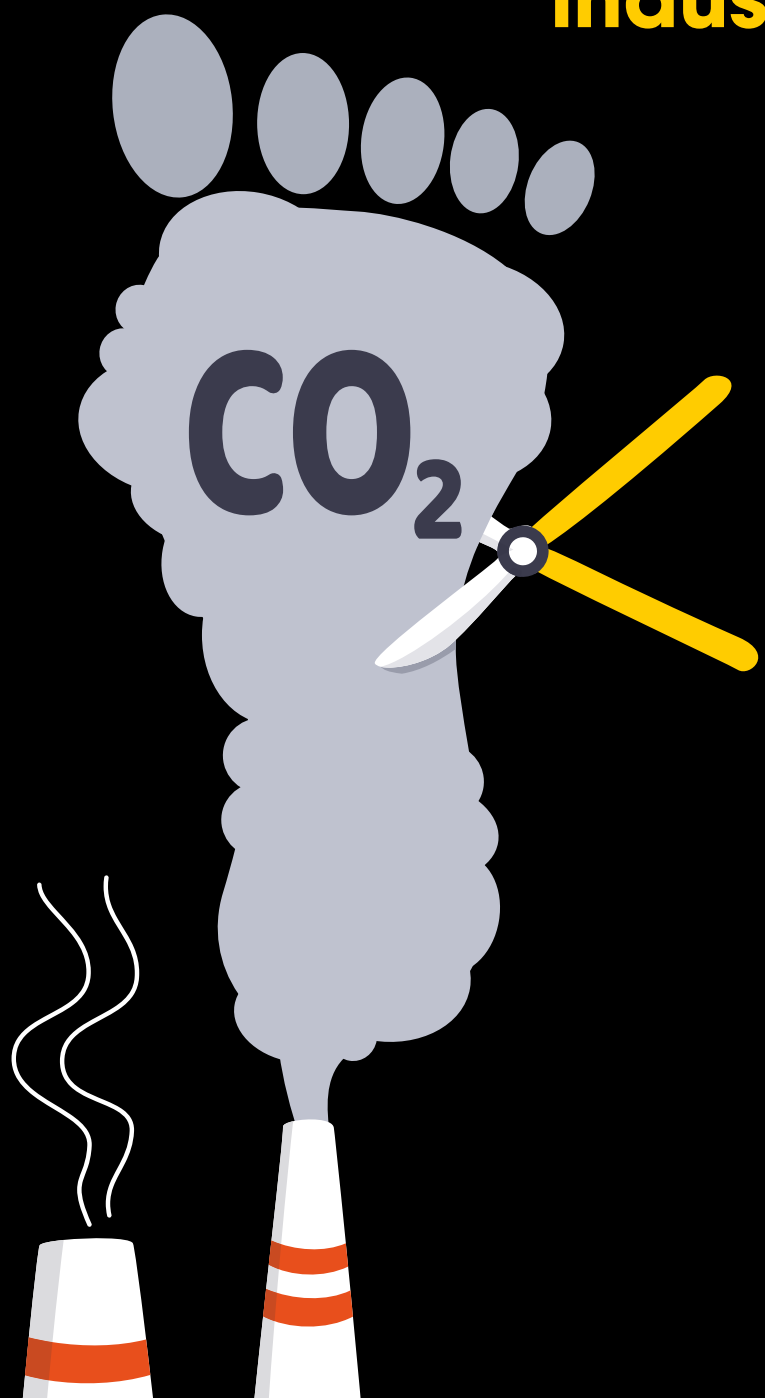
DECARBONISING INDIA

Energy and hard-to-abate industrial sectors

AN ANTHOLOGY AND SUMMARY OF RESEARCH AND FINDINGS



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This publication has been designed to capture the existing state of research in the subject in India, as well as the gaps going forward. It also attempts to capture some of the key elements of the discussions that happened at the first CSE Climate Week in October, 2024.

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DECARBONISING INDIA: ENERGY AND HARD-TO-ABATE INDUSTRIAL SECTORS

An Anthology and Summary of Research and Findings

CONTENTS

THE ENERGY SECTOR: MAKING A SCALABLE AND AFFORDABLE TRANSITION

ENERGY DEMAND AND RELATED EMISSIONS BETWEEN 2024 AND 2030/2050: THE SCENARIOS

The demand for energy in India between now and 2030/2050 is influenced by various factors, including economic growth, population dynamics, technological advancements, and policy frameworks. This publication provides an overview of current energy and hard-to-abate developments in the country and what lies ahead in terms of research to decarbonise the sectors while safeguarding energy security.

INDIA NEEDS TO CHART ITS OWN DECARBONISATION PATHWAY. AS A COMMUNITY, WE NEED TO IDENTIFY RESEARCH AND ACTION GAPS TO MAKE THIS HAPPEN.

- Sunita Narain, Director General, Centre for Science and Environment (CSE)

The reports in the anthology provide insights into potential scenarios for energy demand, related emissions, options for decarbonising coal/thermal power and reducing dependence on them, options for scaling up renewable energy, challenges faced by the electricity sector, and the equity considerations for the roadmap ahead.

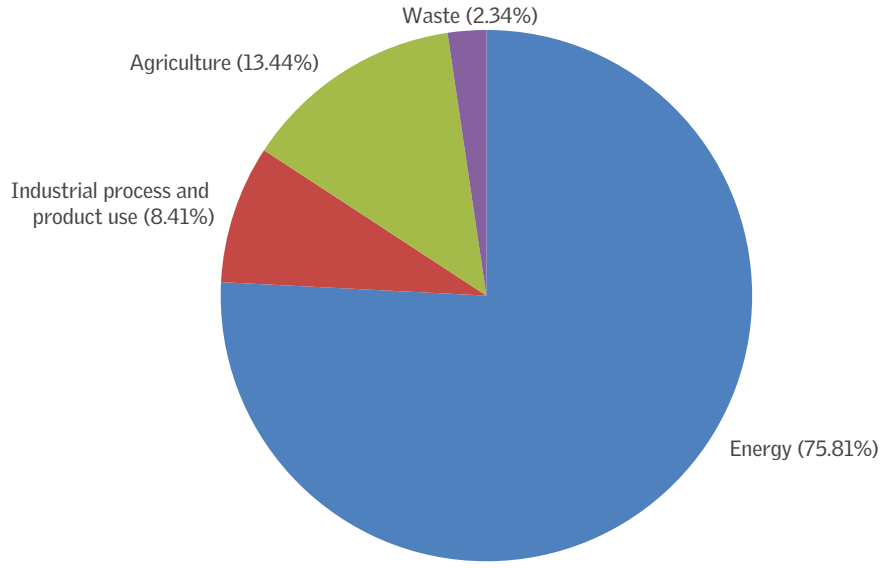
Current emissions

As per the Third National Communication (NC) from the Government of India to UNFCCC, the energy sector, which includes the consumption of fossil fuels in the country and their associated fugitive emissions (from transport to power sector etc), is the main GHG emitting sector in the country, contributing to 76 per cent (*see Graph 1: Distribution of GHG emissions ($GgCO_2e$) by sector, 2019*) of the total GHG emissions in 2019 (excluding LULUCF).[1]

The third NC shows that within the energy sector, it is the power sector that is responsible for the largest share of India's greenhouse gas emissions, accounting for around 39 per cent (*see Graph 2: Percentage share of green house gas emissions by category, 2019*) as of 2019.

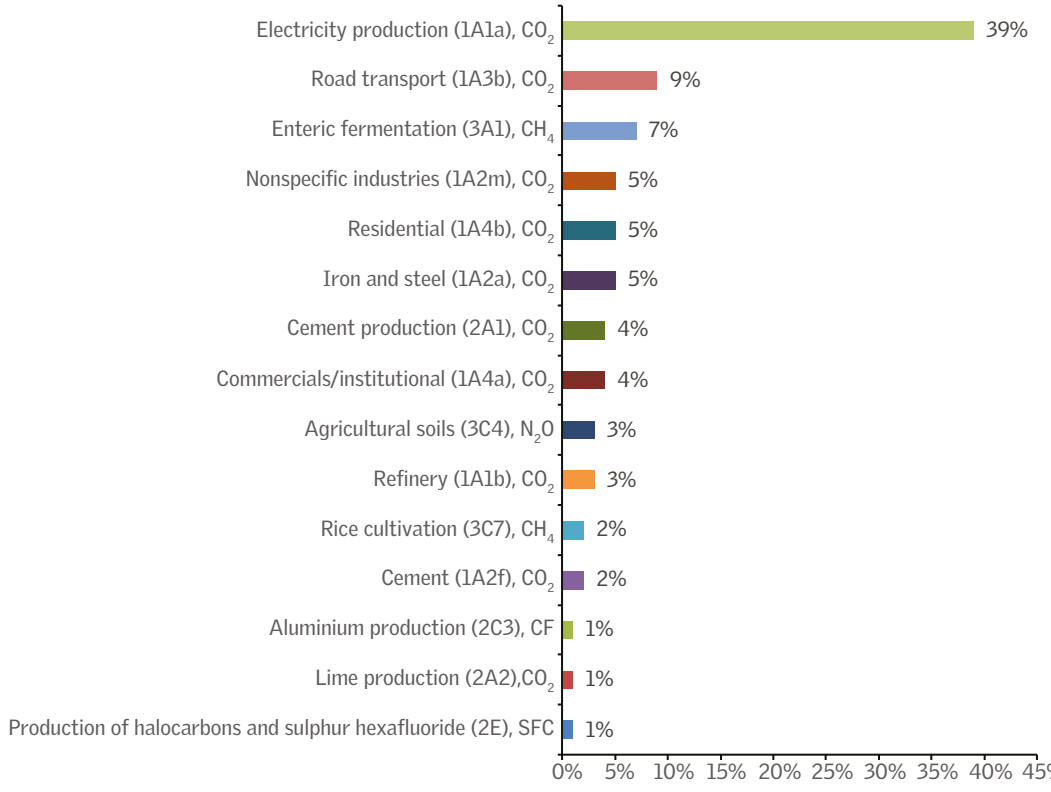
Other recent reports from think tanks estimate that in 2023, India's power sector emissions reached a record high of approximately 1.4 billion metric tons of carbon dioxide equivalent ($GtCO_2e$), with coal power accounting for about 95 per cent of this total.

Graph 1: Distribution of GHG emissions ($GgCO_2e$) by sector, 2019



Source: India - Third National Communication and Initial Adaptation Communication, 2023

Graph 2: Percentage share of green house gas emissions by category, 2019



Source: India - Third National Communication and Initial Adaptation Communication, 2023

WE SHOULD LOOK AT DEVELOPMENT-LED TRANSITION BUT WHAT WE ARE LOOKING AT IS TRANSITION-LED DEVELOPMENT

- Amit Garg, Professor, Public Systems Group, IIM-A

A GOOD THING WOULD BE TO HAVE EMISSION INTENSITY TARGETS FOR POWER PLANTS. WE NEED TO ALIGN NATIONAL AND STATE STRATEGIES.

- Daljit Singh, Fellow, Centre for Social and Economic Progress (CSEP)

Factors affecting energy demand and emissions

Economic growth and urbanisation

- **Increased energy consumption:** As India continues to experience robust economic growth, energy demand is expected to rise significantly. GDP growth projections suggest a substantial increase in energy consumption across all sectors, particularly in industrial and commercial activities.[2]

- **Urbanisation:** Rapid urbanisation will lead to higher electricity demand due to increased residential consumption and infrastructure development. Urban centres will require enhanced energy supply to meet the needs of growing populations.[3]

- **Sectoral growth:** All major energy-consuming sectors—industry, households, transport, and agriculture—are anticipated to see increased demand. Urban population growth will further accelerate this trend, particularly in sectors like buildings and transportation.

Continued role of coal

- **Coal as a key energy source:** Despite the push for renewables, coal is expected to remain a critical component of India's energy mix over the next decade. Projections indicate that India will add between 40 GW and 50 GW of coal-based capacity through 2025 to meet rising power demands. Electricity demand could increase by approximately 5-6 per cent annually, necessitating continued coal usage alongside renewable sources.[5]

- **Long-term coal dependency:** While the share of coal in electricity generation is expected to decline from over 70 per cent currently to around 55 per cent by 2030 (International Energy Agency), coal will still play a significant role in providing base load power. Many experts believe the decline could be much more but would require the needed ecosystem and regulatory framework.

Technological advancements

Advances in technology are likely to enhance energy efficiency across sectors, potentially moderating overall demand growth. Improved efficiency standards for appliances and industrial processes can lead to reduced per capita energy consumption. The integration of biomass co-firing could open up new markets for agricultural residues and waste products, contributing to a circular economy while addressing waste management issues.[6]

Transition to renewable energy

- **Shift towards renewables:** The transition from coal to renewable energy sources will reshape the energy landscape. The phase-down of coal is expected to drive an increase in renewable energy capacity, which will cater to a growing share of overall energy demand.[4]

- **Electric vehicle (EV) adoption:** The increasing adoption of electric vehicles is projected to significantly impact electricity demand. The transition to EVs will require substantial investments in charging infrastructure and grid capacity to accommodate the additional load, and if this load has to come from renewables, that will require additional capacity of RE in the country.

Future projections for 2030 and 2050

As per the latest National Electricity Plan, it has been estimated by CEA that renewable energy installed capacity is likely to be 3,36,553 MW by 2026-27. The contribution of the major renewable energy sources to reach an installed capacity of 3,36,553 MW by 2026-27 and 5,96,275MW by 2031-32. The contribution of RES will be around 35.04 per cent of the total energy of the country in the year 2026-27 and 43.96 per cent by 2031-32.[7]

Another report estimates, by 2050, India's total energy consumption is projected to reach approximately 120 quadrillion British thermal units (Btu), making it one of the largest consumers of energy globally. [8]

In phasing it out, we have to improve flexible operations of coal-based plants for electricity dispatch, especially with increasing levels of renewable energy.

- Anjan Kumar Sinha, Technical Director, Intertek

Two-thirds of additional energy demand is being generated by coal. The question then becomes how much of this additional demand can be met by clean energy.

- Ashwini K. Swain, Fellow, Sustainable Futures Collaborative

The scenarios for energy demand in India by 2030 and 2050 indicate a significant increase driven by economic growth, urbanisation, and technological advancements. However, challenges such as DISCOM financial viability, regulatory inconsistencies, and infrastructure limitations must be addressed to ensure that the energy sector can meet future demands sustainably. A coordinated approach involving policy reforms, investment in infrastructure, and effective management of subsidies will be critical for navigating this complex landscape successfully.

PATHWAYS TO REDUCE DEPENDENCE ON AND DECARBONISE THE COAL/THERMAL SECTORS BY 2030/2050

The future of coal and thermal power in India by 2030 and 2050 is shaped by various factors, including government policies, technological advancements, and international commitments to reduce greenhouse gas emissions.

We have set targets for 500 GW of Renewable Energy and if we add hydrogen then it is approximately 650 GW by 2030. We have to now assess if we are on track and how do we get there

Gurpreet Chugh,
Managing Director-India,
ICF

Options for reducing dependence on and decarbonising coal/thermal power

Long-term goal setting and planning

India is on track to meet its Nationally Determined Contributions (NDCs) for 2030 but faces challenges in long-term planning for decarbonisation. A coordinated approach that includes setting emission intensity targets rather than absolute emissions targets will allow flexibility in resource allocation among different energy sources, including renewables and thermal power.[9]

Improving efficiency of existing fleet

By adopting a combination of advanced technologies, operational optimisations, and innovative materials, coal-fired power plants can significantly enhance their performance while reducing emissions, aligning with global climate goals and ensuring a more sustainable energy future.

Efficient technology for new capacity

- **Supercritical and ultra-supercritical technologies:** These technologies operate at higher pressures and temperatures, significantly reducing CO_2 emissions compared to conventional plants.

- **Advanced ultra-supercritical (AUSC) technology:** The Department of Science and Technology's AUSC program aims to further improve efficiency by operating at higher pressures and temperatures. This technology has the potential to replace older, less efficient plants, contributing to both efficiency gains and lower emissions.[10]

Co-firing biomass

The practice of co-firing biomass with coal in existing power plants offers a pathway to reduce overall emissions. By integrating biomass, which is considered a renewable source, coal-fired plants can lower their carbon footprint significantly. This has also been mandated for all coal based thermal power plants by the Ministry of Power. [11]

Flexibility of coal-based power plants

- **Retrofitting existing plants:** Existing coal plants can be retrofitted for flexibility to complement intermittent renewables. This includes adjusting operational patterns to provide grid stability and support renewable energy integration.[12]

- **Coal-renewable hybrid projects:** Developing hybrid systems that combine coal with renewable energy sources can enhance grid reliability while gradually reducing reliance on coal. This approach can help manage peak loads and stabilise supply. [12, 13]

Challenges facing the coal/thermal power sector

Economic factors

- **Cost competitiveness:** With the declining costs of renewables, coal faces increasing competition from cheaper alternatives.[14]

- **Economic dependence on coal:** Many regions in India rely heavily on coal for employment and local economies. Transitioning away from coal may face resistance from stakeholders who are economically tied to the coal industry.

- **Financial viability of DISCOMs:** Payment Delays- Distribution companies (DISCOMs) are struggling financially, with significant overdue payments impacting their ability to invest in infrastructure necessary for transitioning towards renewable energy while maintaining thermal capacity.

Environmental concerns

- **Emissions and climate commitments:** As a major greenhouse gas emitter, India's reliance on coal poses challenges in meeting international climate commitments. The country has committed to increasing its non-fossil fuel capacity but faces scrutiny over its continued investment in coal. [15] [16]

Infrastructure limitations

- **Grid stability:** As renewable energy sources are integrated into the grid, maintaining stability becomes increasingly complex. The existing grid infrastructure needs upgrades to accommodate both renewable and thermal generation effectively.[17]

Policy and regulatory challenges

- **Inconsistent policies:** Fluctuating regulatory frameworks can create uncertainty for investors in both coal and renewable sectors. A clear long-term policy direction is needed to balance the transition while ensuring energy security. [1]

We need methodological tools on how to factor in shifting development pathways and track and simulate impact on emissions.

- Kaveri K Iychettira, Assistant Professor, School of Public Policy, IIT-D

Strategic recommendations

Towards 2030

- **Interim targets:** Establishing interim emission intensity targets for coal-fired power plants can guide gradual reductions in coal use while allowing for a smoother transition to renewables. India refrained from signing the Global Renewable Energy and Energy Efficiency Pledge at COP28 aimed at tripling renewable energy capacity to at least 11,000 GW by 2030.

- **Investment in renewables:** Significant investment in renewable energy infrastructure is necessary to replace coal capacity. [19] [20] [21]

Towards 2050

- **Complete decarbonisation:** The goal should be to achieve complete decarbonisation of the electricity sector by 2050, with a clear roadmap that includes phased reductions in coal usage.

- **Enhanced planning mechanisms:** Implementing a Five-Year National Electricity Plan (NEP) that is adaptive and incorporates stakeholder feedback will be crucial for achieving long-term goals.[19, 20, 21]

By 2030, India is expected to continue reducing its reliance on coal through increased investment in renewables and improved operational flexibility of existing thermal plants. By 2050, the aim is to have a decarbonised electricity sector with minimal coal usage, supported by robust planning and policy frameworks that facilitate this transition.

PATHWAYS OF SCALING UP RENEWABLE ENERGY BY 2030/2050, AND RELATED CHALLENGES

The future of renewable energy (RE) in India by 2030 and 2050 is characterised by ambitious targets, significant opportunities, and notable challenges. The reports provide a comprehensive view of the options available for scaling up RE capacity and the hurdles that must be overcome to achieve these goals.

Options for renewable energy by 2030 and 2050

- **Targeted capacity goals**: India aims to reach 500 GW of non-fossil fuel-based electricity generation by 2030, with a potential increase to 1 TW (1,000 GW) by 2035. This includes substantial contributions from solar (448 GW) and wind (122 GW) energy sources.[22]

- **Diversification of energy sources**: The transition will encompass not only solar and wind but also other renewable energy sources such as biomass, hydroelectric power, hybrid systems, and storage solutions. The integration of these sources will be vital for achieving a balanced energy mix.

- **Solar energy growth**: India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area, with most parts receiving 4-7 kWh per sq. m per day. As on 31.03.2022, India has achieved 5th rank in the world in solar power deployment.

In the RE sector, the long duration battery storage costs are falling rapidly. RE thus has the potential to provide round-the-clock power.

- Debmalya Sen, India Lead-Advanced Energy Solutions, World Economic Forum

Emerging tech in renewable energy like building integrated photovoltaic offers great scope for powering buildings in energy-efficient ways.

