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The climate response: Tapping into India's climate and energy transition opportunity

July 2025

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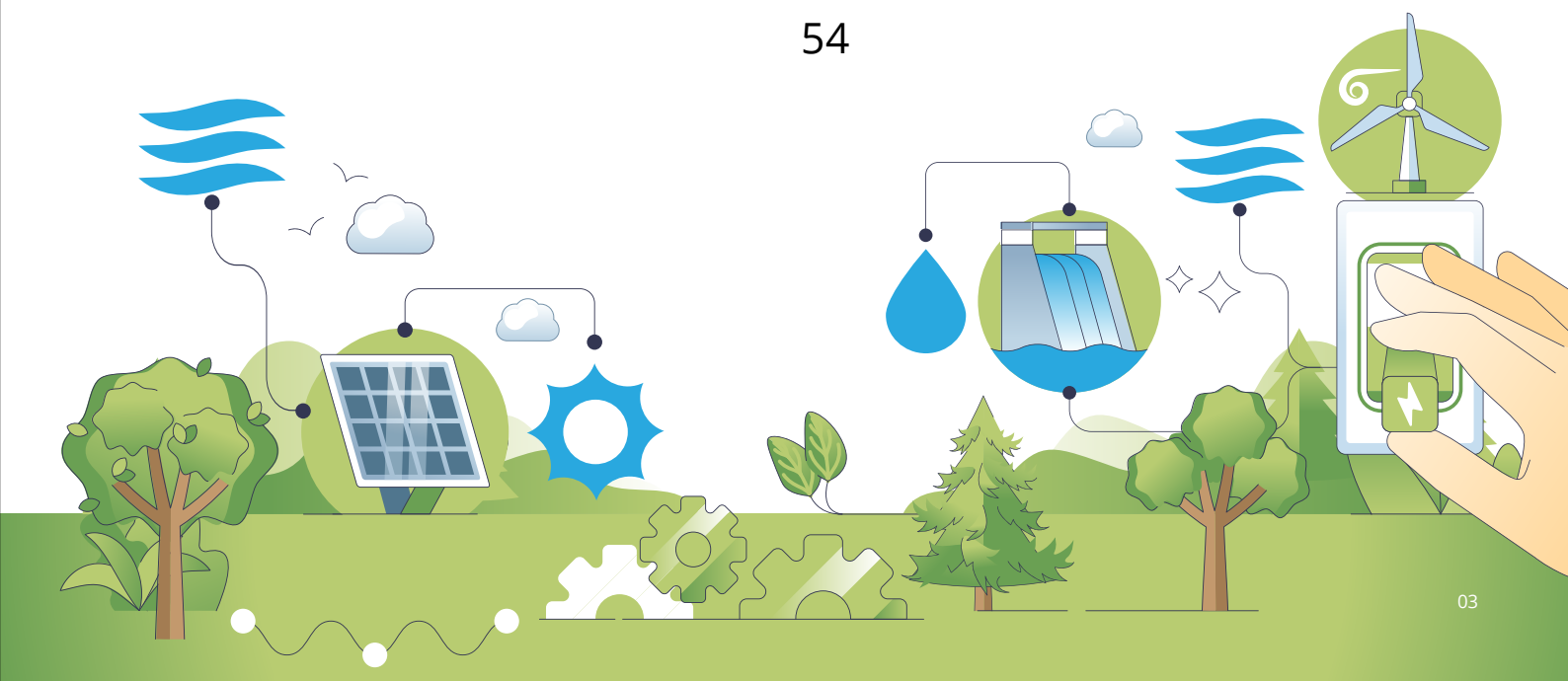

Foreword

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With countries placing greater emphasis on building a low-carbon economy, the importance of climate finance has never been more pronounced. As economies evolve, energy demands shift, and climate risks intensify, financial mechanisms lie at the heart of navigating this transformation.

