players, central government for any policy
6	**Battery recycling ecosystem:** The accelerated adoption of BEVs has necessitated the creation of an organised battery recycling market through policy and incentive measures. Despite that, the number of EVs on road are insignificant. With more EV batteries reaching the End of Life (EOL), presence of an organised battery recycling market will become critical. The government, in collaboration with industry players, should focus on creating an organised battery recycling ecosystem.	Central government, think tanks, such as NITI Aayog

The transport sector is required to completely transition to low-emissions technology to achieve net-zero. In addition, it needs initiatives for efficient urban planning and facilitating the modal shift to reduce travel demand. The future policy endeavours should account for the potential supply chain and geo-political risks associated with import dependence on critical minerals, such as lithium and cobalt.

Other enablers for energy transition in India

Implementation of a carbon tax

In addition to the above-mentioned technology and enablers, India, similar to other countries, may consider implementing a carbon tax to address environmental, economic, and social challenges associated with carbon emissions and climate change. By placing a price on carbon emissions, India can incentivise industries and individuals to adopt cleaner technologies, thereby reducing carbon footprints and advancing towards a low-carbon economy. The revenue generated from the carbon tax can be channeled into funding renewable energy projects, promoting research and innovation in clean technologies, and bolstering adaptation measures against climate impacts. For many emerging sectors, such as GH2, carbon tax will help in faster adoption. However, in a fossil fuel dominated country such as India, imposing tax would call for careful considerations.

Low-cost and innovative financing

Given the large magnitude of investment required for the energy transition in India, the government and concessional funding would not be sufficient. Innovative financing models need to be adopted to attract private investment into the market and bridge the funding gap.

- **Collaboration:** Both private and public sectors play a critical role in advancing the energy transition agenda. No one can do without the other. The philanthropic sector can also make useful concessional contributions to de-risking energy transition initiatives and projects.
- **Role of the public sector:** The sector plays a critical catalysing role by providing a conducive and predictable enabling environment for long-term investment decisions of the private sector. It can also engage and attract private investors and developers to build and finance pipelines of bankable energy transition projects.
- **Role of Multilateral Development Banks (MBDs):** MDBs can play a critical role in meeting the financial and technical gap and fulfil India's energy transition requirements. They can provide direct and indirect financial assistance to meet large-scale financing requirements. In addition to concessional financing, these institutes can offer credit enhancement schemes (such as Credit Risk Guarantee Funds, First Loss guarantee etc.) to help de-risk projects and attract capital to novel and risky projects. Further, they can help undertake test projects in the form of pilots/proof of concepts to better understand feasibility, costs, and benefits of new and untested technologies in the market.

Conclusion

India's transition to a diversified and low-carbon energy system is already underway, driven by national targets and supportive government policies. The central and state governments, businesses and industries, and research centres and innovators now can accelerate the deployment of established decarbonisation technologies and development of others. India needs to work backward to achieve net-zero, and develop decisive plans and implementation roadmaps for its energy transition. Ensuring timely implementation is also critical. Long, intermediate, and short-term plans, along with diligent follow-ups, need to be developed to ensure smooth implementation with minimal slippage.

Policy and regulatory enablers are critical in opening and developing new markets and adopting novel technologies, such as battery storage and GH2. Without a definitive and favourable policy environment, bringing attractive investment in markets that are in the nascent stages but critical to India's successful energy transition, is important. Timely development of new technologies is important. Faster and more cost-efficient adoption of sustainable technologies is possible through fostering innovation, investment in research and development, acquisition of technical know-how from technically advanced markets, and developing local manufacturing capabilities. Awareness and capacity building of concerned public and private sector stakeholders will be necessary for smooth and fast adoption of new technologies.

The energy transition for a developing nation such as India would be an expensive proposition, with an estimated requirement of an average annual spend of ~US$ 300 billion between 2022 and 2070, warranting significantly higher outlay in the initial years. Given the large magnitude of investment required, government and concessional funding would not be sufficient. Innovative financing models need to be adopted for attracting private investment into the market and bridging the funding gap.

India's energy-transition pathways

About Deloitte

Deloitte refers to one or more of Deloitte Touche Tohmatsu Limited ("DTTL"), its global network of member firms, and their related entities (collectively, the "Deloitte organization"). DTTL (also referred to as "Deloitte Global") and each of its member firms and related entities are legally separate and independent entities, which cannot obligate or bind each other in respect of third parties. DTTL and each DTTL member firm and related entity is liable only for its own acts and omissions, and not those of each other. DTTL does not provide services to clients. Please see www.deloitte.com/about to learn more.

All the facts and figures that talk to our size and diversity and years of experiences, as notable and important as they may be, are secondary to the truest measure of Deloitte: the impact we make in the world.

So, when people ask, "what's different about Deloitte?" the answer resides in the many specific examples of where we have helped Deloitte member firm clients, our people, and sections of society to achieve remarkable goals, solve complex problems or make meaningful progress. Deeper still, it's in the beliefs, behaviours and fundamental sense of purpose that underpin all that we do.

Deloitte Globally has grown in scale and diversity—more than 415,000 people in 150 countries, providing multidisciplinary services yet our shared culture remains the same.

About FICCI

Established in 1927, FICCI is the largest and oldest apex business organisation in India. Its history is closely interwoven with India's struggle for independence, its industrialization, and its emergence as one of the most rapidly growing global economies.

A non -government, not -for -profit organisation, FICCI is the voice of India's business and industry. From influencing policy to encouraging debate, engaging with policy makers and civil society, FICCI articulates the views and concerns of industry. It serves its members from the Indian private and public corporate sectors and multinational companies, drawing its strength from diverse regional chambers of commerce and industry across states, reaching out to over 2,50,000 companies.

FICCI provides a platform for networking and consensus building within and across sectors and is the first port of call for Indian industry, policy makers and the international business community.

Address: FICCI, Federation House, Tansen Marg, New Delhi 110001
Website: www.ficci.in
Email: power@ficci.com; renewables@ficci.com

Connect with us

Debasish Mishra
Partner
debmishra@deloitte.com

Shubhranshu Patnaik
Partner
spatnaik@deloitte.com

Anish Mandal
Partner
anmandal@deloitte.com

Ms. Jyoti Vij
Additional Director General, FICCI
Jyoti.vij@ficci.com

Mr Arpan Gupta
Additional Director & Head - Mines, Metals, Cement, Power, Coal and Renewable Energy, FICCI
arpan.gupta@ficci.com

Mr Nishit Jain
Deputy Director – Power & Renewables, FICCI
nishit.jain@ficci.com

Contributors

Deloitte Touche Tohmatsu India LLP

Anish Mandal

Himadri Singha

Shubham Bhadana

FICCI

Jyoti Vij

Arpan Gupta

Nishit Jain

Acknowledgements

Deloitte India

Arti Sharma

Elamathi Raja

Himadri Singha

Jayita Mukherjee

Spriha Jayati

FICCI

Mr Shivanand Nimbargi
Chair, FICCI Renewable Energy CEOs Council and Managing Director & CEO, Ayana Power

Sh. Vipul Tuli
Chair, FICCI Power Committee and Chairman, South Asia & CEO, Hydrogen Business, Sembcorp Industries