- Shantanu Roy, Policy Specialist, Center for Study of Science, Technology and Policy (CSTEP)

The solar power installed capacity has increased significantly in the last five years from 2.6 GW in March 2014 to 90 GW in August 2024.

- **Wind energy integration**: Wind is an intermittent and site-specific resource of energy and therefore, an extensive Wind Resource Assessment is essential for the selection of potential sites. The Government, through National Institute of Wind Energy (NIWE), has installed over 800 wind-monitoring stations all over the country and issued wind potential maps at 50 m, 80 m, 100 m and 120 m above ground level. The recent assessment indicates a gross wind power potential of 302 GW in the country at 100 m and 695.50 GW at 120 m above ground level. Most of this potential exists in seven windy States. [23]

- **Hydro power:** Generation from hydroelectric plants and pumped storage plants has a crucial role to play for future RE capacity expansion. Hydro power plants have fast ramp rates, they provide stability for RE generation and help in meeting peak demand.[24]

Total hydropower potential in the country was assessed as 84,044 MW (at 60 load factor) from a total number of 845 identified hydroelectric schemes which when fully developed would result in an installed capacity of about 148 GW. The hydroelectric potential includes 592 Hydroelectric schemes, each having installed capacity above 25 MW totalling to be 145 GW. The total energy potential has been assessed as 600 billion units per year. As on 31st March 2024, Hydro Electric Schemes (above 25 MW capacity) have a total installed capacity of 46.9 GW including Pumped Storage Schemes (PSS) capacity of 4.7 GW. [25]

Challenges facing renewable energy development

Financial constraints

- **Market dynamics/bidding complexity:** The shift to Firm and Dispatchable Renewable Energy (FDRE) tenders introduces complexities in bidding processes that require developers to enhance their market understanding and risk management capabilities.

- **Investment requirements and risks:** Achieving the targeted renewable capacity will require an estimated USD 293 billion by 2030, with an additional USD 101 billion needed to align with net-zero pathways proposed by the International Energy Agency (IEA). Current investment levels are insufficient to meet these needs, creating a significant funding gap.

- **Payment delays:** Delays in payments from distribution companies (DISCOMs) can deter investment in new projects, creating cash flow issues for developers and hindering project execution.[26, 27, 28]

- **Incentives and subsidies:** The recent MSEDCL coal-solar tender priced at INR 4.08/kWh highlights the economic landscape in which renewable energy must compete. To make RE more attractive, especially solar and wind with storage, subsidies may be necessary to lower their effective costs and enhance their competitiveness against traditional coal-based generation.[29 30]

To scale up renewable energy, diversifying energy sources as well as looking at hybrid systems and storage mechanisms are imperative.

- Parth Kumar, Programme Manager, Industrial Pollution, Centre for Science and Environment (CSE)

Infrastructure limitations

- **Land acquisition:** Securing land for large-scale renewable projects remains a significant hurdle. The scale required for solar farms, for instance, can lead to conflicts over land use, particularly in regions where local communities rely on those lands for agriculture or grazing.

- **Transmission infrastructure:** Significant upgrades to transmission infrastructure are required to accommodate the increased capacity from renewables. This includes expanding high-voltage transmission lines and developing new substations to facilitate the integration of renewable energy sources into the grid.[31]

- **Energy storage solutions:** The integration of battery storage systems is crucial for managing the intermittent nature of renewable sources.

Environmental concerns

- **Sustainability issues:** While expanding renewable capacity is crucial, it must be balanced with environmental considerations related to land use, biodiversity, and resource sustainability.

Regulatory and policy challenges

- **Inconsistent policies:** Fluctuating regulatory frameworks can create uncertainty for investors and developers. A stable policy environment is crucial for attracting long-term investments in renewable energy projects.

While ambitious capacity targets, technological innovations like battery storage and green hydrogen, and evolving policy frameworks offer pathways for growth, financial constraints, infrastructure limitations, and regulatory inconsistencies must be addressed proactively. A coordinated approach involving multiple stakeholders will be essential for realising India's renewable energy ambitions while ensuring sustainability and economic viability.

What will this mean in terms of finance/technology?

The transition to renewable energy (RE) in India by 2030 and 2050 entails significant financial and technological implications, as outlined in the provided reports. This transition is crucial for decarbonising the power sector and meeting international climate commitments.

We should think of what kind of services we need; rather than thinking of technology. We need least cost options and not lock in technology choices.

- Ann Josey, Fellow, Prayas (energy group), Pune

Financial implications

Investment needs

- **Substantial capital requirements:** India is projected to require up to USD 385 billion to achieve its target of 500 GW of renewable energy capacity by 2030. This includes around USD 190 billion to USD 215 billion for capacity addition and an additional USD 150 billion to USD 170 billion for transmission and distribution infrastructure. There is a need for coordinated long-term planning to attract the necessary funding, which could be in the range of hundreds of billions of dollars by 2030. This includes investments in infrastructure, technology, and capacity building. [32,33]

- **Investment in R&D:** Significant investments in research and development are necessary to innovate and scale low-emission technologies. Emphasise the need for a technology roadmap that supports the development of CCS, battery storage, and hybrid systems.

- **Innovative financing mechanisms:** To mobilise this capital, innovative financing solutions such as green bonds, public-private partnerships, and blended finance models must be explored. A wholesale change in bidding approaches for renewable projects can enhance financial viability and attract more investors.

Risk management

- **Mitigating financial risks:** The transition from coal to renewables involves inherent financial risks, particularly related to payment delays from distribution companies (DISCOMs). Reports indicate that overdue payments can exceed billions, creating cash flow issues for project developers. Effective risk management strategies are essential to ensure financial stability in the renewable sector.

- **Supportive regulatory framework:** A supportive regulatory environment is crucial for enhancing investor confidence. This includes clear policies on tariffs, subsidies, and incentives that can help stabilise returns on investment.

Challenges in mobilising finance

- **Payment delays from DISCOMs:** Overdue payments from distribution companies (DISCOMs), totalling approximately USD 10.42 billion, create significant cash flow issues for project developers, deterring investment in new renewable projects. Private sector will play a key role in improving DISCOM finances and enhance overall efficiency in the electricity distribution sector.[34,35]

- **High capital costs and interest rates:** The financing landscape is complicated by rising interest rates and high capital costs, which can reduce expected returns on equity for renewable projects.[36]

Diverse financing sources

- **Need for innovative financing mechanisms:** To meet ambitious targets, India must tap into diverse financing sources, including domestic and international investments. This could involve green bonds, blended finance from development banks, and deepening corporate bond markets to lower costs compared to traditional bank loans. [37] [38]

- **Public and private sector collaboration:** Continued policy support is crucial for attracting private sector investments while also ensuring that public funding mechanisms are robust enough to support the transition. [39] [40]

Economic externalities

- **Societal payouts from coal:** Coal generates significant revenue through taxes, royalties, and dividends from state-owned enterprises like Coal India Limited. However, these financial benefits must be weighed against the environmental and health costs associated with coal usage.[41]

Technological implications

- **Integration of new technologies:** Need for integrating advanced technologies such as energy storage systems, smart grids, and flexible coal plants that can support a higher share of renewables in the energy mix. Continued investment in R&D is vital for developing innovative solutions that can lower costs and improve efficiency. A focus on domestic manufacturing of renewable technologies can also reduce import dependence and enhance local job creation. [41]
- **Decarbonisation efforts:** Importance of innovation in cleaner technologies in thermal power generation, such as carbon capture and storage (CCS). Investing in these technologies can help mitigate emissions from existing coal-fired power plants.[41, 42]
- **Energy storage solutions:** As solar and wind become more prevalent, investments in energy storage technologies will be essential for managing intermittency and ensuring grid stability. This includes battery storage systems that can help smooth out supply fluctuations.
- **Smart grid development:** Implementing smart grid technologies will enhance demand-side management and facilitate better integration of renewable sources into the existing infrastructure. This is vital for maintaining grid reliability as renewable penetration increases.

The success of energy transition to renewable energy lies with integration of storage. Current capacities are limited & quantum of requirement is huge.

- Raghav Pachouri, associate director, Vasudha Foundation

- **Decentralised energy solutions:** Exploring decentralised energy solutions, such as microgrids and localised renewable projects, can reduce reliance on large-scale coal plants and increase resilience. This approach aligns with the trend towards renewable energy sources.
- **Long-term planning frameworks:** Effective long-term planning is essential for ensuring adequate infrastructure to support renewable energy growth. Developing an integrated National Electricity Plan (NEP) that includes both generation and transmission components can facilitate a smooth transition.[43]
- **Capacity building:** There is a pressing need for capacity building within distribution companies to enhance their resource planning capabilities. As highlighted in multiple

reports, effective resource planning will enable these companies to optimise their energy mix while meeting emissions intensity targets.

The shift towards renewable energy in India by 2030 and 2050 presents both opportunities and challenges in terms of finance and technology. Mobilising substantial investments through innovative financing mechanisms and creating a supportive regulatory framework are critical for success. Technologically, advancements in energy storage, smart grid implementation, and capacity building within distribution companies are essential to achieve a reliable and sustainable energy future. Additionally, long-term planning must account for climate resilience to ensure the robustness of the power sector amidst changing environmental conditions.

Support for vulnerable consumers is the need of the hour.

- Parth Kumar, Programme Manager, Industrial Pollution, Centre for Science and Environment (CSE)

SUBSIDY STRUCTURE NEEDED FOR THE TRANSITION?

The transition to renewable energy (RE) in India necessitates a well-structured subsidy framework to support the shift from fossil fuels, particularly coal, to cleaner energy sources. This framework must address the current challenges in the electricity sector while promoting sustainable development and equitable access to energy.

Key components of a subsidy structure for transition

Targeted revenue subsidies

- **Support for vulnerable consumers:** Targeted revenue subsidies ensure that electricity remains affordable for these small consumers, particularly as cross-subsidies from large commercial and industrial consumers diminish due to their shift towards renewable energy options.[45]

- **Estimation and disbursal improvements:** There is a pressing need for improved mechanisms for estimating subsidy requirements and ensuring timely disbursal to DISCOMs.[46]

- **Just transition funds:** Establishing funds to support communities and workers affected by the coal phase-out can mitigate economic impacts. This support could be crucial in maintaining social equity during the transition.[47]

Cross-subsidy reforms

- **Addressing cross-subsidy decline:** As larger consumers increasingly opt for alternative energy sources, the burden of supporting small consumers falls more heavily on state subsidies. A reformed structure that compensates DISCOMs for lost revenues while ensuring quality supply to small consumers is crucial.[48]

- **Incentives for renewable energy adoption:** The subsidy structure should also incentivise large consumers to adopt renewable energy solutions.

Policy integration and coordination

- **Long-term planning:** There is a need for coordinated long-term planning that integrates subsidy structures with broader decarbonisation goals. This involves aligning financial support mechanisms with renewable energy targets and ensuring that subsidies promote investments in clean technologies.[49]

Innovative delivery mechanisms

- **Improved governance and accountability:** Innovations in governance processes are needed to enhance accountability in subsidy delivery. This includes better targeting of subsidies to ensure they reach intended beneficiaries without excessive leakage or inefficiencies.[50]

- **Digital solutions:** Implementing digital platforms for subsidy distribution can streamline processes, reduce administrative costs, and improve transparency, making it easier for small consumers to access available support.

Environmental and economic considerations

- **Balancing fiscal responsibility with sustainability:** While increasing state subsidies is inevitable, it is essential to balance this with fiscal responsibility. The subsidy structure should not only focus on short-term relief but also encourage long-term investments in sustainable energy infrastructure and efficiency improvements.[51]

- **Pollution control technologies:** Subsidies for implementing pollution control technologies in existing coal plants can help reduce emissions during the transition period.[52]

- **Encouraging private sector participation:** To complement public funding, policies should be designed to attract private investment into renewable energy projects through tax incentives or matching grants, thereby reducing reliance on state subsidies over time.

- **Flexible pricing mechanisms:** Implementing flexible pricing models that reflect the true cost of energy generation and consumption can encourage efficient energy use. This approach aligns with recommendations in various reports regarding the need for updated pricing strategies.

- **Flexibility in bidding processes:** A wholesale change in bidding approaches is necessary to facilitate the growth of renewables. Subsidies could be tied to performance metrics in these bids, encouraging developers to meet specific sustainability targets while ensuring competitive pricing.

Effective governance, innovative delivery mechanisms, and alignment with long-term decarbonisation goals are critical components of a comprehensive subsidy structure. By implementing these strategies, India can ensure an equitable transition towards a sustainable energy future while maintaining economic stability.

KEY DISCOM CHALLENGES AND STRUCTURAL BARRIERS TO AN EFFECTIVE ENERGY TRANSITION

The roadmap for transitioning to a sustainable energy future in India faces significant challenges, particularly concerning electricity distribution companies (DISCOMs) and other systemic issues. These challenges are critical to address to ensure the viability of the energy sector and the achievement of decarbonisation goals.

DISCOM-related challenges

Financial instability

- **Accumulated losses:** As of FY 2022-23, DISCOMs collectively reported losses of approximately INR 6.77 lakh crores, with an annual increase of about 10 per cent since 2015-16.[53] DISCOMs rely heavily on state government revenue subsidies to maintain operations. In FY 2022–23, these subsidies amounted to INR 1.66 lakh crores, about 18 per cent of total revenue requirements for DISCOMs.[54]

Operational inefficiencies

- **High costs of power procurement:** Power procurement costs account for around 70 per cent of DISCOM expenses. Poor planning and long-term contracts with high costs contribute significantly to financial losses. Additionally, inefficiencies in coal procurement and rising coal prices exacerbate these issues.

- **Energy losses:** High levels of energy theft, poor metering, and inadequate energy accounting lead to substantial revenue losses. The Aggregate Technical and Commercial (AT&C) losses in India is around 18-19 per cent, compared to 6-7 per cent in developed countries. This inefficiency in revenue recovery further strains DISCOM finances. Though initiatives like Deen Dayal Upadhyaya Gram Jyoti Yojana aims to reduce AT&C losses, further innovations are required to minimise energy loss.[55]

- **Flexibility requirements:** Coal plants should enhance their flexibility in operations to accommodate fluctuations in renewable generation. This transition will require investment in technology and training for DISCOM staff.[56]

Regulatory and policy challenges

- **Inconsistent tariff adjustments:** Many states have not adjusted tariffs regularly to keep pace with rising costs. For instance, in Rajasthan and Tamil Nadu, there were no tariff increases for several years, leading to accumulated deficits that necessitate drastic future tariff hikes.[57]

- **Delayed payments from government entities:** Delays in subsidy payments from state governments and other departments create cash flow problems for DISCOMs, compounding their financial difficulties.

- **Need for structural reforms:** There is a pressing need for regulatory reforms that promote autonomy and transparency within DISCOMs. This includes enhancing the capabilities of State Electricity Regulatory Commissions (SERCs) and ensuring that DISCOMs can operate more independently from political pressures.

Other challenges

Rising energy demand

- **Increased consumption:** Power demand has grown significantly, with an increase of 8.9 per cent between FY 2021 and FY 2023. This surge in demand places additional pressure on DISCOMs to deliver reliable electricity while managing rising costs associated with coal procurement. [58]

- **Dependence on coal:** Despite the push for renewables, coal remains a critical component of India's energy mix. The rising prices of imported coal have escalated power purchase costs for DISCOMs, complicating their financial

situation further. Without a clear strategy for phasing down coal while increasing renewable capacity, DISCOMs may struggle to adapt.[59] [60]

Technological adaptation

- **Need for modernisation:** As the energy landscape evolves with increased renewable integration, DISCOMs must adopt new technologies for better grid management and efficiency. This includes investments in smart grids and energy storage solutions to handle intermittent renewable sources effectively.

Public finance implications

- **Impact on state budgets:** The financial burden on DISCOMs translates into significant implications for state budgets. If state governments were to fully absorb the losses incurred by DISCOMs, it could lead to a substantial increase in public expenditure, impacting overall fiscal health. For example, the required support could represent about two per cent of the State Gross Domestic Product (GSDP) on average across several states. [61]

Socio-economic impacts

- **Stranded assets risk:** The rapid transition towards renewables may lead to stranded assets in the coal sector, affecting regions dependent on coal mining and thermal power generation. This shift could create economic challenges for communities reliant on these industries.[62]

- **Cost-competitiveness of renewables:** As renewable energy becomes cheaper, coal faces increasing competition. Coal plants must adapt their pricing strategies or risk becoming obsolete.[63]

- **Workforce transition:** The RE sector requires different skill sets compared to traditional coal-based industries, leading to potential job mismatches and necessitating retraining programs for workers transitioning from fossil fuels to renewables. [64]

- **Public acceptance:** Gaining public support for the transition, especially in coal-dependent regions, is crucial. Resistance from communities that fear job losses or energy price increases can stall progress.

Policy and regulatory framework

- **Inconsistent policies:** The lack of a cohesive policy framework can create uncertainty for investors and hinder the timely development of renewable

projects. Fluctuating regulatory environments make it difficult for DISCOMs to plan effectively. [65]

- **Comprehensive policy framework needed:** A coordinated approach including, revising subsidy structures, enhancing operational efficiencies in DISCOMs, and establishing a regulatory environment conducive to investment in renewables is essential to reform the electricity sector comprehensively.

The challenges facing DISCOMs and the broader electricity sector in India are multifaceted and deeply interlinked with financial stability, operational efficiency, regulatory frameworks, and technological advancements. Addressing these challenges is critical for ensuring a successful transition to a sustainable energy future while maintaining affordability and reliability for consumers. A strategic approach involving policy reforms, targeted subsidies, and investments in technology will be essential for navigating this complex landscape effectively.

EQUITY CONSIDERATIONS FOR THE ROADMAP

The roadmap for India's energy transition involves several equity considerations that are crucial for ensuring a just and inclusive shift towards renewable energy.

The models we are currently using are techno-economic models. We don't have robust socio-technical models yet.

- Manish Kumar Shrivastava, Senior Fellow & Associate Director, TERI

Key equity considerations

Social justice and inclusion

- **Impact on marginalised communities:** The transition to renewable energy must consider the potential adverse effects on marginalised communities, particularly those dependent on traditional energy sources. Policymakers must ensure that benefits are equitably distributed and that any disbenefits are minimised.

- **Land acquisition issues:** The acquisition of land for renewable energy projects often disproportionately affects rural households, which rely on land for their livelihoods. The Land Acquisition Act of 2013 mandates assessments to evaluate impacts on local communities, but effective implementation is critical to prevent inequities.

- **Community engagement:** Policymakers need to engage with local communities to understand their needs and

perspectives. This includes considering alternative land use strategies that protect livelihoods, such as disaggregating large solar parks into smaller plots to minimise displacement and disruption.[66]

Gender equity

- **Under-representation of women:** Women constitute only about 10 per cent of the workforce in India's energy sector, with even lower participation in technical roles. Women face systemic barriers that hinder their entry and retention in the renewable energy workforce, particularly in technical positions.

- **Empowerment initiatives:** Programs aimed at empowering women in renewable energy roles can enhance their participation and leadership. For instance, initiatives that provide training and support for women in technical fields can promote more inclusive decision-making processes.

Job creation and workforce transition

- **Employment opportunities:** The renewable energy sector has the potential to create millions of jobs. Estimates suggest that installing 238 GW of solar and 101 GW of wind capacity could generate approximately 3.4 million jobs by 2030. However, these jobs may not match the quantity or quality of employment currently provided by fossil fuel industries, particularly coal. [67]

- **Reskilling initiatives:** A significant challenge lies in transitioning workers from fossil fuel sectors to renewable energy jobs. Policies that support retraining and re skilling initiatives to help these workers transition to new roles in the renewable energy sector are essential.[68] [69]

Economic opportunities

- **Stranded assets:** The rapid shift away from coal could lead to stranded assets in coal-dependent regions, creating economic challenges for communities reliant on coal mining. Policymakers must consider strategies to mitigate these impacts through targeted support and diversification of local economies.[70]

- **Financial security:** As the renewable sector grows, it is vital to ensure that communities dependent on fossil fuel supply chains do not face increased financial insecurity. This requires designing policies that support economic diversification and resilience in affected regions. [71]

Energy access and affordability

- **Addressing energy poverty:** Approximately 150 million people in India lack access to electricity. The transition must prioritise providing affordable and reliable energy access to underserved communities. Distributed renewable solutions, such as solar home systems, can play a crucial role in addressing energy poverty while ensuring that marginalised populations are included in the benefits of the transition.[71] [72]

- **Affordability concerns:** As new technologies are deployed, it is essential to ensure that costs do not disproportionately burden low-income households. Policymakers should consider subsidy structures that support vulnerable populations while promoting clean energy adoption.