India, one of the fastest-growing economies in the world, is aligning its development goals alongside its climate commitments, with energy demand set to triple by 2050. While fossil fuels, particularly coal, currently make up 59% of its energy mix, India is taking bold steps toward decarbonisation with targets like 500 GW of non-fossil fuel energy by 2030, a 45% reduction in emissions intensity from 2005 levels, and a net-zero emissions goal by 2070. To support this transition, a significant financial boost is needed.

The country will require an estimated $1.5 trillion by 2030 to fund climate mitigation and resilience efforts. This investment will not only reduce emissions but also boost job creation, enhance energy security, and protect vulnerable communities from climate risks. Financial instruments, such as green bonds, climate funds, and blended finance models, are playing an increasingly important role in mobilising capital for sustainability initiatives. Unlocking investment at scale and ensuring equitable access to climate finance, will help drive long-term resilience in India's most climate-sensitive sectors. By strategically harnessing climate finance, India can accelerate its decarbonisation efforts, offering immense investment potential in sectors poised for sustainable growth and innovation. This report highlights the investment potential to help India transition to a resilient, low-carbon economy.

As you engage with the findings, we invite policymakers, investors, and industry leaders to recognise the opportunity at hand. The coming decade will be influenced by those who take decisive action — and India has the potential to lead a global paradigm shift toward a more sustainable and prosperous future.

Introduction

The global context: Climate change and energy transition

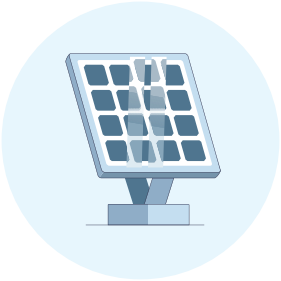
Climate change is one of the most pressing challenges of our time. Rising global temperatures are primarily driven by human activities, notably burning fossil fuels (coal, oil and gas). This has led to widespread disruptions in ecosystems, economies and communities, causing severe and lasting consequences. The Earth's surface temperature is about 1.2°C[1] higher than pre-industrial levels, reaching an unprecedented peak in the last 100,000 years. The previous decade (2011–2020) was the hottest on record, with the past four decades exceeding all historical temperature averages since 1850[2].

Such shifts necessitate actions from stakeholders across multiple areas, resulting in investment opportunities that accelerate the mitigation efforts.

The energy sector is the most significant contributor to global GHG emissions causing global temperature rise, with fossil fuels accounting for 80 percent of global energy production[3]. Thus, transitioning to cleaner energy sources is essential for reducing emissions and mitigating global warming. Many countries have pledged to achieve net-zero emissions by 2050, but to keep global warming below 1.5°C, emissions must be reduced by 50 percent by 2030. This goal requires significantly cutting down fossil fuel consumption, as more than two-thirds of known fossil fuel reserves must remain untapped by 2050 to prevent catastrophic climate impacts.

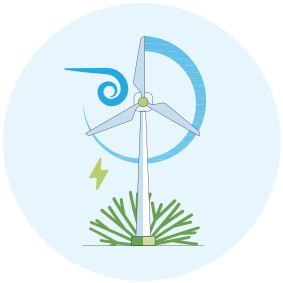
However, a sustainable future depends on more than the use of clean energy. A circular economy and waste management approach is key to reducing environmental impact. By shifting from a linear "take-make-dispose" model to one focused on recycling, reusing and regenerating materials, industries can lower emissions, minimise landfill waste and reduce resource extraction. Similarly, sustainable transport infrastructure, including electrified public transport, high-speed rail, smart cities and urban mobility solutions, will be critical in cutting transport-related emissions and improving urban air quality. Water sector resilience is also crucial as climate change intensifies droughts, floods and freshwater shortages. Investments in water conservation, smart irrigation and wastewater recycling are essential to ensure long-term water security. The transformation must also extend to sustainable agriculture, which is highly vulnerable to climate change. Precision farming, agroforestry and regenerative practices can improve soil health, enhance carbon sequestration and ensure food security while minimising resource usage. Enablers such as digital systems and platforms for climate action, such as AI-driven monitoring, climate risk forecasting and blockchain-based carbon tracking, can enhance decision-making and accelerate mitigation efforts across areas.