- **Distributed energy resources:** Initiatives like the Pradhan Mantri Surya Ghar Muft Bijli Yojana aim to solarise households and cover a significant portion of installation costs, thus promoting equity in energy access through distributed solar solutions.[73]

Procedural justice

- **Stakeholder engagement:** An equitable transition requires active participation from all stakeholders, particularly those from marginalised communities.

- **Transparency and accountability:** Building trust among stakeholders is essential for a successful transition. Transparent processes that hold decision-makers accountable can help mitigate concerns about inequities arising from large-scale renewable projects.

Equity considerations are fundamental to India's roadmap for transitioning to renewable energy. Addressing issues related to social justice, gender equity, economic opportunities, energy access, and procedural justice will be crucial for ensuring a just transition that benefits all segments of society. Policymakers must adopt inclusive strategies that engage diverse stakeholders and prioritise the needs of marginalised communities while leveraging the potential of renewable energy to drive sustainable development.

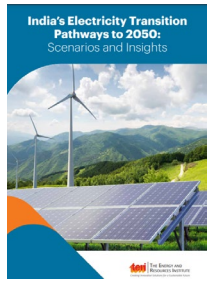
RESEARCH ANTHOLOGY ON ENERGY TRANSITION

SYNCHRONIZING ENERGY TRANSITIONS TOWARD POSSIBLE NET ZERO FOR INDIA: AFFORDABLE AND CLEAN ENERGY FOR ALL

Author/s: Garg A., Patange, O., Vishwanathan S.S., Nag, T., Singh, U., and Avashia V.

Year: 2024

Report summary: The report attempts to answer key questions related to India's energy trajectory such as how much energy does India need to achieve the high value of Human Development Index (HDI); what are pathways to achieve this; what are the energy mix projections for this until 2070 (our declared net-zero target year); what would be the cost of electricity to the end user; what would be the carbon emissions until 2070; what would be the investments required for energy transitions towards net-zero at 2070; estimation of other challenges and opportunities (RE integration, the requirement of critical minerals, Carbon Capture Utilisation and Storage (CCUS), natural gas, ethanol, hydrogen) in energy transitions towards achieving net-zero (NZ) in 2070. We find that there is no silver bullet to achieve NZ, myriad technologies must co-exist in our energy basket as coal is projected to continue until the next two decades as the backbone of the Indian energy system. Also, no NZ is possible without substantial nuclear power and Renewable energy generation by 2070.



INDIA'S ELECTRICITY TRANSITION PATHWAYS TO 2050

Author/s: Neshwin Rodrigues, A.K. Saxena, Shubham Thakare, Raghav Pachouri, G. Renjith

Year: 2023

Report summary: The report discusses India's electricity transition pathways towards 2050 under different demand and supply scenarios. Electricity demand is expected to increase fourfold by 2050. Decarbonising the power sector by shifting to cheaper renewable energy sources could lower overall system costs by 30-40 per cent compared to today. The unconstrained renewable energy scenario with the highest renewable capacity addition is the most cost-optimal. Large-scale renewable integration could reduce grid emissions intensity by up to 90 per cent by 2050. A detailed assessment of India's renewable resource potential and land requirements is needed given the scale of renewable capacity addition required.

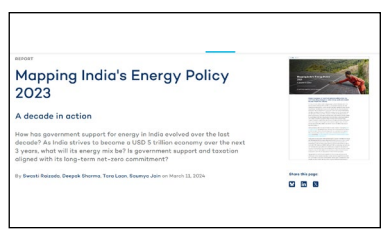
Energy storage technologies will play a crucial role in integrating high shares of variable renewable energy into the grid. Though coal-based plants could meet only around 10 per cent of generation by 2050, they will still have an important role in meeting daily and seasonal peak demand. Investments of USD 1.2–1.6 trillion will be needed by 2050 for new generation capacity and energy storage to meet growing electricity demand. Further research is needed to assess the stability and resilience of the grid with high renewable penetration as well as the impact of cross-border electricity trade. Periodic reviews of the study are also required.

INDIA'S ENERGY OVERVIEW 2024

Author/s: Raghav Pachouri and Sonam Sinha

Year: 2024

Report summary: This document offers a detailed analysis of India's energy and electricity sector, covering key aspects such as the primary energy mix, per-capita consumption, and electricity capacity. It outlines major trends in electricity additions over the last five years, with a focus on state-wise solar and wind installations, and contrasts renewable energy potential with current installations. The report also examines India's electricity generation mix, source-specific performance metrics, and causes of thermal generation losses and outages. Additionally, it presents an overview of the Indian Electricity Exchange (IEX) market, national and state-level electricity demand, supply, peak demand trends, and coal and petroleum statistics. Daily oil and gas price updates, electric mobility progress, recent renewable energy initiatives, and key data highlights from August 2024 are also included, offering a comprehensive view of the evolving energy landscape.



PORTAL: MAPPING INDIA'S ENERGY POLICY 2023

Author/s: Swasti Raizada, Deepak Sharma, Tara Laan, Saumya Jain

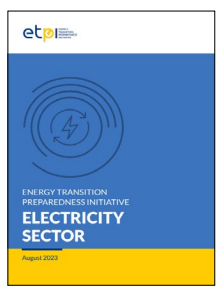
Year: 2024

PORTAL: MAPPING INDIA'S ENERGY SUBSIDIES 2023

Joint initiative by: IISD, CEEW, Vasudha Foundation, Global Subsidies Initiative

Year: 2023

Report and portal summary: "Mapping India's Energy Policy 2023 is the latest publication in a series of annual updates by IISD on government support for energy in India. The publication highlights the key shifts in India's energy policy over the last decade. We find that India's fossil fuel subsidies have declined by 59 per cent since 2014—an accomplishment that many other large economies have struggled to achieve. However, the 2022 energy crisis—together with India's growing energy demand—led the country to bolster all forms of energy supplies and adopt a mixed approach to fossil fuels and clean energy. India's mixed approach led its energy subsidies to increase to INR 3.2 lakh crore (USD 39.3 billion) in FY 2023—the highest amount in nine years. Both clean energy and fossil fuel subsidies grew by around 40 per cent from FY 2022. Fossil fuels subsidies remained five times the subsidies for clean energy in FY 2023."



ENERGY TRANSITION PREPAREDNESS INITIATIVE — ELECTRICITY SECTOR

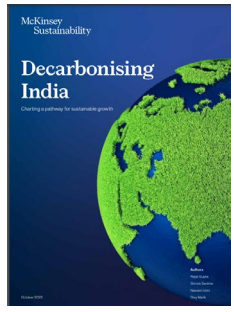
Author/s: Josey et al.

Year: August, 2023

Report summary: Energy Transition Preparedness Initiative (ETPI) is a joint initiative by PEG, SFC and World Resources Institute India India. It is a multi-year, trans-sectoral project to study energy transition preparedness and progress in selected states in India. ETPI aims to study critical process, planning and institutional aspects of the transition as a necessary complement to the techno-economic drivers covering the three sectors — viz. electricity, transport, and building — and crosscutting aspects of energy transition. Find out more about the research initiative at etpi.in

The study covers 24 themes across these sectors and key thematic areas as outlined in the ETPI Guidebook. Among these, 11 themes pertain to aspects of the electricity sector related to policy vision, renewable promotion, development of coal thermal sector, DISCOM finances, sales migration, agricultural supply and demand, role of regulatory institutions, demand side management and integrated resource planning. This study is conducted to understand trends in ten states

namely- Bihar, Delhi, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Tamil Nadu. It covers the status of various issues as on 2020-21 and progress on selected themes.



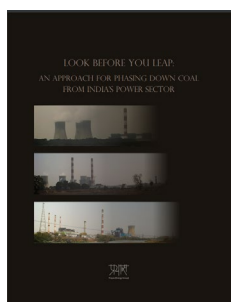
DECARBONISING INDIA: CHARTING A PATHWAY FOR SUSTAINABLE GROWTH

Author/s: Rajat Gupta

Year: 2022

Report summary: This report outlines two possible pathways for India's decarbonisation by 2070: the Line of Sight scenario based on current policies and the Accelerated scenario with more aggressive policies and faster technology adoption. Both scenarios could create significant carbon savings for the world, with the Accelerated scenario abating 80 additional $GtCO_2e$ compared to the LoS scenario.

India's transition must be set up within this decade as most of India's future growth and infrastructure development will happen after 2030. Policy signals and demand creation are needed now to guide investments. India would benefit from the transition through lower power costs, higher farmer incomes, and forex savings. However, land pressure and job impacts would need to be managed. Transitioning key sectors like power, transport, industry, and agriculture would require scaling up investments, financing, technology breakthroughs, and demand signals like carbon pricing. Seven levers could deliver most of the potential abatement — renewable energy, electrification, green hydrogen, sustainable agriculture, circularity, natural climate solutions, and CCUS. Urgent actions are needed within this decade to accelerate the transition in an orderly manner, including setting a detailed decarbonisation plan, implementing a carbon market, enabling financing, scaling up renewables, optimising land use, and fostering manufacturing and R&D capabilities.



LOOK BEFORE YOU LEAP: AN APPROACH FOR PHASING DOWN COAL FROM INDIA'S POWER SECTOR

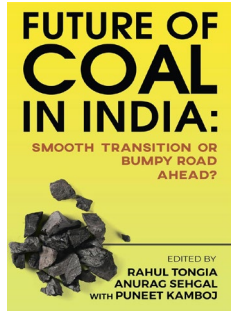
Author/s: Ashok Sreenivas, Maria Chirayil

Year: 2022

Report summary: The report discusses the need for a carefully planned approach to phase down coal from India's power sector. An unplanned phase down could lead to challenges like

power shortage, high cost of power, and resource lock-ins. The authors propose an analysis-based approach that considers planning at the state level to account for state-specific factors, accounting for growing future demand and demand variations across time and seasons, considering existing legal and contractual obligations of power plants, factoring in economic and technical considerations and adhering to norms and considering financial and capital requirements.

The report recommends using sophisticated modeling tools to develop multiple scenarios that reflect different possible futures. This can help inform demand and supply assessments which would lead to decisions on capacity retirement and addition. Such an analysis-based approach, along with periodic reviews, would help phase down coal while meeting demand at least cost, minimising emissions, and avoiding undesirable lock-ins. The approach would also aid in planning for a just transition and mines opening and closure.



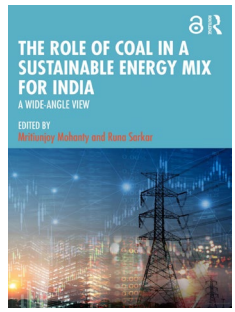
FUTURE OF COAL IN INDIA: SMOOTH TRANSITION OR BUMPY ROAD AHEAD?

Edited by Rahul Tongia, Anurag Sehgal, Puneet Kamboj

Year: 2020

Report summary: This report discusses the future of coal in India and the challenges and opportunities it faces. Coal currently provides about half of India's energy due to its domestic availability and low cost. However, renewables are now the cheapest option for new power generation. While coal has many negative externalities, it also provides significant economic benefits through jobs, revenue, and subsidies to sectors like Indian Railways. India imposes a low implicit carbon tax on coal of only around USD three per ton of CO_2 emitted, making it difficult to impose a higher tax that could impact electricity prices. Going forward, India will focus on a controlled coal transition, increasing domestic coal supply, growing renewables, and cleaning up coal emissions. But coordinating these efforts remains challenging.

Post COVID-19, fiscal constraints and political will for systemic change may be reduced, though there are also calls for a 'greener' recovery. Coal will likely remain an important part of the energy mix for decades.



THE ROLE OF COAL IN A SUSTAINABLE ENERGY MIX FOR INDIA

Chapter: Future-proofing India's Coal PSUs

Author/s: Saarthak Khurana, Arnab Sarkar, and Balasubramanian Viswanathan

Year: 2023

Report summary: The report discusses the need for coal-based public sector undertakings in India like Coal India Limited and NTPC to diversify and decarbonise their businesses in the face of India's climate commitments and transitioning energy system. CIL and NTPC currently dominate India's coal and power sectors but face risks from India's targets to reduce coal use and transition to renewables.

The report provides a framework to identify the financial risks to CIL and NTPC from a changing energy system using different scenarios. It further recommends that CIL and NTPC develop diversification strategies in low-carbon businesses like renewables and storage to mitigate risks and maintain their dominant positions. It proposes a framework using SWOT analysis, Porter's diamond analysis, and multi-criteria decision analysis to identify suitable diversification opportunities.

The report recommends frameworks and strategies to identify and pursue suitable low-carbon opportunities while ensuring financial viability. Partnerships among firms can help them diversify into green businesses like green hydrogen, leveraging their individual strengths and sharing risks.

DECOMMISSIONING OF COAL-BASED PLANTS IN INDIA AND ITS RAMIFICATIONS

Author/s: Somit Dasgupta

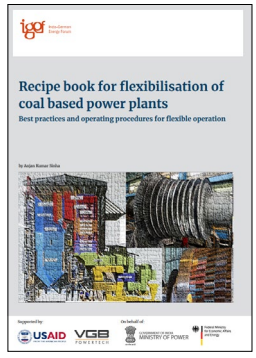
Year: 2024

Report summary: Coal currently accounts for about 50 per cent of India's installed power capacity and 73 per cent of power generation. However, phasing out coal-based power is essential for India to achieve its net-zero target by 2070.

Gas-based power in India is not viable due to high prices and lack of domestic gas supply. Environmental norms for coal plants in India have also been diluted. There are several issues around decommissioning coal plants in India like employment

losses, impact on government revenues, and lack of proper land use policies. There are also no proper laws mandating remediation of decommissioned plant sites.

For India to phase out coal plants, it needs to increase the pace of renewable energy capacity addition significantly. However, several issues like high interest rates, cumbersome land acquisition, and poor financial health of DISCOMs are hampering growth of renewables in India. The paper concludes that India will likely have to continue relying on coal-based power for the next few decades to meet the growing demand.

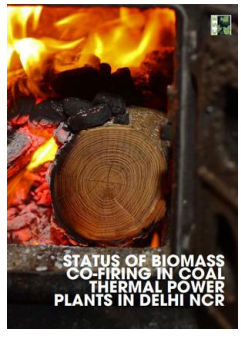


RECIPE BOOK FOR FLEXIBILISATION OF COAL BASED POWER PLANTS BEST PRACTICES AND OPERATING PROCEDURES FOR FLEXIBLE OPERATION

Author/s: Anjan Kumar Sinha

Year: 2020

Report summary: The Indian energy transition is unique due to its coal-dependent energy mix. The success of the deployment of large-scale renewable energy will be dependent on the support from coal generation flexibility. This book provides cost-effective solutions and guidance for the adoption of flexibility by coal-based generating plants.



STATUS OF BIOMASS CO-FIRING IN COAL BASED THERMAL POWER PLANTS IN DELHI NCR

Author/s: Anubha Aggarwal

Year: 2023

Report summary: In October 2021, the Ministry of Power (MoP) mandated the use of biomass residue for co-firing in coal-based thermal power plants. The policy was introduced to address the twin challenges of curbing emissions from coal power plants and pollution from burning crop residue. According to the policy, coal is to be replaced with densified biomass, called pellets, by 5–10 per cent by weight.

The Centre for Science and Environment conducted an extensive field survey to understand the status of biomass co-firing, and what limits its uptake in the 11 coal-based power plants in Delhi NCR. Records show that not even one per cent of the coal used has been replaced with biomass in any of the coal thermal power plants in Delhi NCR. Co-firing is being carried out only intermittently based on the availability of biomass. Keeping a check on the escalating cost of biomass pellets and providing more clarity when it comes to regulatory mechanisms are two measures that can help with the implementation of the mandate.

BIO-MASS POWER GENERATION AND ITS CHALLENGES ESPECIALLY IN REFERENCE TO CO-FIRING IN COAL BASED THERMAL POWER PLANTS

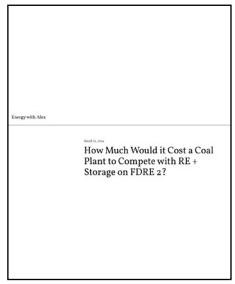
Author/s: R. K. Sharma

Year: 2022

Report summary: The report discusses biomass power generation and co-firing in coal power plants in India, especially in Rajasthan state. Biomass power generation can help reduce carbon emissions, tackle farm stubble burning and utilise agricultural waste. The government has policies promoting biomass utilisation and co-firing up to 5-10 per cent in coal power plants to reduce emissions and utilise farm residue.

Rajasthan has good potential for biomass and renewable energy. However, biomass power generation in the state is still low at around 0.44 per cent of total installed capacity. Key challenges for biomass co-firing are the availability, transportation and storage of biomass pellets, technical modifications required at power plants, fire safety issues, and higher costs compared to coal.

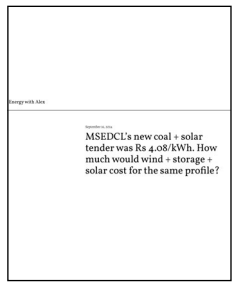
Biomass has a higher ash content, alkali metals and volatile matter which can cause slagging, fouling and corrosion in power plants. There are also issues with biomass pellet supply and pricing. The report recommends increasing India's pellet manufacturing capacity, providing incentives to farmers, and establishing stable supply chains and pricing mechanisms for biomass to increase biomass power generation. There are considerable technical, logistical and economic challenges that need to be addressed for its large-scale adoption in India.



HOW MUCH WOULD IT COST A COAL PLANT TO COMPETE WITH RE + STORAGE ON FDRE?

Author/s:Alexander Hogeveen Rutter

Year: 2024



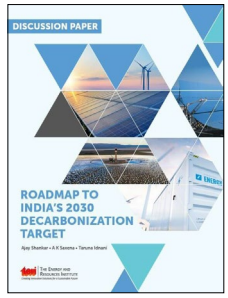
MSEDCL'S NEW COAL + SOLAR TENDER WAS RS. 4.08/KWH. HOW MUCH WOULD WIND + STORAGE + SOLAR COST FOR THE SAME PROFILE?

Author/s: Alexander Hogeveen Rutter

Year: 2024

Combined summary: When it comes to decarbonising India's power sector, a common narrative is that energy storage is "not ready" or "too expensive" to be deployed, and therefore new coal is still required to meet firm load. In particular, SECI's FDRE-2 tender was cancelled after tendering as it was deemed "too expensive". The first report analyzes the cost of FDRE-2 relative to new coal to meet the same generation profile. Similarly, a recent MSEDCL coal + solar tender was said to be cost competitive with new RE + storage. The second report analyzes the cost of meeting the same generation profile using wind + solar + storage.

In both analyses, new wind + solar + storage is shown to be substantially cheaper than new coal to meet the same level of reliability/generation profile. Together, these reports clearly demonstrate the fallacy of the environment vs. development trade-off (at least in the power sector). Furthermore, they emphasise the need for new power to be procured in technology-neutral competitive auctions (rather than the current practice of separate tenders for coal and renewables).



ROADMAP TO INDIA'S 2030 DECARBONIZATION TARGET

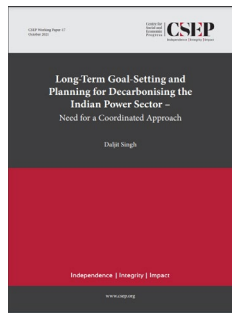
Author/s: Ajay Shankar, AK Saxena, Taruna Idnani

Year: 2022

Report summary: While India has made progress towards renewables, fossil fuels still account for over 70 per cent of

power generation. The report examines feasible pathways for India to achieve its decarbonisation targets by 2030. Some key challenges include rapidly increasing electricity demand as India develops and living standards rise, high current dependence on coal for power generation, and a need for significant investments in renewable energy and grid infrastructure.

The report recommends actions like scaling up renewable energy capacity, improving grid flexibility, transitioning industry to low-carbon fuels, electrifying transport, and promoting energy efficiency. Achieving India's 2030 targets will require coordinated efforts across government, industry and the public to rapidly transition the country's energy system.

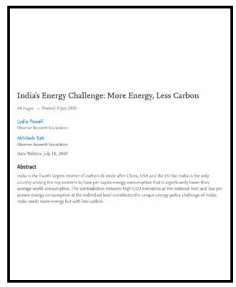


LONG-TERM GOAL-SETTING AND PLANNING FOR DECARBONISING THE INDIAN POWER SECTOR — NEED FOR A COORDINATED APPROACH

Author/s: Daljit Singh

Year: 2021

Report summary: So far, India has done well in mitigating GHG emissions from its power sector with dramatic additions of renewable energy (RE) to its generation mix. However, the road ahead will be challenging, requiring a coordinated approach to long-term goal-setting and planning. For an economic, rapid and smooth energy transition the following approach is recommended: (1) Establish an autonomous and credible agency that will set the target year for complete decarbonisation of the power sector; (2) Break up the period between now and the target date into shorter periods of five years, each with its own interim target for permissible emission intensity in terms of grams of CO_2-eq per kWh of electricity sold, to be applied to all load-serving entities; (3) Assign the responsibility for monitoring the progress of reductions in emissions reduction and recommending mid-course corrections to the independent agency; (4) Strengthen the capacity of distribution companies for effective long-term resource planning.



INDIA'S ENERGY CHALLENGE: MORE ENERGY, LESS CARBON

Author/s: Lydia Powell, Akhilesh Sati

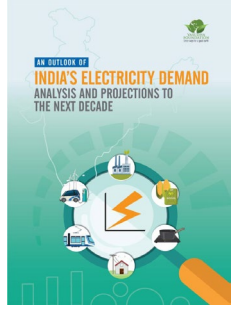
Year: 2020

Report summary: The report discusses India's energy challenges and potential policies to address them. India needs to provide more access to electricity and cooking fuels

while reducing carbon emissions. However, low demand due to low incomes limits the effectiveness of energy access policies. Improving economic conditions and women's empowerment are key.

India's renewable energy targets have been ambitious but have also led to oversimplification of projects, driving out small players. There needs to be a balance between cost and carbon savings goals.

Policies to commercialise coal mining and bring natural gas under GST can help create fuel markets. Support for natural gas power generation and a gas trading hub can boost production. Separating energy supply as a public good from distribution as an economic good can help energy access and direct benefit transfers and prepaid cards can improve revenue collection. State-level policies tailored for local conditions can help the wind energy industry. Policies to decarbonise transport through electrification must consider the large costs and loss of tax revenue from petroleum. A technology-agnostic approach is needed. Using natural gas as a transport fuel through CNG and LNG can provide environmental and economic benefits if brought under GST and with a gas grid to facilitate distribution. Increasing competition, regulatory independence, and market signals through a gas trading hub can boost domestic oil and gas production.

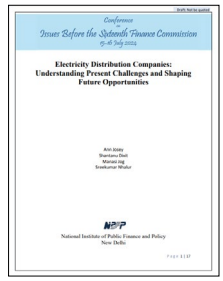


AN OUTLOOK OF INDIA'S ELECTRICITY DEMAND ANALYSIS AND PROJECTIONS TO THE NEXT DECADE

Author/s: Raghav Pachouri, Shubham Thakare, Sonam Sinha

Year: 2023

Report summary: Electricity demand forecasting is crucial for effective power system planning, ensuring reliable and affordable power. With India's electricity demand set to grow rapidly, driven by post-pandemic economic recovery, electrification of transport, increased residential appliance use, and manufacturing expansion under government policies, this report provides a detailed analysis of national and state-level electricity demand projections over the next decade. The projections are based on historical data, current consumption trends, demographic shifts, and economic indicators. Two key methodologies—Econometric Regression (ER) and Partial End-Use Method (PEUM)—are employed to assess future electricity demand comprehensively


Conference
Issues Before the Fifteenth Finance Commission
15-16 July 2024

Electricity Distribution Companies: Understanding Present Challenges and Shaping Future Opportunities

Ann Josey
Shantanu Dixit
Manasi Jog
Sreekumar Nhalur

National Institute of Public Finance and Policy
New Delhi

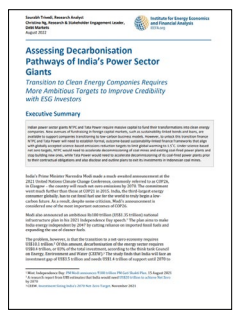
ELECTRICITY DISTRIBUTION COMPANIES: UNDERSTANDING PRESENT CHALLENGES AND SHAPING FUTURE OPPORTUNITIES

Author/s: Ann Josey, Shantanu Dixit, Manasi Jog and Sreekumar Nhalur

Year: 2024

Report summary: This working paper highlights the financial challenges of state-owned electricity distribution companies which supply about 80 per cent of power in India. It also presents the fiscal implications of rising losses and subsidies, especially given the magnitude of state government support provided to these companies.

The main thrust of this piece is on how technological advancements and market structure changes will further adversely impact DISCOMs' business unless timely actions are taken. Such impacts will increase the dependence of DISCOMs on fiscal support, thereby intensifying the public finance challenge. The paper also highlights changes that must be made to the role of DISCOMs to help them adapt to the future energy landscape. The aim of such changes is to ensure DISCOM viability, ease the burden on the state exchequer, and protect small consumers who rely on publicly owned DISCOMs for their electricity needs


Assessing Decarbonisation Pathways of India's Power Sector Giants

Transition to Clean Energy Companies Requires More Ambitious Targets to Improve Credibility with ESG Investors

Executive Summary

ASSESSING DECARBONISATION PATHWAYS OF INDIA'S POWER SECTOR GIANTS

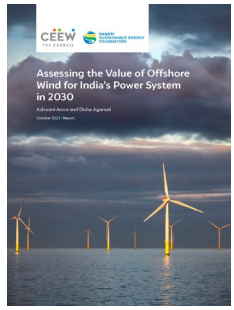
Author/s: Saurabh Trivedi & Christina Ng

Year: August 2022

Report summary: The report discusses the decarbonisation plans of two major Indian power companies, NTPC and Tata Power, in comparison to Italian power company Enel. NTPC and Tata Power need to establish more ambitious greenhouse gas emissions reduction targets that are aligned with science-based targets to help transform into low-carbon companies and attract foreign investors. Currently their emissions reduction targets are below what is recommended to limit global warming to 1.5 degrees Celsius.

However, they lack a clear investment strategy and financing framework to achieve these targets. Enel has set more ambitious short, medium and long-term emissions reduction targets that are certified by the Science Based Target initiative and aligned with well below 2 degree Celsius scenario. This has helped the company raise billions in transition finance through sustainability-linked bonds. They have outlined a roadmap and investment plan to achieve its clean energy targets.

The report recommends that NTPC and Tata Power establish a formal sustainability-linked finance framework with science-based emission reduction targets and financing strategies to help access sustainable finance markets and transition into low-carbon companies.



ASSESSING THE VALUE OF OFFSHORE WIND FOR INDIA'S POWER SYSTEM IN 2030

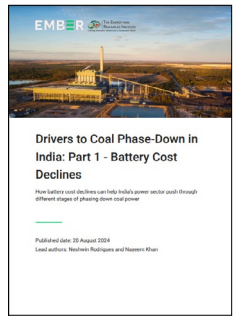
Author/s: Disha Agarwal & Ashwani Arora

Year: 2023

Report summary: This report assesses the potential benefits of offshore wind energy for India's power system in 2030. It analyses two scenarios — Pool A with only onshore wind and solar PV, and Pool B with four per cent offshore wind in addition to eight per cent onshore wind and 19 per cent solar PV.

The report finds that adding offshore wind to the energy mix can improve capacity value and system adequacy during peak demand hours, especially in the monsoon months, lowering the chances of renewable energy curtailment. Further, it reduces uncertainty and reserve requirements by lowering the variability in the generation profile, especially during non-solar generation hours. This will have a negligible impact on the variability and ramping needs of the system. Existing ramping capabilities may be sufficient.

Adding offshore wind to the energy mix will result in avoided power procurement costs from the exchange compared to the levelised cost of electricity of offshore wind. However, savings are negative for peak demand hours. There will be minimal impact on the load following capability and balancing needs of the system. Additional balancing reserves may not be required due to offshore wind. It will also lead to reduced renewable energy over-generation and lower chances of curtailment, especially at the all-India level.



DRIVERS TO COAL PHASE-DOWN IN INDIA: PART 1 — BATTERY COST DECLINES

Author/s: Neshwin Rodrigues & Nayeem Khan

Year: 2024

Report summary: The report emphasies the critical role of declining Battery Energy Storage Systems (BESS) costs in facilitating India's coal phasedown and meeting the country's net-zero emissions target by 2070. To achieve this, BESS costs need to fall by 15 per cent annually, enabling India to avoid new coal capacity additions after 2030.

The report outlines three key stages for coal phasedown: slowing coal growth, a plateau in coal generation, and eventually an absolute decline as renewable energy (RE) plus storage becomes more cost-effective than coal. While RE can meet up to 83 per cent of daytime demand by 2032, battery storage limitations constrain RE penetration during non-solar hours, requiring further technological advancements.

2023 BATTERY REPORT

Author/s: Zheng Et. al.

Contributors: Sen Et. al.

Year: 2023

Report summary: The battery storage market rebounded in 2023 from the supply crunch which had led to increase in costs for the sector in 2022 for the first time. In a market where EV growth has not been up to expectations, stationary energy storage demand has been seen as a major growth area. Lithium ion remains the leader in the space with a lot of innovation and R&D resulting in better performance and lower costs. Sodium ion is expected to make a mark in the sector towards the end of the decade. China remains the leader dominating 80 per cent of the total value chain and also taking up 58 per cent of global demand. In the near term, the market is expected to see huge oversupply which will further result in lowering of prices.

AGRIVOLTAICS FOR THE INDIAN CONDITION: EXPLORING POTENTIAL OF AGROVOLTAICS IN INDIA

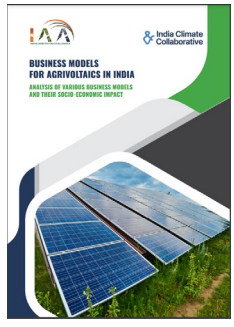
Author/s: Saptak Ghosh

Year: 2023

Report summary: The article highlights the significant potential of Agrivoltaics in India, which combines agriculture with photovoltaic systems to optimise land use. Large land parcels for utility scale solar projects will become increasingly difficult to obtain in the future. In this context, innovative applications such as Agrivoltaics offer a sustainable solution, especially given their huge potential in India.

However, for Agrivoltaics to be successful in India, parameters such as max. permissible crop yield reduction per cent, need to be developed. Deliberations with relevant stakeholders need to be conducted, and food security concerns need to be prioritised.

Key pathways for implementation include developing business models, like joint ventures between farmers and developers. Such models, if supported by government incentives, could enhance Agrivoltaics viability. Further, scientific research is essential to assess crop suitability and tariff designs based on geography. For large-scale adoption, policy frameworks must address the technical, regulatory, and financial aspects.



BUSINESS MODELS FOR AGRIVOLTAICS IN INDIA

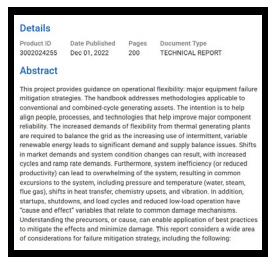
Author/s: Suhas Sathyakiran, Shubhashree Chakraborty, Gopala Krishnan, Prasoon Anand, Subrahmanyam Pulipaka

Reviewers: Shweta Srinivasan, Saptak Ghosh, Shantanu Roy

Year: 2024

Report summary: The report explores the potential business models for Agrivoltaics in India, combining solar energy generation with agricultural activities to optimise land use. Key business models include individual farmer-owned setups, community-owned Farmer Producer Organizations (FPOs), developer-owned projects, and DISCOM-led initiatives. Each business model offers distinct pathways for revenue generation, such as selling electricity to DISCOMs, leasing land to solar developers, or integrating Agrivoltaics with value-adding infrastructure like food processing units.

The models aim to enhance farmer incomes through diversified revenue streams while fostering rural development and sustainable agriculture. They also address challenges like financing, technical expertise, and equitable revenue sharing. Partnerships between stakeholders, including farmers, developers, DISCOMs, and FMCG companies, would be vital for these business models to be realised. In addition, scaling up these business models will require investment, policy support, and research efforts to drive development in India's heartlands.


Details

Product ID	Date Published	Pages	Document Type
3002024255	Dec 01, 2022	200	TECHNICAL REPORT

Abstract

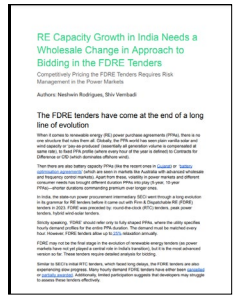
This project provides guidance on operational flexibility: major equipment failure mitigation strategies. The handbook addresses methodologies applicable to conventional and combined-cycle generating assets. The intention is to help align people, processes, and technologies that help improve major component reliability. The increased demands of flexibility from thermal generating plants are required to balance the grid as the increasing use of intermittent, variable renewable energy leads to significant demand and supply balance issues. Shifts in market demands and system condition changes can result, with increased cycles and ramp rate demands. Furthermore, system inefficiency (or reduced productivity) can lead to overwhelming of the system, resulting in common excursions to the system, including pressure and temperature (water, steam, flue gas), shifts in heat transfer, chemistry upsets, and vibration. In addition, startups, shutdowns, and load cycles and reduced low-load operation have "cause and effect" variables that relate to common damage mechanisms. Understanding the precursors, or cause, can enable application of best practices to mitigate the effects and minimize damage. This report considers a wide area of considerations for failure mitigation strategy, including the following:

OPERATIONAL FLEXIBILITY: FAILURE MITIGATION STRATEGIES HANDBOOK

Principal Investigators: Anjan Kumar Sinha, N. Kumar, C. Lee, T. Burnett, W. Mitchell

Year: 2022

Report summary: The success of RE integration depends on the extent to which thermal power plants can be flexible while ensuring reliability of generation, safety and economic viability of flexible generation. Since the usage of intermittent, variable renewable energy sources increases and causes serious demand and supply balance difficulties, thermal-producing plants must become more flexible to maintain grid balance. needs for cycles and ramp rates may rise as a result of changes in system conditions and market needs. Reduced productivity or system inefficiency can also overload the system, which can cause common deviations including vibration, changes in heat transfer, chemistry upsets, and variations in pressure and temperature (water, steam, and flue gas). Additionally, "cause and effect" variables related to common damage processes are present in startup, shutdown, load cycle, and reduced low-load operation. Applying best practices to lessen the impacts and reduce damage can be made possible by understanding the precursors, or cause.


RE Capacity Growth in India Needs a Wholesale Change in Approach to Bidding in the FDRE Tenders

Competitively Pricing the FDRE Tenders Requires Risk Management in the Power Markets

Authors: Neshwin Rodrigues, Shiv Vembadi

The FDRE tenders have come at the end of a long line of evolution

RE CAPACITY GROWTH IN INDIA NEEDS A WHOLESALE CHANGE IN APPROACH TO BIDDING IN THE FDRE TENDERS

Author/s: Neshwin Rodrigues & Shiv Vembadi

Year: 2024

Report summary: This article explores the transformation of renewable energy (RE) development in India, particularly with the introduction of SECI's Firm & Dispatchable Renewable Energy (FDRE) tenders in 2023. These tenders mark a shift from simple, cost-centric models to

more complex frameworks that demand advanced market understanding and risk management from developers. Drawing from more mature PPA schemes in Europe, the article highlights the need for Indian developers to adapt to these new challenges.

Key areas of focus include managing market volatility, optimising battery storage, and addressing RE price cannibalisation. Developers must also evolve into sophisticated market players by enhancing trading capabilities and market modelling to remain competitive in this advanced procurement landscape. The article underscores that this transition is essential for Indian developers to succeed in the growing and increasingly complex renewable energy market.

The critical role of state government revenue subsidy in electricity supply

Manabika Mandal, Sreekumar Nhalur and Ann Josey, Prayas (Energy Group), Pune

Pre-publication draft of a chapter of "State of Finance in India", the upcoming report by Centre for Financial Accountability, Economic Research Foundation & Focus on Global South

October 2020

Abstract

Historically, electricity supply has been considered as an input to catalyse development, but there is an increasing trend to transform it to a market commodity. Revenue subsidy – from the state (state government subsidy) and from commercial and industrial consumers (cross subsidy) – has helped to lower the electricity tariff of small consumers – be it households, shops and establishments, or agriculture. However, increasing cost of electricity supply and sector inefficiencies inflate subsidy requirement. This paper provides a brief background of the role of electricity subsidy in the Indian electricity sector in recent years, emphasising the importance of well- designed and properly targeted subsidy to support basic and productive needs of small consumers. It outlines the current challenges in estimating subsidy requirement, delays in disbursal to distribution companies and targeting of subsidy.

A new challenge to ensure tariff support for small consumers is the inevitable reduction of cross subsidy from large commercial and industrial consumers, driven by changes in technology, economics and electricity distribution business model. Cross subsidising consumers are increasingly opting for their own electricity supply options (via market-based purchase or setting up their own renewable energy plants) and the distribution company has to ensure quality, affordable power supply to small consumers without cross subsidy support. In this situation, adequate state subsidy is essential to ensure good quality supply to small consumers and thus realise the development dividend which investments in electrification aim to achieve. With the unavoidable increase in state subsidy, improving accountability of subsidy estimation and timely payment is necessary. These require changes in governance and accountability processes, and innovations like better subsidy targeting and delivery, and reducing the cost of supply for subsidised consumers.

1. Introduction

Financial health of electricity distribution companies (DISCOMs) plays a pivotal role in ensuring access to affordable electricity supply for small consumers such as households, shops and establishments, and agriculture. This is because they receive electricity supply at a subsidised tariff. State government revenue subsidy (or state subsidy from hereon) to DISCOMs forms a significant portion of their total revenue receipts in various states, and is expected to further increase with recent electrification efforts, as well as changes in the sector.

State subsidy received by all DISCOMs in India was ₹ 98,653 Crore in FY19 (PFC 2020, 2), which was 1.6 times the MGNREGA allocation in the same year (Open Budgets India 2021). Table 1 captures details about state subsidy figures in India between financial years 2016-17 and 2018-19 (FY17-FY19). On an all-India basis, state subsidy is growing at 15% per annum and is 17% of total

THE CRITICAL ROLE OF STATE GOVERNMENT REVENUE SUBSIDY IN ELECTRICITY SUPPLY

Author/s: Manabika Mandal, Sreekumar Nhalur and Ann Josey

Year: 2020

Report summary: This paper provides a brief background of the role of electricity subsidy in the Indian electricity sector in recent years, emphasising the importance of well- designed and properly targeted subsidy to support basic and productive needs of small consumers. It outlines the current challenges in estimating subsidy requirement, delays in disbursal to distribution companies and targeting of subsidy.

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THE NEED FOR PRIVATE SECTOR PARTICIPATION IN INDIA'S ELECTRICITY DISTRIBUTION SECTOR

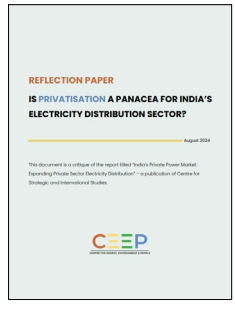
Authors: Gurpreet Chugh & Ashish Singla

Year: 2020

Report summary: India's power distribution companies (DISCOMs) are struggling with heavy losses and inefficiency issues. The government aims to introduce structural reforms to improve the situation.

Private sector participation through various models like distribution licences, franchises and management contracts has been limited. The government now plans to privatise some DISCOMs. Reforms in other countries show that financially viable and operationally strong distribution utilities are key to overall sector performance. However, privatisation efforts have had mixed success. For retail competition to be effective, there needs to be a functioning wholesale electricity market and resource adequacy planning. This will enable retailers to procure power efficiently and offer a variety of services to consumers. Separating distribution and retail functions through "carriage and content separation" and introducing retail competition is seen as a potential way forward for India. However, there are several challenges that need to be addressed like existing PPAs, past liabilities, tariff setting, commercial losses, metering and selecting qualified retailers.

The report argues that lessons can be drawn from international precedents and customised for India to implement retail competition and increase private sector participation in distribution.



IS PRIVATISATION A PANACEA FOR INDIA'S ELECTRICITY DISTRIBUTION SECTOR ?

Authors: Simran Grover & Manish Kumar Mahto

Year: 2024

Report summary: Drafted as a response to a paper published by Centre for Strategic and International Studies (CSIS) that discusses pathway for increasing private sector participation in the distribution section in India, CEEP's reflection paper critically examines the notion that privatisation as a silver bullet for the inefficiencies and fiscal crisis plaguing India's electricity distribution sector.