[1]https://www.un.org/en/climatechange/what-is-climate-change
[2]https://www.un.org/en/climatechange/what-is-climate-change
[3]https://www.eesi.org/topics/fossil-fuels/description



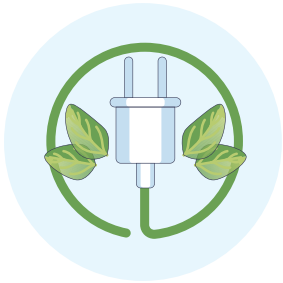
Make renewable energy technology a global public good

It is vital to address and dismantle obstacles to sharing knowledge and technology, such as those related to intellectual property rights, to make renewable energy a public good.



Improve global access to components and raw materials

Active steps must be taken to improve accessibility to key materials for manufacturing components and products across sectors. An equitable transition to renewable energy will also require investments in skills training, research and innovation. It will need incentives to develop supply chains which imbibe sustainable practices and safeguard ecosystems.



Level the playing field for renewable energy technologies

The next generation of national climate plans, or Nationally Determined Contributions (NDCs), presents a crucial opportunity to realign global efforts with the goals of the Paris Agreement and integrate climate action with sustainable development. The NDC must set renewable energy targets aligned with the Paris Agreement goal of 1.5°C and strive to increase renewables' share in global electricity generation from today's 29 percent to 60 percent by 2030.

The UN has outlined **five critical actions**[4] the world needs to prioritise now to transform our energy systems and speed up the shift to renewable energy:

Prioritise subsidies to renewable energy

Providing incentives and subsidies to renewable energy will have multi-fold benefits, such as helping reduce emissions, supporting sustainable economic growth, creating jobs, improving public health and promoting greater equality, especially for the disadvantaged and vulnerable communities globally.

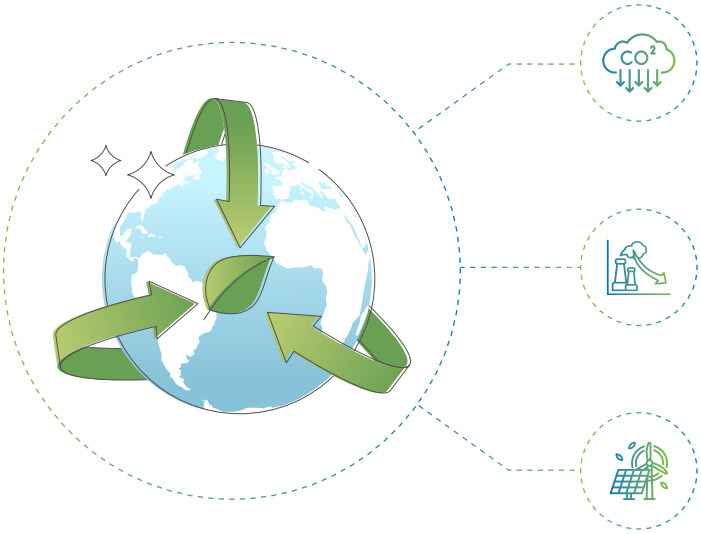
Significant investments in renewables

Achieving the goal of net zero will require annual investments of at least US$4 trillion in renewable energy until 2030, including in technology and infrastructure. Global financial systems, including multilateral development banks and other public and private financial institutions, should align their lending portfolios to accelerate the renewable energy transition.

[4]https://www.un.org/en/climatechange/five-ways-jump-start-renewable-energy-transitio

Global efforts

Countries across the globe have undertaken numerous efforts to actively develop and implement regulations and policies to drive the decarbonisation agenda. In December 2015, 194 states and the EU adopted the Paris Agreement to limit the rise in global temperature to well below 1.5°C.[5] Under the Agreement, countries have committed to submitting and delivering voluntary pledges that set out how to lower their emissions and adapt to climate change. These are known as Nationally Determined Contributions (NDCs). UK, Germany, Japan, Australia, Canada, the EU, and some other countries have pledged to become net zero by 2050, with planned policies to decarbonise the grid and investments in clean energy technologies. Other notable goals adopted are listed as follows:[8]



A total of 35 countries have made commitment to achieve carbon neutrality before or by 2050

The UK aims to reduce emissions by 68 percent below 1990 levels by 2030 and has enhanced ESG disclosures.