The paper contends that the success of private DISCOMs is frequently overstated even though privatisation efforts have largely been confined to urban areas. It raises concerns regarding socialisation of risks and privatisation of profits as there is an evident resistance of the private sector to engage with risks inherent to rural distribution. Further, evaluation of performance in urban areas reveal that relative performance of public DISCOMs in equivalent urban areas is quite comparable. More importantly, the discourse on privatisation completely overlooks the strong performance of several public DISCOMs such as those in Chandigarh, Haryana, Gujarat, and Kerala.

While acknowledging the operational and financial hurdles faced by public-sector DISCOMs, the paper argues that these issues stem from deeper structural, governance, and political-economic factors. Private DISCOMs are ill prepared to navigate risks all the risks in the distribution sector as it is evident from their inclination towards service C&I consumers and urban consumers alone. CEEP advocates for a more nuanced approach to power sector reforms that addresses structural issues such as risk distribution in the sector, governance issues including autonomy of DISCOMs and regulators.

A COMPREHENSIVE REVIEW OF STATE RPO FRAMEWORK AND REGULATIONS

Author/s: Sneha Mannur, Saumendra Aggrawal, Ashwin Gambhir

Year: June 2024

Report summary: The RPO framework has been an important driver for increasing renewable energy capacity in India. However, compliance and monitoring of RPO targets remains weak at the state level with irregular monitoring and reporting of compliance leading to shortfalls in many states. Improving transparency and accountability of obligated entities, especially regarding compliance, is crucial for the success of RPO.

RPO targets vary across states, so do aspects like applicability, compliance, data reporting, penalties and incentives. Sharing of best practices across states can promote cross-learning and wider adoption of good practices. A basic level of uniformity in the RPO framework across states while allowing for state specific innovations would help in comparability.

The paper provides a critical review of state RPO regulations and compliance and makes recommendations to improve the RPO framework. These include recommendations around data reporting formats and timelines, compliance verification process, non-compliance penalties, carry forward provisions, incentives for over compliance and revision of RPO targets. Adopting some uniform guidelines and best practices at the national level along with state specific frameworks can help improve RPO compliance and monitoring significantly.

LESSONS FOR RENEWABLE INTEGRATION IN DEVELOPING COUNTRIES: THE IMPORTANCE OF COST RECOVERY AND DISTRIBUTIONAL JUSTICE

Author/s: Dr. Kaveri K. Iychettira

Year: July 2021

Report summary: While elements of the standard power sector reform model like unbundling and market signals can help integrate renewables, cost recovery and distributional concerns need to be addressed first. The report reviews literature on differences in power sector reforms between developed and developing countries. It finds that developing countries face challenges like lower state capacity, redistributional politics, and external pressures.

The article presents two case studies of India and China to illustrate the challenges they face in integrating renewables. Based on the review and case studies, the report highlights the need to address cost recovery issues to implement unbundling and market reforms in developing countries. Revenue shortfalls and losses make cost recovery difficult. Distribute costs and benefits equitably to gain public acceptance of reforms. Reforms often benefit the wealthy more, implement reforms gradually while ensuring basic electricity access for the poor. Address regulatory and institutional capacity constraints to implement economic dispatch and market signals effectively.

In summary, the report argues that cost recovery and distributional concerns must be central to the design of institutions and reforms for integrating renewables in developing countries. The standard power sector reform model needs to be adapted to local contexts to be effective.

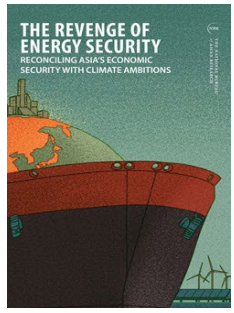
FOSTERING ENERGY TRANSITIONS IN THE GLOBAL SOUTH: INSIGHTS FROM CHILE, JORDAN, MALAYSIA, AND KENYA

Author/s: Dr. Maria Apergi, Dr. Esther Schuch, Laima Eicke

Year: December 2022

Report summary: The report discusses key insights from energy transition cases studies in Chile, Jordan, Malaysia, and Kenya. Market liberalisation and complementary policies are crucial for energy transitions to succeed. The case studies show that reforms to make electricity markets more liberalised would enable more actors to participate and drive long-term changes to the energy mix. But market interventions need to target different policy areas simultaneously. The incumbent fossil fuel system is difficult to change and impedes energy transitions. Countries are locked into long-term contracts with fossil fuel suppliers that make it hard to transition to renewables. Centralised decision making tends to hold back energy transitions. Where the government dominates the energy sector, decisions prioritise short-term costs and interests of state-owned companies over stakeholders.

More inclusion in decision making processes is needed. Ambitious energy transition policies are needed for countries to maintain or expand their positions in renewable energy value chains. Without determined action, developing countries risk being left behind. Targeted interventions are needed that consider the specific context and challenges of each country to ensure energy transitions are just and inclusive.



THE REVENGE OF ENERGY SECURITY: RECONCILING ASIA'S ECONOMIC SECURITY WITH CLIMATE AMBITIONS

Author: Erica Downs, Vandana Hari, Meredith Miller, Jennifer F. Sklarew, and Rahul Tongia

Year: November 2023

Report summary: This collection of essays examines the evolving role of energy security and climate goals in shaping Asia's energy transitions. The energy shocks from the Fukushima disaster and Russia-Ukraine war have highlighted Asia's energy vulnerabilities due to heavy reliance on imported fossil fuels. Countries are seeking ways to diversify energy supplies, improve energy efficiency, and accelerate clean energy transitions. Liquefied natural gas (LNG) is seen as an important transition fuel to reduce dependence on coal. However, Asia's LNG importers have become wary of LNG's price volatility

and supply instability. Countries are looking to diversify LNG sources and secure more long-term supply contracts.

Renewable energy is growing rapidly but faces challenges in scaling up to meet energy demand with energy storage solutions being limited and expensive. Nuclear power and natural gas with carbon capture are seen as key to meeting baseload needs while reducing emissions. International collaboration on clean energy financing, technology development, infrastructure investments, energy efficiency best practices, and critical mineral supply chains can help accelerate Asia's clean energy transitions and improve energy security. In Southeast Asia, LNG is viewed as expensive and risky despite having the potential to displace coal and reduce emissions. Greater regional cooperation, stronger regulatory frameworks, and international support are needed to realise LNG's full benefits.

PERSPECTIVES ON CHALLENGES AND EMERGING RISKS IN INDIA'S UTILITY SCALE SOLAR

Author: Arvind Poswal

Year: 2024

Report summary: In the past decade, India's renewable energy capacity surged from 36 GW to 144 GW, with utility-scale solar accounting for 44.8 per cent of this growth. As the solar sector is projected to reach over 300 GW by 2030, challenges have emerged, including uneven project distribution among states, policy gaps hindering Renewable Purchase Obligations (RPOs), and conflicts over land use. Additionally, the infrastructure needed for efficient transmission and distribution presents significant hurdles. This book delves into the complexities of India's solar landscape, emphasizing the urgent need for a holistic framework that prioritizes access, affordability, reliability, sustainability, and inclusiveness in the transition to clean energy.

DEVELOPING AN EFFECTIVE STATE-LEVEL COMPRESSED BIOGAS POLICY IN INDIA: CURRENT STATUS AND KEY STRATEGIES- POLICY BRIEF

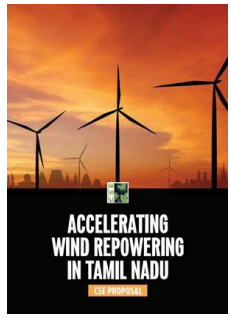
Author: Rahul Jain

Year: 2024

Report summary: The adoption of compressed biogas (CBG) projects in India has been slow—with just 100 projects in operation as of August 2024—falling well below the goal of 5,000 plants by 2030.

A key obstacle to CBG development is the ineffective execution of policies at the state level. While several states have significant CBG potential, they still lack clear policies and incentives. Only four states—Uttar Pradesh, Haryana, Bihar, and Gujarat—currently have bioenergy policies that support CBG.

To address this issue, this policy brief identifies critical elements for crafting state-specific CBG policies. It also reviews existing state bioenergy policies and draws on international best practices to guide effective policy-making for state governments and renewable energy agencies.



ACCELERATING WIND REPOWERING IN TAMIL NADU

Author: Noble Varghese and Jay C. Shiv

Year: 2024

Report summary: In the heart of windswept Tamil Nadu, India's wind-energy champion, lies hidden potential. Ageing wind turbines, once leaders in clean energy production, are nearing the end of their lives. But what if they could be reborn? By replacing these older turbines with efficient, modern turbines, the state could double its wind energy generation and once again become a green giant.

The path to repowering is, however, riddled with challenges. This report delves into the roadblocks and the triumphs of initial repowering projects, from fragmented ownership of turbines to inflexible energy policies. It explores the exciting possibilities and offers a glimpse into the struggles and rewards of harnessing the power of the wind.

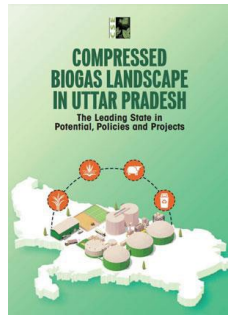
IMPLEMENTATION CHALLENGES OF THE PM-KUSUM SCHEME

Author: Vaani Khanna

Year: 2024

Report summary: The PM-KUSUM scheme, with its three components, was introduced in 2019, with the aim to solarize agriculture and encourage investment in the solar- energy sector by farmers with uncultivated barren land. Since its inception, 4 lakh diesel and electric water-pumps for irrigation have been replaced with solar water-pumps, leading to massive reductions in emissions and increased savings for farmers.

However, only about 30 per cent of the target set under the scheme has been achieved so far. This report shows that through decentralized implementation models and provisions of varying payment options for farmers, these gaps can be addressed. Component B, entailing replacement of electric and diesel electric pumps has seen the most widespread implementation in Indian states, with Haryana and Rajasthan leading in terms of installation. Taking examples from case studies from these states, as well as from under-performing ones, recommendations have been provided for central and state governments to ensure better on-ground implementation.



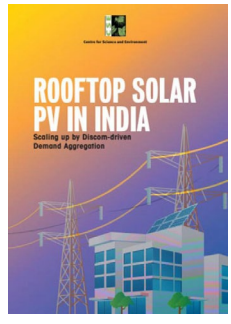
COMPRESSED BIOGAS LANDSCAPE IN UTTAR PRADESH

Author: Rahul Jain and Jay C Shiv

Year: 2024

Report summary: Among the 28 states in India, Uttar Pradesh stands out with the highest potential for biomethane generation due to abundant organic feedstock availability. The state, demonstrating ambition, introduced a dedicated bioenergy policy in 2022 and is currently leading the nation with around 100 CBG projects underway.

According to the report, Uttar Pradesh has the capability to install 1,000 CBG projects by harnessing just 20 per cent of its surplus organic feedstock. Along with delving into the economic aspects of CBG projects, the report showcases successful practices within the state, identifies grassroots challenges, and offers policy recommendations. This information is invaluable for policymakers, think tanks, researchers and investors interested in promoting clean energy and effective waste management in both the state and across India.



ROOFTOP SOLAR PV IN INDIA—SCALING UP BY DISCOM-DRIVEN DEMAND AGGREGATION

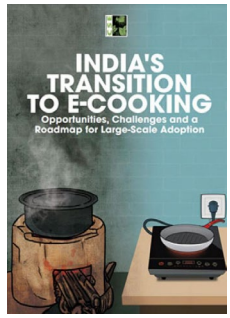
Author: Maitreyi Karthik

Year: 2023

Report summary: India's installation of rooftop solar (RTS) photo voltaic (PV) is far behind the Government of India's target of achieving 40 GW of RTS PV installation by 2022. While the year of achieving the RTS PV installation target has been revised by the government to 2026, the capacity remains unchanged. Although there is currently no definitive

information on overall residential rooftop capacity in the public domain, residential RTS PV has a very nominal share of the total rooftop solar PV installed capacity of 10.9 GW, with about 2 GW accounting for about 20 per cent of the overall RTS PV capacity.

This report argues, based on a cost–benefit analysis for DISCOM-driven residential RTS PV in ten selected states, that residential rooftops can contribute about 29 GW of residential RTS PV by 2030 even if the most conservative approach is followed. On the basis of potential of residential RTS PV and developments in its commercial and industrial (C&I) segment, it becomes important to consider scaling residential RTS PV to increase the share of the generation of clean power feeding into the grid. This requires experimenting with various models, involving multiple stakeholders.



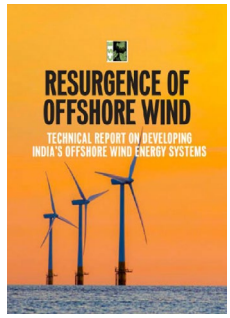
INDIA'S TRANSITION TO E-COOKING

Author: Jay C Shiv

Year: 2023

Report summary: Despite Indian government efforts over seven decades to enable access to clean cooking fuels, about 500 million people in India still cook on polluting fuels such as wood, biomass, animal dung cakes, agri residue and kerosene. The resulting indoor air pollution causes about 0.6 million premature deaths in every year, and untold damages in the form of serious health risks. This report found that it also leads to CO2 emissions of over 350 million tonne every year in the country—which is more than India's transport sector or industrial sector's emissions.

This report aims to provide a roadmap for large-scale adoption of e-cooking for rural households in the country. As rural India accounts for two-thirds of the total number of households and access to other means of clean cooking, such as LPG, is limited in rural areas, this report emphasizes that the intervention will have more impact in rural households than its urban counterpart.



RESURGENCE OF OFFSHORE WIND

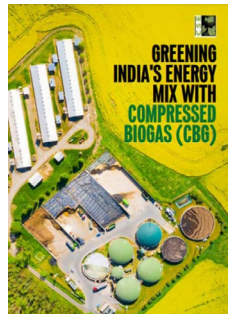
Author: Binit Das

Year: 2023

Report summary: India's demand for electricity is predicted to grow between 6 to 7 per cent every year over the next decade. To meet this demand, while meeting its NDC (to

have 50 per cent of installed capacity for power generation comprise of non-fossil fuel-based energy sources), there is a need to accelerate the growth of wind and other renewable energy sources.

With its coastline extending over 7,500 km, India is well suited for the development of offshore wind energy. Moreover, it holds promise as an alternative source of energy for a country like India due to the lack of uncultivable land and challenges faced in acquiring land, apart from other bureaucratic hurdles for harnessing energy. This technical report explores how India can best utilize its offshore wind energy potential.



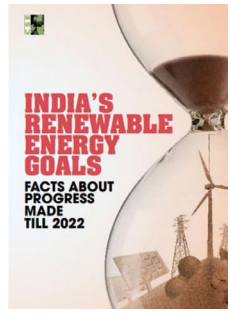
GREENING INDIA'S ENERGY MIX WITH COMPRESSED BIOGAS (CBG)

Author: Rahul Jain

Year: 2023

Report summary: India is expected to experience a great increase in energy demand over the next few decades, with its share of global energy consumption doubling by 2050. Increased use of modern bioenergy is essential for transitioning to less carbon-intensive energy sources and usage of compressed biogas (CBG) within bioenergy is needed for spreading the benefits of the transition locally.

This report presents a comprehensive view of India's current CBG strategy and its future course. It engages with the challenges the country faces in adopting CBG at a large-scale and gives recommendations to overcome those challenges.



INDIA'S RENEWABLE ENERGY GOALS, FACTS ABOUT PROGRESS MADE TILL 2022

Author: Jasleen Bhatt and Binit Das

Year: 2022

Report summary: India has set ambitious renewable energy targets for itself. The achievement of these targets is necessary from the viewpoints of climate and energy security, pollution abatement, and also to secure clean energy for all, including the poor. This book is an update on the facts of the progress we have made thus far. It is meant as a resource to help us step into the future on a surer footing.

HARD-TO-ABATE SECTORS: LOW CARBON GROWTH IN KEY INDUSTRIES

THE IRON AND STEEL SECTOR

Scenarios for production, demand, and emission trajectories through 2030–50

India's steel demand is expected to grow substantially over the coming decades due to infrastructure development, urbanisation, and industrial expansion. The steel sector's annual production could almost double by 2030, positioning India as one of the largest steel consumers globally.

IT IS IMPORTANT THAT THE HARD-TO-ABATE MUST BE LABELLED AS 'PRIORITY-TO-ABATE' SECTORS.

- Prabodha Acharya, Group Chief Sustainability Officer, JSW Group

According to the third national communication to the UNFCCC, India's steel sector contributed 5 per cent of national GHG emissions in 2019 which is equal to 158 million tonnes of CO_2e. As of 2022, India produced 120 million tonnes of crude steel which is planned to reach 255 million tonnes with a capacity of 300 million tonnes by 2030 as per the National Steel Policy 2017 by the Ministry of Steel.

As highlighted in multiple reports, the growing demand will necessitate a combination of increased production capacity and sustainable practices. Estimates suggest that demand will continue rising until 2050, with emissions potentially increasing significantly unless green solutions are adopted. The Indian steel sector is a major contributor to industrial emissions, responsible for nearly half of the manufacturing sector's greenhouse gas (GHG) emissions. In 2021-22, the sector emitted 297 million tonnes of CO_2[1]. Currently, emissions from the steel industry in India are high due to its reliance on coal-based production methods. Emissions could rise to around 660 million tonnes per year by 2030 in business as usual scenario, driven by an increase in steel production to 255 million tonnes by 2030. If current practices persist, emissions could reach 837 million tonnes per year by 2050, assuming steel production hits 600 million tonnes.[2]

Options for decarbonisation in the near-term and long-term

Near-term options

- **Energy efficiency and resource efficiency improvements**: Steel producers can adopt energy management best practices to optimise energy use in existing operations. This includes upgrading equipment, improving thermal efficiency, and implementing process automation.[3,4] Retrofitting existing blast furnaces with more energy-efficient technologies and practices can reduce

energy consumption to some extent, especially as India plans to increase the capacity of blast furnaces. Additionally resource efficiency initiatives like iron ore beneficiation and others can enhance emission reduction in near term.

- **Electric arc furnace (EAF) technology**: Increasing the share of EAFs in steel production can significantly reduce carbon emissions compared to blast furnaces.[5] But this needs to be assured that the major feed for this technology in India i.e. direct reduced iron should be manufactured with cleaner fuels like natural gas, green hydrogen, bio fuels etc. and paralelly more good quality scrap can be sourced to feed the furnaces.
- **Increase scrap utilisation:** By maximising the use of scrap steel in EAFs and blast furnaces, the industry can lower emissions. This method produces up to 75 per cent less CO_2 than traditional blast furnace methods.[6] Encouraging recycling practices within the industry and for end-users can enhance scrap availability.[7] An ecosystem needs to be developed for effective implementation of scrap related policies and improving the collection and treatment systems that lead to better accounting of steel scrap along with improving its quality.
- **Switching fuels**: Transitioning to cleaner fuels, such as natural gas, biochar, to replace coal in certain processes. Using natural gas/hydrogen instead of coke as a reducing agent in iron-making can significantly lower emissions. This switch has been adopted in various pilot projects and can be scaled up in the future. While more of a bridge to long-term solutions, initial investments in hydrogen infrastructure can facilitate its use in steel production processes, particularly for direct reduction methods.[8]
- **Direct renewable energy integration:** Many steel producers in India are also exploring direct integration of renewable energy into their operations. This includes setting up captive solar and wind farms to supply power for various stages of steel production. Some Indian steel companies, like Tata Steel and JSW Steel, have announced plans to increase the share of renewable energy in their operations in the coming years.[9]

THERE IS HUGE ROLE OF PROCUREMENT FOR DRIVING DEMAND FOR LOW-CARBON STEEL.

- Ankur Malyan, Manager, Rocky Mountain Institute (RMI)

Long-term options

- **Scrap-based steel production**: In the long term India will have a even higher domestic availability of steel scrap which would then create the opportunity to have a larger share of the country's steel production by using steel scrap.
- **Hydrogen-based steelmaking:** Hydrogen-based steelmaking is one of the most promising disruptive technologies. In this process, hydrogen is used as a reducing

agent instead of carbon-rich coke to remove oxygen from iron ore in the steel production process. Known as Hydrogen Direct Reduction of Iron (H-DRI), this method produces water as a byproduct instead of CO_2. In theory, this could reduce CO_2 emissions by up to 90cent compared to traditional blast furnace methods.[10] India has the potential to adopt hydrogen-based steelmaking due to its vast renewable energy resources, which are critical for producing green hydrogen. Pilot projects in Europe and early investments in India are already exploring this route.