The EU has committed to increasing the share of renewable energy in final energy consumption to at least 42.5 percent by 2030.

India's role in global climate efforts

India accounts for about 18 percent of the world's population, it uses only about 6 percent[6] of the world's primary energy. Its per capita energy consumption equals 0.6 tonnes of oil equivalent (toe), compared with the global per capita average of 1.8 toe.[7] It recognises the importance of sustainable development and has taken proactive measures to address climate change concerns. India is a signatory to major international climate agreements, including the Paris Agreement. It is also working towards enhancing its climate resilience and implementing its NDCs.

India has made numerous efforts to promote renewable energy and sustainability, and some of the key efforts are captured as follows:

[5]https://www.un.org/en/climatechange/paris-agreement
[6]UNFCCC Report
[7]MoF (PIB notification dated 4th July'19)
[8]World Energy Outlook 2021 of IEA

National efforts to combat climate change: At the Conference of the Parties (COP26), India presented five nectar elements (Panchamrit) as a part of its commitment to combat climate change:

- Reduce emissions intensity (as a percent of its GDP) by 45 percent by 2030 (base year 2005)
- Meet 50 percent of its energy requirements from renewable sources by 2030
- Cut the total projected carbon emissions by 1 billion tonnes by 2030
- Take its non-fossil energy capacity to 500 GW by the end of 2030
- Achieve net zero emissions by 2070.

Global efforts: India is working with other countries and multilateral organisations on sustainability:

- Co-founded the International Solar Alliance (ISA) with France to attract US$1 trillion of investment in solar projects by 2030 in solar-rich countries
- Launched the Global Biofuels Alliance (GBA) at the G20 Summit in 2023, which is a concerted effort to address pressing energy and economic challenges through sustainable biofuels
- Pledged contributions to the Green Climate Fund (GCF), a climate finance fund established within the framework of the United Nations Framework Convention on Climate Change (UNFCCC) and actively encourages other G20 member countries to increase their support.

Other initiatives: India has taken capacity-building initiatives to strengthen its domestic sustainability ecosystem:

- The National Action Plan on Climate Change (NAPCC) outlines strategies for building climate resilience across sectors, as India faces significant climate risks, including extreme weather events, rising sea levels and changing monsoon patterns.
- India is focusing on mobilising green finance to support climate-friendly projects and investments. It has established the National Bank for Financing Infrastructure and Development (NaBFID) to finance green infrastructure projects.
- The country is investing in R&D to drive innovation in clean technologies. It is exploring advancements in renewable energy technologies, electric mobility and energy storage solutions.

Defining the opportunity

The success of the energy transition depends on transforming the global energy sector from fossil-based to zero-carbon sources, reducing energy-related CO2 emissions and limiting the global temperature to within 1.5°C of pre-industrial levels. However, the decarbonisation of the energy sector requires urgent action on a global scale. This requires countries, multilateral organisations and corporations to invest in renewable energy, biofuels and other clean energy solutions such as green hydrogen and its derivatives.

Potential investment opportunities across key sustainable areas (in the near future, till 2030)

Renewable energy: Solar, wind, hydro	Bioenergy: Includes biofuels such as bioethanol, methanol, Sustainable Aviation Fuel (SAF) and Compressed Biogas (CBG)	Green hydrogen and its derivatives (including green ammonia)
US $200-$250 Billion	**US $75–$80 Billion**	**US $90-$100 Billion**
Energy storage solutions	Water sector	Digital systems and platforms for climate
US $250-$300 Billion	**US $60–$75 Billion**	**US $60-$75 Billion**
Circular economy and waste management	Sustainable transport infrastructure	Sustainable agriculture
US $18-$20 Billion	**US $600–$650 Billion**	**US $20-$22 Billion**

India's climate and energy landscape

India's energy and climate landscape is characterised by high energy demand, a growing renewable energy sector and significant climate vulnerabilities. India is witnessing the effects of climate change with extreme weather events such as rising temperatures and erratic rainfall patterns. The average temperature has increased by 0.7°C in the past century,[9] and by 2050, climate impacts could reduce India's GDP by 2.8 percent.[10]

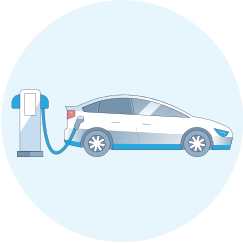
Fossil fuels, particularly coal, heavily dominate the country's energy mix. While coal is essential for economic growth, it poses significant risks to India's climate objectives.

[9]MoEFCC (PIB notification dated 24th Mar'22)
[10]RBI's report on Currency & Finance 2022-23 https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/RCF03052023395FAF37181E40188BAD3AFA59BF3907.PDF

Current energy mix[11]

Currently, 59 percent of India’s energy comes from coal.[12] However, the country is making strides in renewable energy, with 209 GW of installed capacity in 2024 and plans to reach 500 GW (non-fossil fuels) by 2030.

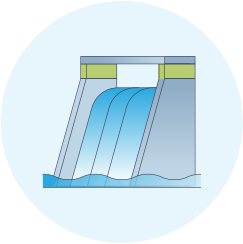
Coal (59 percent)
The country's heavy reliance on coal is driven by its abundance and cost-effectiveness, making it a crucial component of its energy security.



Oil (29 percent)
Oil consumption is expected to rise with a growing demand for mobility and industrial expansion.

Natural gas (6 percent)
There is potential for growth in sectors such as power generation, city gas distribution and industrial use.

Renewable energy (2 percent)
Ambitious targets, aiming for 500 GW of non-fossil capacity by 2030, with renewable energy being the primary component.



Hydropower and nuclear
(3 percent)
These play a stable role, contributing about 2 percent and 1 percent, respectively.
The Union Budget 2025-26 has allocated ₹20,000 crore for R&D in Small Modular Reactors (SMRs), targeting at least 5 indigenously designed operational SMRs by 2033. This aligns with India's target of 100 GW nuclear power capacity by 2047.

India’s long-term climate and energy vision

India’s long-term climate and energy vision is anchored in achieving sustainable growth while addressing the dual challenges of climate change and energy security. It envisions transitioning to a low-carbon economy that promotes inclusivity, economic development and environmental sustainability. Its commitment to reaching net-zero emissions by 2070 is central to this vision, emphasizing a gradual shift from fossil fuels to renewable energy sources. This transition is not just about energy production but also energy efficiency, infrastructure development and technological innovation.

Climate challenges

India’s multifaceted climate challenges stem from its rapid growth and rising energy demands. As the economy expands, energy consumption increases, contributing to GHG emissions due to India's reliance on fossil-fuel-derived energy sources. The country is also witnessing the effects of climate change through rising average temperatures, unseasonal rainfall and frequent extreme weather events. These shifts are disrupting agriculture, water resources and the livelihoods of millions, leading to concerns over food security and health.

[11]Niti Ayog ICED; also unprocessed biomass is not included in the energy mix
[12]Niti Ayog ICED

Addressing these climate challenges requires a fundamental shift towards clean energy. While India has made progress in renewable energy development, with significant investments in solar and wind power, much more is needed to meet its ambitious climate targets. The transition to clean energy must be accompanied by investments in energy efficiency, biofuels, renewable and green energy, grid modernisation and battery storage, ensuring reliability and affordability. Moreover, the country needs to scale up investments in sustainable agriculture, water management and urban planning to build resilience against climate-induced disruptions.

Increasing mean temperature

India has witnessed a rise in average temperatures over the past few decades, which has resulted in several implications:

Energy demand: High temperatures increase energy demand, particularly for cooling purposes. Growth in commercial and residential segments are driving India's electricity demand, High temperatures and heatwaves.