- **Carbon capture and storage** (**CCS**): Investing in technologies that capture CO_2 emissions generated during production and store them underground. Capturing CO_2 emissions at source and storing them underground can help mitigate the impact of steel production. This technology is still in its infancy in India but offers substantial potential for long-term emissions reductions.[11] Moreover, exploring options for utilising captured CO_2 in other industrial processes can improve the economic viability of CCS.

Challenges in achieving decarbonisation

- **High costs**: Green hydrogen production, CCUS, and renewable energy systems are capital-intensive, making it difficult for smaller players to adopt these technologies. Scaling up green hydrogen technology in India will require significant investment in renewable energy infrastructure to produce green hydrogen. Moreover, hydrogen production, storage, and distribution infrastructure must be developed on a large scale to support a full transition to hydrogen-based steelmaking.[12]
- **Energy and infrastructure**: Access to consistent and affordable renewable energy, as well as upgrading grid infrastructure, are key challenges. The intermittency of renewable power sources like wind and solar further complicates steel production
- **Technological maturity**: Technologies like green hydrogen and CCUS are still in the early stages of development, making large-scale adoption difficult.
- **Policy and financial gaps**: Lack of policy incentives and financing options for decarbonisation is a significant hurdle, particularly for comparatively smaller industries that dominate India's secondary steel sector

PRIORITISE FINANCIAL INVESTMENTS AND CREATE COLLABORATIVE NETWORKS TO DRIVE INNOVATION IN INDIA.

- Yash Kashyap, Senior Analyst, Climate Policy Initiative

Equity considerations

Decarbonising the steel sector could disproportionately impact smaller players that may lack the resources to invest in expensive fuels and technologies like hydrogen and CCUS[13]. Equity considerations also extend to workers employed in coal-based steelmaking regions who will need to transition to new green jobs. Reskilling programs and financial support are crucial to ensure a just transition for these workers[14,15]. Additionally, a green financing model, which includes subsidies and loans for low-carbon technologies, will be necessary to ensure all stakeholders can participate in the transition.

THE CEMENT SECTOR

Scenarios for production, demand, and emission trajectories through 2030–50

India's cement sector is expected to grow significantly, driven by urbanisation and infrastructure development. According to the third national communication to the UNFCCC, India's cement sector contributed around 179 million tonnes of CO_2e emissions in 2019. The cement sector and cement production emissions contribute 6 per cent to overall national emissions. By 2050, cement production and demand could increase up to three to four times compared to current levels. This would result in a near tripling of CO_2 emissions if business-as-usual practices continue.

The Indian cement industry is expected to see significant growth by 2050, driven by increased demand for infrastructure and housing. Projections suggest that by 2030, cement demand will increase by **116 per cent**, reaching approximately **660 million metric tons** (**MMT**), with a compound annual growth rate (CAGR) of **6.6 per cent**[16]. It is estimated that with 660 million tonnes of cement production in a business as usual scenario, the emissions from the sector can go up to 420 million tonnes by 2030.[17]

Options for decarbonisation in the near-term and long-term

The sector can reduce its emissions using both short-term and long-term strategies:

Near-term options:

- **Clinker substitution**: Clinker substitution is a crucial near-term strategy for reducing emissions in the cement sector. By increasing the use of **supplementary cementitious materials** (**SCMs**) like **fly ash** and **slag** , manufacturers can lower the clinker factor in cement production. Since clinker production is responsible for a significant portion of CO_2 emissions,

reducing its quantity directly correlates with lower emissions. Studies indicate that blended cements incorporating SCMs can achieve reductions in emissions by approximately **20-40 per cent** compared to traditional Portland cement.[18]

- **Energy efficiency**: Energy efficiency improvements in cement production processes represent another effective near-term decarbonisation option. By adopting advanced technologies and practices, cement manufacturers can optimise energy use and reduce waste. For example, the implementation of waste heat recovery systems can capture excess heat generated during the production process and repurpose it for heating or power generation, potentially saving 20-30cent of energy[19]. Additionally, upgrading equipment and adopting best practices in operational management can further enhance energy efficiency. Many cement companies in India are investing in energy-efficient technologies as part of their sustainability initiatives, recognising that these measures not only reduce emissions but also lower operational costs in the long run.
- **Use of alternative fuels**: The use of alternative fuels is a viable near-term strategy for the Indian cement industry to reduce carbon emissions associated with energy consumption. By substituting traditional fossil fuels, such as coal and petcoke, with biomass, municipal waste etc., cement plants can significantly decrease their greenhouse gas emissions.[20]
- **Use of renewable energy**: Captive or grid electricity, which constitutes approximately 12 per cent of the total emissions from the cement industry, can be replaced with electricity sourced from wind and solar power plants.[21]

Utilisation of RDF as an alternate fuel in cement plants is one of the biggest opportunities for decarbonization in current times. A feasible economic model is required to foster ambition.

- Parth Kumar, Programme Manager, Industrial Pollution, Centre for Science and Environment (CSE)

Long-term options:

- **Carbon capture, utilisation, and storage** (**CCUS**): **CCUS** involves capturing CO_2 emissions produced during cement manufacturing processes, particularly from kilns that generate significant thermal emissions. Implementing CCUS in India's cement industry could potentially reduce process emissions. However, scaling CCUS will require significant investment in infrastructure, development of capture technologies, and supportive regulatory frameworks to ensure safe and effective long-term storage.

- **Use of green hydrogen:** The use of green hydrogen in cement production presents a transformative opportunity for reducing thermal emissions. Green hydrogen, produced from renewable energy sources through electrolysis, can replace fossil fuels traditionally used in kilns. By integrating hydrogen into the production process, the cement industry can significantly reduce its carbon footprint, particularly in the high-temperature stages of cement manufacturing. While this technology is still in early stages, research and pilot projects indicate that hydrogen could provide a pathway to achieve substantial reductions in CO_2 emissions when scaled effectively. The development of infrastructure for hydrogen production and distribution will be essential to facilitate this transition.
- **Electrification**: Cement kiln electrification is still in its nascent stage but it has great scope for decarbonising. If powered by renewable energy, it can totally cut the thermal emissions from burning of fossil fuels during clinker formation. Thermal emissions amount to over 40 per cent of carbon emissions from cement plants.[22]
- **Innovative materials**: Development of low-carbon alternatives like limestone calcined clay cement (LC3) has potential to reduce emissions by 30 per cent.[23] and geopolymer concrete could significantly cut emissions.

GOVERNMENT CAN DEVELOP A POLICY FOR PROCURING LOW-CARBON CEMENT AND MANDATE UTILISATION OF A SHARE OF C&D WASTE IN CONSTRUCTION.

- Ankur Mittal, Research Scholar, BITS Pilani

Challenges in achieving decarbonisation

Several hurdles stand in the way of decarbonising the cement sector:

- **Technological readiness**: Many of the most promising decarbonisation technologies, such as hydrogen-based production, kiln electrification, CCUS etc., are still at an early stage of development or commercially unviable.
- **High costs**: The implementation of alternative fuels and low-carbon technologies like CCUS is capital-intensive and requires government and private sector investment.[24]
- **Supply chain issues**: Challenges exist in scaling up the supply of alternative materials and fuels like biomass or Refused Derived Fuel (RDF), and integrating these into production processes.
- **Policy support**: There is a lack of comprehensive policy frameworks to drive large-scale decarbonisation in the cement sector. Existing policies focus more on energy efficiency than on deep emission reductions.[25]

THE ALUMINIUM SECTOR

Scenarios for production, demand, and emission trajectories through 2030–50

India's aluminium production is expected to grow significantly as demand increases due to its applications in power, construction, and automotive industries. According to the third national communication to the UNFCCC, the aluminium sector contributed 49 million tonnes CO_2e, contributing 1 per cent of overall national emissions. The country's per capita aluminium consumption is currently at 2.5 kg compared to the global average of 11 kg[26]. However, as the economy grows, aluminium demand will rise sharply, potentially tripling by 2050. With this increase, CO_2 emissions are also expected to rise unless significant decarbonisation efforts are made.

The aluminium industry emitted 77 million tonnes of CO_2 in 2019-20[27], and if no intervention occurs, this could reach unsustainable levels in the future. However, decarbonisation pathways that emphasise renewable energy and technological upgrades could mitigate this.

Options for decarbonisation in the near-term and long-term

Near-term options

- **Energy efficiency:** Energy efficiency improvements in both alumina refining and aluminum smelting as a pivotal strategy for decarbonisation. By optimising existing processes and implementing more efficient technologies, companies can significantly reduce emissions without substantial cost increases.[28]
- **Renewable energy sources**: Solar and wind power, presents a significant opportunity for emissions reduction. Reports indicates that utilising renewable energy could potentially lower emissions by 49 per cent. However, the intermittency of renewable energy remains a challenge, necessitating the need for robust energy storage solutions and grid management strategies to ensure a consistent energy supply.[29]

"MITIGATION STRATEGY FOR EVERY SECTOR TO CHALLENGE CBAM IS TO DECARBONISE. DOMESTIC CARBON TAX CAN BE AN ADDITIONAL GOVERNMENT APPROACH.

- Prachi Priya, Assistant Vice President, Economic and Public Policy Research and Advocacy and ESG Strategy, Hindalco Industries Limited

Long-term options[30]

- **Shifting to renewable energy**: While it can abate 49cent of emissions, there are challenges in meeting the high electricity demands entirely with renewables. Some estimates suggest only about 70cent could be replaced by renewables by 2050.
- **CCUS**: Adopting carbon capture, utilisation and storage technologies and alternative fuels can help abate the remaining emissions but involve higher costs.
- **Switch to low-carbon technologies**: Options like retrofitting smelters with inert anodes and using biomass for fuel switching are under consideration for further decarbonisation.

Challenges in achieving decarbonisation

Several challenges hinder decarbonisation:

- **High costs**: Achieving net-zero aluminium could require an additional capital expenditure of USD 29 billion. This includes investment in renewable energy infrastructure and upgrading current production facilities. Moreover, producing net-zero aluminium is projected to increase operating costs by around USD 3.5 billion per year, making the final product 61 per cent more expensive compared to conventional aluminium
- **Technology limitations**: Technologies like CCUS and advanced energy efficiency measures are still in developmental stages and need significant scaling. The aluminium industry is highly dependent on continuous, reliable electricity, and renewable energy's intermittency makes this transition complex.
- **Grid bottlenecks**: Many renewable power sources (like offshore wind farms) are far from production facilities, creating inefficiencies in electricity transmission and risking grid congestion

ALUMINUM SECTOR CAN BE DECARBONISED THROUGH OPTIONS SUCH AS INCREASED USE OF RECYCLED MATERIAL AND RE UPTAKE.

- Debasish Ghosh, Vice President and Head, Energy and Decarbonization, Hindalco Industries Limited

Equity considerations for decarbonising the sector

Equity considerations in decarbonising the Indian aluminum sector focus on ensuring a fair transition that includes workers, regions, and communities dependent on traditional energy sources and production methods. The shift to renewable energy and energy-efficient technologies may lead to job

disruptions, particularly for workers in fossil fuel-dependent sectors, requiring re-skilling and support for alternative employment. Additionally, regions reliant on traditional aluminum production could face economic disparities as new green technologies are adopted unevenly. It's important to ensure that smaller producers and economically weaker regions have access to clean energy solutions. Land-use changes due to renewable energy projects, like solar or wind farms, could also impact local communities, necessitating their inclusion in decision-making processes to protect their land rights and livelihoods. Addressing these factors will ensure a just and inclusive transition in the aluminum sector

THE FERTILISER SECTOR

Scenarios for production, demand, and emission trajectories through 2030–50

The demand for fertilisers in India is expected to grow significantly, driven by the need to support increasing agricultural productivity to meet the demands of a growing population. According to the third national communication to the UNFCCC, fertiliser production contributed 4.9 million tonnes of CO_2e in 2019 under manufacturing industries. The Indian fertiliser industry is the second largest producer of fertiliser in the world, with a production capacity of ~58 million tonnes per annum (Mtpa) in 2022–23. The urea, DAP, and OCF industries emitted nearly 25 million tonnes of CO_2 equating to an emission intensity of 0.58 CO_2/t-fertiliser.

Of the total emissions, 85 per cent of the emission in the fertiliser sector is due to the use of natural gas as fuel and feedstock while only 15 per cent of the emissions results from electricity use. The sector contributes about 1cent of the country's total GHG emissions. With the expected growth in agricultural production, emissions could rise if fossil fuel-dependent production processes continue. However, the decarbonisation of the sector could offset some of these emissions, particularly with shifts toward green ammonia, which has the potential to significantly reduce the carbon footprint.[31]

EMISSIONS ARE HIGHER IN APPLICATION RATHER THAN PRODUCTION OF FERTILISER. BALANCED USE OF FERTILISER WILL REDUCE EMISSIONS.

- Vikas Kumar, General Manager, Technical Services, Indorama India Pvt. Ltd

Options for decarbonisation in the near-term and long-term

Near-term options

- **Energy efficiency improvements**: According to a think tank's report, implementing energy-efficient technologies can reduce emissions by approximately 10cent. It is estimated that 4 per cent of the reduction in the emissions intensity is achieved through technologies with a negative cost of abatement, while the remaining 6 per cent is achieved through EE technologies that have a positive abatement cost.
- **Transition to renewable energy**: Integrating renewable energy sources in production processes can further reduce emissions, albeit marginally, by about 2cent.

Long-term options

- **Green ammonia**: This involves using renewable energy to produce ammonia, which can potentially reduce emissions by 151 per cent. This switch could lead to net-negative emissions for the sector, as green ammonia would require CO_2 sourced from other processes to produce urea.[32]
- **CCS**: Implementing CCS technologies can be part of the long-term strategy, especially for complex fertilisers.

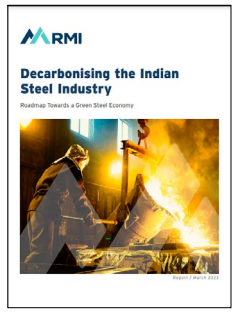
Challenges in achieving decarbonisation

Several challenges exist in the pathway to decarbonise the fertiliser sector. Some of the major challenges are:

- **Financial barriers**: Significant upfront investment is required to transition to green technologies and renewable energy. Financial incentives and policies are essential to facilitate this transition.
- **Technological hurdles**: The existing infrastructure is heavily reliant on natural gas, and transitioning to new technologies like green ammonia requires advancements and scaling of production processes.
- **Market dynamics**: The fertiliser market is price-sensitive, and the adoption of green technologies may initially lead to higher costs, which could deter stakeholders.

In conclusion, while the Indian fertiliser sector faces substantial challenges in decarbonising and meeting future demands, strategic investments in green technologies and policies can pave the way for a more sustainable future.

RESEARCH ANTHOLOGY ON HARD-TO-ABATE SECTORS



DECARBONISING THE INDIAN STEEL INDUSTRY: ROADMAP TOWARDS A GREEN STEEL ECONOMY

Authors: RMI

Year: 2023

Report summary: The importance of steel in supporting India's growth will increase with economic development, infrastructure build-out, and urbanisation in India. The emissions from the sectors are estimated to grow by 200 per cent by 2050. This requires decarbonising the steel industry to ensure India meets its economic ambitions and climate mitigation goals. This report identifies five key levers to decarbonise steel: the use of green hydrogen for steel production; the introduction of a more significant share of renewable electricity in captive electricity consumption; carbon capture, utilisation, and storage (CCUS) to decarbonise existing carbon-intensive steel production processes; greater use of scrap to make steel; and increasing energy efficiency across steel production processes.

The report proposes a roadmap for realising a low-carbon steel economy in India, identifying six key objectives:

I. Establishing the definition and standards of green and low-carbon steel
II. Advancing the uptake of alternative green energy sources such as green H2 and renewable energy:
III. Announcing a green steel procurement policy and targets to encourage market creation and demand aggregation
IV. Supporting R&D to advance breakthrough technologies and solutions like H2 and CCUS
V. Promoting alternative emissions mitigation actions through pilots and clusters
VI. Framing mechanisms and frameworks for financing the green steel transition

ACHIEVING GREEN STEEL: ROADMAP TO A NET ZERO STEEL SECTOR IN INDIA

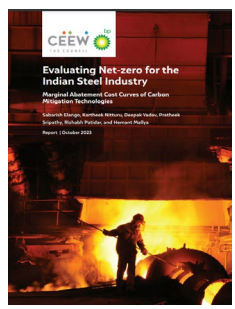
Authors: Will Hall, Sachin Kumar, Sneha Kashyap, Shruti Dayal.

Year: 2022

Report summary: The report discusses strategies for decarbonising India's steel sector and achieving net-zero emissions by 2070. India's steel industry is growing rapidly to meet demand from

development but faces challenges in competitiveness, technology availability, and capital requirements for transitioning to low carbon production. Achieving net-zero will require maximising energy efficiency, increasing scrap utilisation, supporting demonstration plants for new technologies, future-proofing new capacity, and retiring older polluting facilities.

In the near term, actions like green product standards, procurement alliances, and research and development support can help accelerate the transition. Over the longer term, a comprehensive policy framework with phase out policies and support for neat-zero emission plants is needed. Rapid scaling of renewable electricity and green hydrogen production will be essential to enable low carbon steelmaking technologies like hydrogen direct reduction and molten oxide electrolysis. This poses major infrastructure challenges. With a targeted action plan and supportive policies, India has an opportunity to pioneer a model of 'industrialisation without carbonisation,' and equip its steel industry for a net-zero world. An ambitious decarbonisation strategy for the steel sector can attract investment, talent, and help compete in global markets.



EVALUATING NET-ZERO FOR THE INDIAN STEEL INDUSTRY

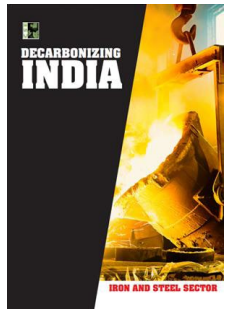
Authors: Sabarish Elango, Kartheek Nitturu, Deepak Yadav, Pratheek Sripathy, Rishabh Patidar, and Hemant Mallya

Year: 2023

Report summary: This report evaluates emission mitigation options to achieve net-zero carbon emissions through marginal abatement cost (MAC) curves for the existing plants in the steel industry under four pillars: energy efficiency, renewable power, alternative fuels and carbon management. The study considers four major steelmaking pathways: BF-BOF, coal DRI-IF, coal DRI-EAF and gas DRI-EAF.

The total capital investment required to achieve near net-zero emissions for existing steel plants will amount to USD 283 billion (INR 21.2 lakh crore) with an additional annual operating expenditure of USD 8.8 billion (INR 66.7 thousand crore) to achieve net-zero. About 56 per cent of emissions from existing capacity will rely on CCUS for abatement, pointing to the need for expedited development of the CCUS ecosystem in India.

Energy efficiency measures can reduce the emission intensity of steel by nine per cent, followed by RE measures at 19 per cent and alternative fuels at six per cent. CCUS has the potential to abate 56 per cent of the steel sector emissions. The report recommends incentivising the adoption of best available EE technologies, incentivising RE power and developing a CCS ecosystem in India for full decarbonisation. Access to green finance and a robust R&D ecosystem will also be critical to achieve net-zero in the steel industry.



DECARBONIZING INDIA'S IRON AND STEEL SECTOR

Author/s: Parth Kumar

Year: 2022

Report summary: The iron and steel sector is a hard-to-abate sector in terms of greenhouse gas emissions, but it is an equally critical contributor to the economic development of the country. India is the second largest producer of crude steel in the world and plans to almost triple its production by 2030. Under a business-as-usual scenario, the CO_2 emissions from crude steel production are estimated to grow to almost 2.5 times by 2030. This report provides a detailed insight into the GHG emissions of the iron and steel sector and its future emission scenarios for 2030 -the report provides, based on available information, unit and company-wise data on emissions, which will help design the road ahead. The report suggests a roadmap for the sector, highlighting the pathways for GHG emissions reduction. The assessment clearly finds there are huge opportunities to bend the carbon dioxide curve for this emission intensive sector, but it will need planning, technology and adequate funds.

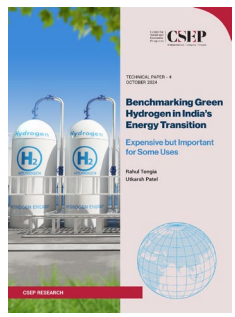
FINANCING INDUSTRIAL DECARBONIZATION — CHALLENGES AND SOLUTIONS FOR INDIA'S IRON AND STEEL SECTOR

Authors: Yash Kashyap and Dhruba Purkayastha

Year: 2024

Report summary: CPI's most recent Global Landscape of Climate Finance shows that in 2021-22 global finance for mitigation activities in industry amounted to just USD nine billion, and needs to increase rapidly for a transition to net-zero

emissions. This discussion paper focuses on the technologies, challenges, and current state of financing for the decarbonisation of India's iron and steel sectors, the country's largest GHG-emitting high-growth industrial sector and one of the most challenging to decarbonise. It introduces a conceptual framework for enabling the financing of (sector-agnostic) low-carbon industrial activities at the industry level, as well as measures to stimulate the demand and supply of climate-aligned finance. It also highlights financing and de-risking mechanisms that can support low carbon technologies in the iron and steel sector.



BENCHMARKING GREEN HYDROGEN IN INDIA'S ENERGY TRANSITION: EXPENSIVE BUT IMPORTANT FOR SOME USER

Author/s: Rahul Tongia & Utkarsh Patel

Year: 2024

Report summary: We estimate the cost of gH_2 production in India in 2030, using actual all-India RE generation data from 2019. This allows a unique analysis of the trade-off between plant load factor of electrolysers and cost of production. We find that, under optimistic assumptions, the cost of input RE would be about 1.4 USD/kg-H_2 in 2030, bringing the total cost of gH_2 production to around 2 USD/kg after including capital and operating expenditures and subsidies. This is double the oft-stated target of 1 USD/kg-H_2. We also determine the cost-efficiency of replacing fossil fuels with green H_2 using marginal CO_2 abatement costs across potential applications of H_2. We find abatement costs in the range of 70–175 USD/tonne-CO_2 across applications. This is very high compared to alternative abatement options, particularly electrification and direct use of RE. We suggest prioritising integration of RE into the grid and electrification of all viable end-uses in transport and industrial heating. The use of gH_2 and its derivatives should be limited to sectors where electrification is unlikely to be feasible, e.g. oil refining, fertilisers, steelmaking, shipping and aviation (if feasible).

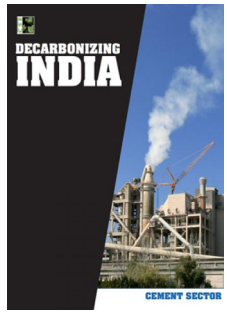
UNLOCKING THE POTENTIAL OF GREEN PUBLIC PROCUREMENT IN THE INDIAN ECONOMY

Authors: RMI

Year: 2024

Report summary: Green public procurement has the potential to drive the transition to low-carbon materials

like steel and cement in India. Public procurement accounts for around 20 per cent of India's GDP, so green public procurement policies could significantly reduce emissions. The report recommends a phased approach for integrating green public procurement characteristics into India's framework, starting with a pre-announcement phase and piloting at the project and policy levels. Initially, in-depth assessments of construction projects are needed to identify opportunities and challenges for green public procurement adoption. Efforts should also focus on developing innovative business models to promote green public procurement and formulating effective policy frameworks. Establishing an expert working group of stakeholders would help drive sustainable practices. Finally, emphasis should be on enhancing subnational policies and institutional mechanisms to promote green public procurement initiatives.

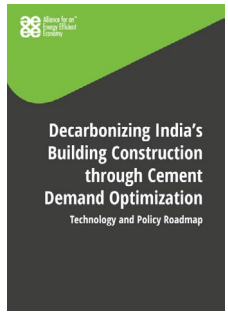


DECARBONIZING INDIA CEMENT SECTOR

Author/s: Parth Kumar

Year: 2023

Report summary: The cement sector is a hard-to-abate sector in terms of greenhouse gas emissions, but it is an equally critical contributor to the economic development of the country. India is the second largest producer of cement in the world and plans to almost double its production by 2030. Under a business-as-usual scenario, the CO_2 emissions from cement production in India are estimated to almost double by 2030. This report provides a detailed insight into the GHG emissions of the Indian cement sector and its future emission scenarios for 2030 -the report provides, based on available information, company-wise data on emissions, which will help design the road ahead. The report suggests a roadmap for the sector, highlighting the pathways for GHG emissions reduction. The assessment clearly finds there are huge opportunities to bend the carbon dioxide curve for this emission intensive sector, but it will need increased utilisation of alternate materials and waste streams along with defining and increased production of low carbon cement, aided with policy interventions, inter-sectoral partnerships, enabling infrastructure, development of futuristic technologies and adequate funds.



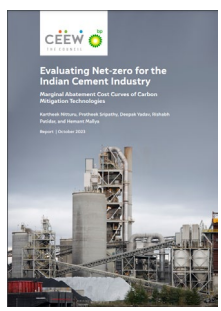
DECARBONIZING INDIA'S BUILDING CONSTRUCTION THROUGH CEMENT DEMAND OPTIMIZATION: TECHNOLOGY AND POLICY ROADMAP

Authors: S. Bhardwaj, D. Tiwari and B. Natarajan

Year: 2020

Report summary: constructions are due to the consumption of building materials and construction & demolition processes. Of all the building materials used, cement is among the most used building materials and is responsible for a significant chunk of embodied emissions. There is a need to reduce the consumption or replace it with low carbon alternatives to decrease these emissions. A number of solutions are available for reducing the carbon content in the cements that are used in construction. Examples are limestone calcined clay, geopolymer concrete, composite cements, and using alternate materials such as voided concrete slab technology, confined masonry, laminated timber. Accelerating the use of all these alternatives can reduced the embodied carbon in the buildings from 25-40 per cent without impacting on the quality of the construction.

The paper discusses some of the policy interventions that can lead to a significant reduction in the embodied carbon in the upcoming constructions in India. They include expediting the development of BIS standards for the various alternatives, enabling policies for mandatory government procurement in buildings and infrastructure development projects, establishing linkages with Energy Conservation Building Code (ECBC) and Eco Niwas Samhita (ENS) to facilitates low carbon alternatives in commercial and residential buildings, respectively.



EVALUATING NET-ZERO FOR THE INDIAN CEMENT INDUSTRY

Authors: Kartheek Nitturu, Pratheek Sripathy, Deepak Yadav, Rishabh Patidar, and Hemant Mallya

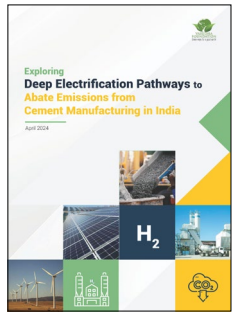
Year: 2023

Report summary: This report analyses carbon abatement measures for achieving net-zero in the cement industry and plots a MAC curve for existing plants across the country. The carbon abatement

measures investigated can broadly be classified into—energy efficiency (EE), use of alternative fuels and raw material (AFR), use of renewable energy and alternative fuels such as biomass and municipal solid waste instead of fossil fuels, clinker factor reduction (CF) and carbon management solutions.

The total cost to decarbonise the existing cement production in India will amount to USD 334 billion in capital expenses and USD three billion in additional annual operating costs. The use of renewable energy, alternative fuels and raw materials has the potential to abate 13 per cent of cement emissions, while reduction in clinker factor will reduce another 11 per cent. However, 67 per cent of the cement industry's emissions would need to be abated through carbon management techniques like CCUS and carbon offsetting.

The report recommends various policy measures to promote energy efficiency-evaluate the suitability of EAF/IF slag as an additive in cement production, develop supply chains for alternative fuels and additives, build a CCU ecosystem, and incentivise research and development to facilitate the decarbonisation of the Indian cement sector.



EXPLORING DEEP ELECTRIFICATION PATHWAYS TO ABATE EMISSIONS FROM CEMENT MANUFACTURING IN INDIA

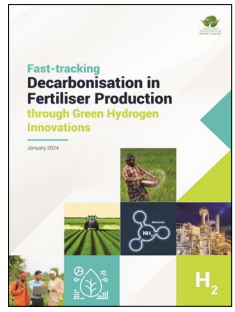
Author: Jaideep Saraswat, Nikhil Mall, Varun B.R., Tushar Katiyar

Year: 2024

Report summary: This report primarily focuses on decarbonisation pathways within cement manufacturing, which constitutes about 95 per cent of emissions. The main contributors to emissions include raw material processing, heat generation, and electricity production. The report focuses on green hydrogen integration, plasma generators powered by renewable electricity, and biomethane production.

Moreover, the report examines case studies of emerging technology providers, including pathways for direct or indirect electrification of energy requirements. Finally, there are recommendations for expediting the adoption of these technologies in the Indian cement sector. It emphasises the importance of policy

and financial support alongside collaborative efforts between industry stakeholders and policymakers to facilitate the transition towards a decarbonised cement sector. Moreover, focused initiatives aimed at scaling up emerging technologies and creating an enabling environment for innovation will be critical in achieving sustainable and low carbon cement production in India.

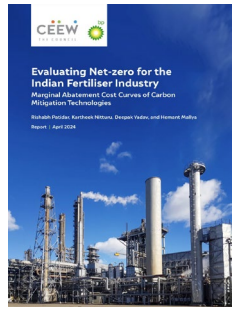


FAST-TRACKING DECARBONISATION IN FERTILISER PRODUCTION THROUGH GREEN HYDROGEN INNOVATIONS

Authors- Jaideep Saraswat, Nikhil Mall, Varun B.R., Tushar Katiyar

Year: 2024

Report summary: This report looks into the production pathways of the majorly produced fertilisers in India— urea, DAP, and Complex Fertilisers (NPK). Further, it delves deeper into the sustainable fertiliser production routes. Two categories of production leading to low-carbon fertilisers, and renewable fertilisers are examined. Further, as urea is the most produced fertiliser in India with over 60 per cent of share in total fertiliser production, this study looks into the possible pathways of green urea production. The key component being the source of carbon-dioxide (CO_2), 'green' urea is thus dependent on the source of non-fossil based CO_2, and can be derived primarily via two routes—biomass, and Direct Air Carbon Capture (DAC) routes.



EVALUATING NET-ZERO FOR THE INDIAN FERTILISER INDUSTRY

Authors: Rishabh Patidar, Kartheek Nitturu, Deepak Yadav, and Hemant Mallya

Year: 2024

Report summary: This report evaluates emission mitigation options to achieve net-zero carbon emissions through marginal abatement cost (MAC) curves for the existing plants in the fertiliser industry, with focus on major fertilisers produced in India, which account for 85 per cent of total fertiliser production—urea, di-ammonium phosphate (DAP), and other complex fertilisers (OCF). The urea, DAP, and OCF account for an emission intensity of 0.58 tCO_2/t-fertiliser. Of the total emissions, 85 per cent of the emission in the fertiliser sector is due to the use of natural gas as fuel and feedstock while

only 15 per cent of the emissions results from electricity use. This study evaluates emission mitigation measures to achieve net-zero carbon emissions under four pillars: energy efficiency (EE), renewable power, alternative fuels and carbon management.

EE technologies have the potential to reduce around 10 per cent of the emissions from the fertiliser sector. Promoting the use of green ammonia can have transformative effects on the fertiliser industry, with a 151 emission reduction, hence carbon management options and afforestation do not hold much potential. The report recommends incentivising best available energy efficiency technologies, promoting renewable energy and green ammonia adoption, and co-locating bioethanol and urea plants to decarbonise the Indian fertiliser industry.

EVALUATING NET-ZERO FOR THE INDIAN ALUMINIUM INDUSTRY

Authors: Pratheek Sripathy, Kartheek Nitturu, Deepak Yadav, and Hemant Mallya

Year: 2024

Report summary: This report evaluates emission mitigation options to achieve net-zero carbon emissions through marginal abatement cost (MAC) curves for the existing plants in the aluminium industry. The study found that the total capital investment required to achieve near net-zero emissions for existing aluminium plants will amount to INR 2,18,241 lakh crore (USD 29 billion), with an additional annual operating expenditure of INR 26,049 crore (USD 3.5 billion). The use of power sourced from RE abates 49 per cent of emissions. However, for deep decarbonisation, adopting RE power would result in a cost increase of 18 per cent while abating 49 per cent of emissions. Alternatively, in a scenario where the switch to RE power does not happen, and carbon capture and storage (CCS) is available at USD 50 per tCO_2, then net-zero aluminium would cost 21 per cent more than the base price.

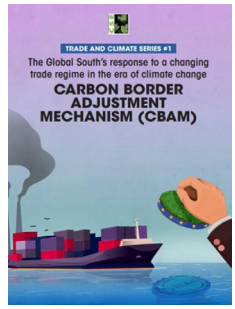
Adopting carbon capture, utilisation and storage technologies and alternative fuels can help abate the remaining emissions but involve higher costs. Achieving net-zero aluminium production will require significant investments. Policies to incentivise renewable energy, developing a CCUS ecosystem and a R&D ecosystem, and implementing robust emissions monitoring frameworks are recommended to facilitate decarbonisation of the Indian aluminium industry.

EU'S CARBON BORDER TAX POSE A BIG CHALLENGE FOR INDIAN BUSINESSES

Authors: Prachi Priya and RV Anuradha

Year: 2024

Article summary: The EU's Carbon Border Adjustment Mechanism (CBAM) will impose taxes on imports from countries like India that have higher carbon emissions than the EU. This will make Indian exports like aluminium and steel less competitive in the EU market. Indian industries lack a clear carbon pricing mechanism, and the implicit costs they face for carbon emissions are different from the EU's explicit carbon tax. Complying with the CBAM's data reporting requirements also raises issues around data privacy. While the CBAM may push countries to reduce emissions, it essentially penalises imports based on the EU's own carbon price. This could make developing country imports more expensive and reverse the flow of climate financing. To comply with the CBAM, India needs clarity on how to calculate an implicit carbon price, protect data privacy, and align its own planned carbon trading system. However, a unilateral mechanism like the CBAM undermines climate justice and economic logic. India needs to think of ways to mitigate the CBAM's impact on its exports.



CARBON BORDER ADJUSTMENT MECHANISM (CBAM): THE GLOBAL SOUTH'S RESPONSE TO A CHANGING TRADE REGIME IN THE ERA OF CLIMATE CHANGE

Author/s: Trishant Dev and Avantika Goswami

Year: 2024

Summary of the Report: The European Union's introduction of the Carbon Border Adjustment Mechanism (CBAM) marks a bold new experiment in global trade and climate policy. By taxing imports like iron, steel, cement, aluminium and fertilisers based on their greenhouse gas (GHG) emission intensities, the EU aims to level the playing field for its firms operating under the Emissions Trading System (ETS). However, this mechanism raises several critical concerns about its broader implications and fairness.

The impact of CBAM is likely to be disproportionately felt by developing countries, potentially hindering their economic growth in key sectors and access to global markets. CBAM also places the onus of decarbonisation on developing countries, which ignores the disproportionate contribution of developed nations to the climate crisis and their past failures to channel resources for developing countries to decarbonise. Consequently, during COP 28 in 2023, developing countries raised serious concerns about the negative impacts of unilateral trade measures like CBAM on their economies. Does the CBAM truly spur global decarbonisation, or does it perpetuate existing inequalities and trade tensions? Our report examines these questions.

References

THE ENERGY SECTOR: Making a scalable and affordable transition

1. *National communications (NC)(2023), National communications (NC),Retrieved from https://unfccc.int/documents/636235 as accessed on 09 October 2024*

2. *Raizada,S., Sharma,D., Laan,T., Jain, S. (2023). Mapping India's Energy Policy, Retrieved from https://www.iisd.org/publications/report/mapping-india-energy-policy-2023 as accessed on 09 October 2024*

3. *Singh, D. (2021). Long-Term Goal-Setting and Planning for Decarbonising the Indian Power Sector — Need for a Coordinated Approach, Retrieved from https://csep.org/wp-content/uploads/2021/10/Long-Term-Goal-and-Planning-Power.pdf as accessed on 09 October 2024*

4. *Rodrigues,N., Khan, N.(2024). Drivers to Coal Phase-Down in India: Part 1 — Battery Cost Declines, Retrieved from https://ember-climate.org/insights/research/drivers-to-coal-phase-down-in-india/ as accessed on 09 October 2024.*

5. *Pachouri, R., Thakre, S.,Sinha, S.(2024), An Outlook of India's Electricity Demand : Analysis and Projections to The Next Decade, Retrieved from https://www.vasudha-foundation.org/an-outlook-of-indias-electricity-demand-analysis-and-projections-to-the-next-decade/ as accessed on 09 October 2024.*

6. *Sharma, R.K.(n.d). Bio-mass Power Generation and its challenges especially in reference to Co-firing in Coal based Thermal Power Plants, Retrieved from https://renewablewatch.in/wp-content/uploads/2022/11/RVUNL_Biomass-Co-Firing.pdf as accessed on 09 October 2024.*

7. *Government of India. (2023).National Electricity Plan (Volume 1), Retrieved from https://cea.nic.in/wp-content/uploads/irp/2023/05/NEP_2022_32_FINAL_GAZETTE-1.pdf as accessed on 09 October 2024.*

8. *Sendich, E., Kahan, A. (2019), EIA analysis explores India's projected energy consumption, Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=42295 as accessed on 09 October 2024.*

9. *Singh, D. (2021). Long-Term Goal-Setting and Planning for Decarbonising the Indian Power Sector — Need for a Coordinated Approach, Retrieved from https://csep.org/wp-content/uploads/2021/10/Long-Term-Goal-and-Planning-Power.pdf as accessed on 09 October 2024*

10. *Department of Science and Technology ( ). Clean Coal Research Initiative, Retrieved from https://dst.gov.in/clean-coal-research-initiative-ccri as accessed on 09 October 2024*

11. *Sharma, R.K.(n.d). Bio-mass Power Generation and its challenges especially in reference to Co-firing in Coal based Thermal Power Plants, Retrieved from https://renewablewatch.in/wp-content/uploads/2022/11/RVUNL_Biomass-Co-Firing.pdf as accessed on 09 October 2024.*

12. *Sinha, A.K.(2020). Recipe book for flexibilisation of coal based power plants Best practices and operating procedures for flexible operation, Retrieved from https://energyforum.in/fileadmin/india/media_elements/publications/20201029_Recipe_book_for_flexibilisation_of_coal_based_power_plants/20201029_Flexibility_of_Coal_AK_Sinha.pdf as accessed on 09 October 2024.*

13. *Jai, S. (2023), India to build 2 billion-tonne coal stock by 2030, then hit pause button, Retrieved from https://www.business-standard.com/economy/news/india-to-build-2-billion-tonne-coal-stock-by-2030-then-hit-pause-button-123123100574_1.html as accessed on 09 October 2024.*

14. Chugh, G., Singla, A. (2020). The need for private sector participation in India's electricity distribution sector, Retrieved from https://www.icf.com/insights/energy/private-sector-participation-india-electricity-distribution as accessed on 09 October 2024.

15. Samant, S. (2023).Can't phase out coal power until storage, tech viable: Power Ministry, Retrieved from https://economictimes.indiatimes.com/industry/renewables/cant-phase-out-coal-power-until-storage-tech-viable-power-ministry/articleshow/105883558.cms as accessed on 09 October 2024.

16. Anon(2024), India to spend up to USD385 billion to meet renewable energy target, Moody's Ratings estimates, Retrieved from https://www.thehindu.com/business/Industry/india-to-spend-up-to-385-billion-to-meet-renewable-energy-target-moodys-ratings-estimates/article68260250.ece as accessed on 09 October 2024.

17. Ministry of Power, 500GW Nonfossil Fuel Target, Retrieved from https://powermin.gov.in/en/content/500gw-nonfossil-fuel-target as accessed on 09 October 2024.

18. Samant, S. (2023).Can't phase out coal power until storage, tech viable: Power Ministry, Retrieved from https://economictimes.indiatimes.com/industry/renewables/cant-phase-out-coal-power-until-storage-tech-viable-power-ministry/articleshow/105883558.cms as accessed on 09 October 2024.

19. Singh, D. (2021). Long-Term Goal-Setting and Planning for Decarbonising the Indian Power Sector — Need for a Coordinated Approach, Retrieved from https://csep.org/wp-content/uploads/2021/10/Long-Term-Goal-and-Planning-Power.pdf as accessed on 09 October 2024

20. Rodrigues,N., Khan, N.(2024). Drivers to Coal Phase-Down in India: Part 1 — Battery Cost Declines, Retrieved from https://ember-climate.org/insights/research/drivers-to-coal-phase-down-in-india/ as accessed on 09 October 2024.

21. Sinha, A.K.(2020). Recipe book for flexibilisation of coal based power plants Best practices and operating procedures for flexible operation, Retrieved from https://energyforum.in/fileadmin/india/media_elements/publications/20201029_Recipe_book_for_flexibilisation_of_coal_based_power_plants/20201029_Flexibility_of_Coal_AK_Sinha.pdf as accessed on 09 October 2024.

22. Anon(2024), A blueprint for RE ambitions, Retrieved from https://www.financialexpress.com/opinion/a-blueprint-for-re-ambitions/3550063/ as accessed on 09 October 2024.

23. Government of India. (2023).National Electricity Plan (Volume 1), Retrieved from https://cea.nic.in/wp-content/uploads/irp/2023/05/NEP_2022_32_FINAL_GAZETTE-1.pdf as accessed on 09 October 2024.

24. National communications (NC)(2023), National communications (NC),Retrieved from https://unfccc.int/documents/636235 as accessed on 09 October 2024

25. Government of India. (2023).National Electricity Plan (Volume 1), Retrieved from https://cea.nic.in/wp-content/uploads/irp/2023/05/NEP_2022_32_FINAL_GAZETTE-1.pdf as accessed on 09 October 2024.

26. Rodrigues,N., Khan, N.(2024). Drivers to Coal Phase-Down in India: Part 1 — Battery Cost Declines, Retrieved from https://ember-climate.org/insights/research/drivers-to-coal-phase-down-in-india/ as accessed on 09 October 2024.

27. Anon(2023), India on path to triple renewable energy capacity by 2030 but faces financing hurdle: Report, Retrieved from https://economictimes.indiatimes.com/industry/renewables/india-on-path-to-triple-renewable-energy-capacity-by-2030-but-faces-financing-hurdle-report/articleshow/105584023.cms as accessed on 09 October 2024.

28. Anon(2024), India to spend up to USD385 billion to meet renewable energy target, Moody's Ratings estimates, Retrieved from https://www.thehindu.com/business/Industry/india-to-spend-up-to-385-billion-to-meet-renewable-energy-target-moodys-ratings-estimates/article68260250.ece as accessed on 09 October 2024.

29. Raizada,S., Sharma,D., Laan,T., Jain, S. (2023). Mapping India's Energy Policy, Retrieved from https://www.iisd.org/publications/report/mapping-india-energy-policy-2023 as accessed on 09 October 2024

30. Rutter, A.H.(2024). MSEDCL's new coal + solar tender was Rs 4.08/kWh. How much would wind + storage + solar cost for the same profile?, Retrieved from

https://energywithalex.wordpress.com/2024/09/16/msedcls-new-coal-solar-tender-was-rs-4-08-kwh-how-much-would-wind-storage-solar-cost-for-the-same-profile/ as accessed on 09 October 2024

31. Ministry of Power, 500GW Nonfossil Fuel Target, Retrieved from https://powermin.gov.in/en/content/500gw-nonfossil-fuel-target as accessed on 09 October 2024.

32. Department of Science and Technology (n.d). Clean Coal Research Initiative, Retrieved from https://dst.gov.in/clean-coal-research-initiative-ccri as accessed on 09 October 2024

33. Matsumoto, A.,Phoumin, H.(2022).Decarbonisation of Thermal Power Generation in ASEAN Countries, Retrieved from https://www.eria.org/uploads/media/Research-Project-Report/RPR-2022-11/Decarbonisation-of-Thermal-Power-Generation-in-ASEAN-Countries.pdf as accessed on 09 October 2024.

34. Chugh, G., Singla, A. (2020). The need for private sector participation in India's electricity distribution sector, Retrieved from https://www.icf.com/insights/energy/private-sector-participation-india-electricity-distribution as accessed on 09 October 2024.

35. Anon (2024). Scaling Up: Renewable energy financing landscape in India, Retrieved from https://powerline.net.in/2024/07/01/scaling-up-renewable-energy-financing-landscape-in-india/ as accessed on 09 October 2024.

36. Anon(2018). Green Energy Finance in India: Challenges and Solutions. Retrieved from https://www.adb.org/publications/green-energy-finance-india-challenges-and-solutions as accessed on 09 October 2024

37. Anon (2024). Scaling Up: Renewable energy financing landscape in India, Retrieved from https://powerline.net.in/2024/07/01/scaling-up-renewable-energy-financing-landscape-in-india/ as accessed on 09 October 2024.

38. Anon(2018). Green Energy Finance in India: Challenges and Solutions. Retrieved from https://www.adb.org/publications/green-energy-finance-india-challenges-and-solutions as accessed on 09 October 2024

39. Anon(2023), India on path to triple renewable energy capacity by 2030 but faces financing hurdle: Report, Retrieved from https://economictimes.indiatimes.com/industry/renewables/india-on-path-to-triple-renewable-energy-capacity-by-2030-but-faces-financing-hurdle-report/articleshow/105584023.cms as accessed on 09 October 2024.

40. Anon(2024), India to spend up to USD385 billion to meet renewable energy target, Moody's Ratings estimates, Retrieved from https://www.thehindu.com/business/Industry/india-to-spend-up-to-385-billion-to-meet-renewable-energy-target-moodys-ratings-estimates/article68260250.ece as accessed on 09 October 2024.

41. Singh, D. (2021). Long-Term Goal-Setting and Planning for Decarbonising the Indian Power Sector — Need for a Coordinated Approach, Retrieved from https://csep.org/wp-content/uploads/2021/10/Long-Term-Goal-and-Planning-Power.pdf as accessed on 09 October 2024

42. Tongia, R.,Sehgal, A., Kamboj, P.(2020). Future of Coal in India: Smooth Transition or Bumpy Road Ahead?, Retrieved from https://www.brookings.edu/books/future-of-coal-in-india-smooth-transition-or-bumpy-road-ahead/ as accessed on 09 October 2024

43. Department of Science and Technology (n.d). Clean Coal Research Initiative, Retrieved from https://dst.gov.in/clean-coal-research-initiative-ccri as accessed on 09 October 2024

44. National communications (NC)(2023), National communications (NC),Retrieved from https://unfccc.int/documents/636235 as accessed on 09 October 2024

45. Josey, A., Mandal, M., Nhalur,S.(2020). The critical role of state government revenue subsidy in electricity supply, Retrieved from https://energy.prayaspune.org/our-work/research-report/the-critical-role-of-state-government-revenue-subsidy-in-electricity-supply as accessed on 09 October 2024.

46. Ibid.

47. Rodrigues,N., Khan, N.(2024). Drivers to Coal Phase-Down in India: Part 1 — Battery Cost Declines, Retrieved from https://ember-climate.org/insights/research/drivers-to-coal-phase-down-in-india/ as accessed on 09 October 2024.

48. Josey, A., Mandal, M., Nhalur,S.(2020). The critical role of state government revenue subsidy in electricity supply, Retrieved from https://energy.prayaspune.org/our-work/research-report/the-critical-role-of-state-government-revenue-subsidy-in-electricity-supply as accessed on 09 October 2024.

49. Samant, S. (2023).Can't phase out coal power until storage, tech viable: Power Ministry, Retrieved from https://economictimes.indiatimes.com/industry/renewables/cant-phase-out-coal-power-until-storage-tech-viable-power-ministry/articleshow/105883558.cms as accessed on 09 October 2024.

50. Josey, A., Mandal, M., Nhalur,S.(2020). The critical role of state government revenue subsidy in electricity supply, Retrieved from https://energy.prayaspune.org/our-work/research-report/the-critical-role-of-state-government-revenue-subsidy-in-electricity-supply as accessed on 09 October 2024.

51. Raizada,S., Sharma,D., Laan,T., Jain, S. (2023). Mapping India's Energy Policy, Retrieved from https://www.iisd.org/publications/report/mapping-india-energy-policy-2023 as accessed on 09 October 2024

52. Matsumoto, A.,Phoumin, H.(2022). Decarbonisation of Thermal Power Generation in ASEAN Countries, Retrieved from https://www.eria.org/uploads/media/Research-Project-Report/RPR-2022-11/Decarbonisation-of-Thermal-Power-Generation-in-ASEAN-Countries.pdf as accessed on 09 October 2024.

53. Josey, A., Dixit, S., Manasi, J., Nhalur,S.(2024). Electricity Distribution Companies: Understanding Present Challenges and Shaping Future Opportunities, Retrieved from https://www.nipfp.org.in/media/medialibrary/2024/07/DISCOM_Finance_Working_Paper_Prayas_090724.pdf as accessed on 09 October 2024

54. Ibid.

55. National communications (NC)(2023), National communications (NC),Retrieved from https://unfccc.int/documents/636235 as accessed on 09 October 2024

56. Josey, A., Mandal, M., Nhalur,S.(2020). The critical role of state government revenue subsidy in electricity supply, Retrieved from https://energy.prayaspune.org/our-work/research-report/the-critical-role-of-state-government-revenue-subsidy-in-electricity-supply as accessed on 09 October 2024.

57. Anon (2024). Scaling Up: Renewable energy financing landscape in India, Retrieved from https://powerline.net.in/2024/07/01/scaling-up-renewable-energy-financing-landscape-in-india/ as accessed on 09 October 2024.

58. Ministry of Power (2024). 12th Edition of the Integrated Rating of Discoms, Retrieved from https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2013501 as accessed on 09 October 2024

59. Sinha, A.K.(2020). Recipe book for flexibilisation of coal based power plants Best practices and operating procedures for flexible operation, Retrieved from https://energyforum.in/fileadmin/india/media_elements/publications/20201029_Recipe_book_for_flexibilisation_of_coal_based_power_plants/20201029_Flexibility_of_Coal_AK_Sinha.pdf as accessed on 09 October 2024.

60. Josey, A., Mandal, M., Nhalur,S.(2020). The critical role of state government revenue subsidy in electricity supply, Retrieved from https://energy.prayaspune.org/our-work/research-report/the-critical-role-of-state-government-revenue-subsidy-in-electricity-supply as accessed on 09 October 2024.

61. Josey, A., Dixit, S., Manasi, J., Nhalur,S.(2024). Electricity Distribution Companies: Understanding Present Challenges and Shaping Future Opportunities, Retrieved from https://www.nipfp.org.in/media/medialibrary/2024/07/DISCOM_Finance_Working_Paper_Prayas_090724.pdf as accessed on 09 October 2024

62. Tongia, R.,Sehgal, A., Kamboj, P.(2020). Future of Coal in India: Smooth Transition or Bumpy Road Ahead?, Retrieved from https://www.brookings.edu/books/future-

of-coal-in-india-smooth-transition-or-bumpy-road-ahead/ as accessed on 09 October 2024

63. Rutter,A.(2024).How Much Would it Cost a Coal Plant to Compete with RE + Storage on FDRE 2?, Retrieved from https://energywithalex.wordpress.com/2024/03/22/how-much-would-it-cost-a-coal-plant-to-compete-with-re-storage-on-fdre-2/ as accessed on 09 October 2024

64. Anon(2024), A blueprint for RE ambitions, Retrieved from https://www.financialexpress.com/opinion/a-blueprint-for-re-ambitions/3550063/ as accessed on 09 October 2024.

65. Anon (2024). Scaling Up: Renewable energy financing landscape in India, Retrieved from https://powerline.net.in/2024/07/01/scaling-up-renewable-energy-financing-landscape-in-india/ as accessed on 09 October 2024.

66. Venugopal, S.(2024). India's energy transition must prioritise social justice, Retrieved from https://idronline.org/article/climate-emergency/indias-energy-transition-must-prioritise-social-justice/ as accessed on 09 October 2024

67. Anon(2024), A blueprint for RE ambitions, Retrieved from https://www.financialexpress.com/opinion/a-blueprint-for-re-ambitions/3550063/ as accessed on 09 October 2024.

68. Tharakan,P., Manikpuri,P.(2023). Ensuring a Just Transition is Key to India's Energy Transition Goals, Retrieved from https://www.adb.org/news/features/ensuring-just-transition-key-india-energy-transition-goals as accessed on 09 October 2024.

69. Tongia, R.,Sehgal, A., Kamboj, P.(2020). Future of Coal in India: Smooth Transition or Bumpy Road Ahead?, Retrieved from https://www.brookings.edu/books/future-of-coal-in-india-smooth-transition-or-bumpy-road-ahead/ as accessed on 09 October 2024

70. Anon(2024), A blueprint for RE ambitions, Retrieved from https://www.financialexpress.com/opinion/a-blueprint-for-re-ambitions/3550063/ as accessed on 09 October 2024.

71. Tharakan,P., Manikpuri,P.(2023). Ensuring a Just Transition is Key to India's Energy Transition Goals, Retrieved from https://www.adb.org/news/features/ensuring-just-transition-key-india-energy-transition-goals as accessed on 09 October 2024.

72. Pachouri, R., Thakre, S.,Sinha, S.(2024), An Outlook of India's Electricity Demand : Analysis and Projections to The Next Decade, Retrieved from https://www.vasudha-foundation.org/an-outlook-of-indias-electricity-demand-analysis-and-projections-to-the-next-decade/ as accessed on 09 October 2024.

73. Ningthoujam,J., Gupta, G., Singh, N., How Distributed Solar Can Reinvigorate India's Electricity Distribution Companies, Retrieved from https://rmi.org/how-distributed-solar-can-reinvigorate-indias-electricity-distribution-companies/ as accessed from 09 October 2024.

HARD-TO-ABATE SECTORS: Low carbon growth in key industries

1. *Kumar, P. (2022). Decarbonizing India Iron and Steel Sector*, Centre for science and environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-s-iron-and-steel-sector-report-11434 as accessed on 09 October 2024.*

2. *Hall, W. et al (2022). Achieving Green Steel: Roadmap to a net zero steel sector in India*, The Energy Resources Institute, New Delhi. *Retrieved from https://www.teriin.org/sites/default/files/files/Achieving_Green_Steel_Roadmap.pdf as accessed on 09 October 2024.*

3. *Sethi, G. (2020). Decarbonisation of Iron and Steel sectors*, The Energy Resources Institute, New Delhi. *Retrieved from https://www.teriin.org/project/decarbonisation-iron-and-steel-sectors as accessed on 09 October 2024.*

4. *Kumar, P. (2022). Decarbonizing India Iron and Steel Sector*, Centre for science and environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-s-iron-and-steel-sector-report-11434 as accessed on 09 October 2024.*

5. *Greening the Steel Sector in India: Roadmap and Action Plan*. Available at https://steel.gov.in/en/greening-steel-sector-india-roadmap-and-action-plan, as accessed on 09 October 2024

6. *Kumar, P. (2022). Decarbonizing India Iron and Steel Sector*, Centre for science and environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-s-iron-and-steel-sector-report-11434 as accessed on 09 October 2024.*

7. *Hall, W. et al (2022). Achieving Green Steel: Roadmap to a net zero steel sector in India*, The Energy Resources Institute, New Delhi. *Retrieved from https://www.teriin.org/sites/default/files/files/Achieving_Green_Steel_Roadmap.pdf as accessed on 09 October 2024.*

8. ibid

9. *Greening the Steel Sector in India: Roadmap and Action Plan*. Available at https://steel.gov.in/en/greening-steel-sector-india-roadmap-and-action-plan , as accessed on 09 October 2024

10. *Hall, W. et al (2022). Achieving Green Steel: Roadmap to a net zero steel sector in India*, The Energy Resources Institute, New Delhi. *Retrieved from https://www.teriin.*

org/sites/default/files/files/Achieving_Green_Steel_Roadmap.pdf as accessed on 09 October 2024.

11. *Sethi, G. (2020). Decarbonisation of Iron and Steel sectors*, The Energy Resources Institute, New Delhi. *Retrieved from https://www.teriin.org/project/decarbonisation-iron-and-steel-sectors as accessed on 09 October 2024.*

12. *Kumar, P. (2022). Decarbonizing India Iron and Steel Sector*, Centre for science and environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-s-iron-and-steel-sector-report-11434 as accessed on 09 October 2024.*

13. *Shrivastava, M. et al (2023). Financing Decarbonization of the Secondary Steel Sector in India: Towards an Enabling Environment*, The Energy Resources Institute, New Delhi. *Retrieved from https://www.teriin.org/event/financing-decarbonization-indian-secondary-steel-sector-towards-enabling-environment as accessed on 09 October 2024.*

14. *Yadav, D. et al (2021). Greening Steel Moving to Clean Steelmaking Using Hydrogen and Renewable Energy*, Council on Energy, Environment and Water, New Delhi. *Retrieved from https://www.ceew.in/sites/default/files/ceew-study-on-clean-and-carbon-neutral-hydrogen-based-steel-production.pdf as accessed on 09 October 2024.*

15. *Sethi, G. (2020). Decarbonisation of Iron and Steel sectors*, The Energy Resources Institute, New Delhi. *Retrieved from https://www.teriin.org/project/decarbonisation-iron-and-steel-sectors as accessed on 09 October 2024.*

16. *Kumar, P. (2022). Decarbonizing India Iron and Steel Sector*, Centre for science and environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-s-iron-and-steel-sector-report-11434 as accessed on 09 October 2024.*

17. ibid

18. ibid

19. *Nitturu, K. et al (2023). Evaluating Net-zero for the Indian Cement Industry*, Council on Energy, Environment and Water, New Delhi. *Retrieved from https://www.ceew.in/sites/default/files/How-Can-India-Decarbonise-For-Net-Zero-Sustainable-Cement-Production-Industry.pdf as accessed on 09 October 2024.*

20. *Kumar, P. (2023). Decarbonizing India: Cement Sector*, Centre for Science and Environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-cement-sector-11867 as accessed on 09 October 2024.*

21. *Nitturu, K. et al (2023). Evaluating Net-zero for the Indian Cement Industry*, Council on Energy, Environment and Water, New Delhi. *Retrieved from https://www.ceew.in/sites/default/files/How-Can-India-Decarbonise-For-Net-Zero-Sustainable-Cement-Production-Industry.pdf as accessed on 09 October 2024.*

22. *Kumar, P. (2023). Decarbonizing India: Cement Sector*, Centre for Science and Environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-cement-sector-11867 as accessed on 09 October 2024.*

23. *Bharadwaj, S. (2020). Reducing Cement Sector Emissions: Approaches to reduce the demand of Cement from Construction*, Alliance for an Energy Efficient Economy, New Delhi. *Retrieved from https://aeee.in/wp-content/uploads/2020/12/cement-sector-emission.pdf as accessed on 09 October 2024.*

24. *Nitturu, K. et al (2023). Evaluating Net-zero for the Indian Cement Industry*, Council on Energy, Environment and Water, New Delhi. *Retrieved from https://www.ceew.in/sites/default/files/How-Can-India-Decarbonise-For-Net-Zero-Sustainable-Cement-Production-Industry.pdf as accessed on 09 October 2024.*

25. *Kumar, P. (2023). Decarbonizing India: Cement Sector*, Centre for Science and Environment, New Delhi. *Retrieved from https://www.cseindia.org/decarbonizing-india-cement-sector-11867 as accessed on 09 October 2024.*

26. Need for an aluminium policy in India. Available at http://164.100.94.191/niti/writereaddata/files/document_publication/niti_aluminum_upload.pdf, as accessed on 09 October 2024

27. *Sripathy, P. et al (2024). Evaluating Net-zero for the Indian Aluminium Industry*, Council on Energy, Environment and Water, New Delhi. *Retrieved from https://www.ceew.in/sites/default/files/how-can-low-carbon-sustainable-aluminium-reduce-carbon-emissions-in-india.pdf as accessed on 09 October 2024.*

28. Ibid

29. Ibid

30. Ibid

31. *Patidar, R. et al (2024). Evaluating Net-zero for the Indian Fertilizer Industry*, Council on Energy, Environment and Water, New Delhi. . *Retrieved from https://www.ceew.in/publications/how-can-india-achieve-sustainable-fertilisers-production-and-reduce-carbon-emissions as accessed on 09 October 2024*

32. *Saraswat, J. et al (2024). Fast-tracking Decarbonisation in Fertiliser Production through Green Hydrogen Innovations,* Vasudha Foundation, New Delhi. *Retrieved from https://www.vasudha-foundation.org/fast-tracking-decarbonisation-in-fertiliser-production-through-green-hydrogen-innovations as accessed on 09 October 2024*

India aims to achieve 500GW of renewable energy and a 45 per cent reduction in GHG emissions per unit of GDP by 2030, in relation to 2005 levels. This report examines the challenges and pathways for decarbonising India's energy and industrial sectors, focusing on scalable and affordable solutions.

This research anthology puts together perspectives on emissions trajectories, renewable energy integration, and low-carbon strategies for energy and hard-to-abate industries like steel, cement, aluminum, and fertiliser by compiling key studies and findings from civil society, research institutes, and grassroots organizations—to map existing knowledge and identify research gaps.

The findings build on *Climate Week* discussions, where sector experts, policymakers, and industry leaders assessed India's progress and outlined strategies for a low-carbon future.

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