Agricultural impact: Rising temperatures and erratic weather patterns disrupt agricultural productivity, affecting food security and rural livelihoods. In the climate change impact assessment, the Ministry of Agriculture & Farmers Welfare found that rainfed rice yields in India are projected to fall by 20 percent in the absence of adaptation methods. In comparison, irrigated wheat yields could reduce by ~19 percent in 2050.[13]

Loss of daily working hours: Increasing temperatures are leading to a loss of daily working hours in India, especially in outdoor activities. UNESCAP report[14] estimates that India will lose ~5.8 percent of daily working hours. This will have economic implications, particularly for vulnerable communities.

Worsening air pollution

Air pollution is another pressing issue, especially in North India, where stubble burning after the harvest season deteriorates air quality. Combined with industrial emissions and vehicular pollution, this practice creates toxic smog that blankets cities such as Delhi-NCR, Amritsar and Jalandhar, this causes severe respiratory problems and long-term health risks.

Persistent high levels of NO_2 and SO_2 can have serious public health implications, including respiratory and cardiovascular diseases. Cities with higher concentrations may need urgent attention to mitigate these health risks. The daily average concentration of PM2.5 particulate matter, recorded in Delhi in 2023, was ~100[15] µg/m,^{3} significantly exceeding the levels (5 µg/m^3) recommended by the WHO.

NDCs and policy frameworks

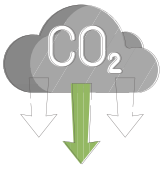
India's commitment to climate change is reflected in its NDCs under the Paris Agreement. These contributions align with the country's broader policy frameworks, focusing on sustainable development while ensuring economic growth and energy security.

[13]Ministry of Agriculture & Farmers Welfare (PIB 21st March'23)
[14]https://www.unescap.org/kp/2024/survey2024#
[15]PIB by MoEF&CC dated 31st Dec'23 (https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1991970)

India's NDC goals

Reduction in the emissions intensity of its GDP by **45 percent** by 2030 (base year 2005)

About **50 percent** of installed electricity generation capacity to be from non-fossil fuel by 2030



Creation of an additional carbon sink of **2.5–3 billion** tonnes of CO_2e by 2030

Policy framework

India's strategy for achieving its NDCs is built on a dual policy framework that combines broad government-led initiatives with industry-specific compliance measures.

National Action Plan on Climate Change (NAPCC)

The NAPCC is India's overarching policy framework for climate action, covering mitigation, adaptation and generation of strategic knowledge on climate change. It comprises national missions in specific areas of solar energy, enhanced energy efficiency, water, agriculture, the Himalayan ecosystem, sustainable habitat, green India and strategic knowledge of climate change.

Regulations targeted at abating industry carbon emissions:

- **Perform, Achieve and Trade (PAT):** PAT was launched by the Ministry of Power to reduce specific energy consumption in energy-intensive industries. It is implemented in cycles of three years each, where the designated consumers are assigned specific energy consumption reduction targets
- **Renewable Purchase Obligation (RPO):** RPO is the requirement mandated, under the Electricity Act (2003), by the Central/State Regulatory Commission to the obligated entities such as discoms, open access consumers and captive power producers
- **Alternate fuel:** Mandate for petrol pumps commissioned after November 2019 to have one alternative energy supply: CNG, biogas or EV charging
- **Biofuel policy:** Policy aimed at promoting the production and adoption of biofuels such as ethanol and biodiesel
- **Green Hydrogen Consumption Obligation (GHCO):** Regulatory mandate that requires specific industries or sectors to use a certain percentage of green hydrogen
- **Extended Producer Responsibility (EPR):** Producers are given significant responsibility (financial and/or physical) for the treatment or disposal of post-consumer products

The government also seeks to create a carbon market through the Carbon Credit Trading Scheme (CCTS), under which obligated entities from 12–14 key sectors will have GHG emission intensity reduction targets.

There will be phase-wise implementation:

Phase-I

Under Phase-I, two types of carbon credits will be generated: Offset carbon credits and converted carbon credits (obligated entities opted to convert ESCerts[16] from PAT & RE project. RPO and PAT continue to operate, and obligated entities must comply with these targets.

Phase-II

Under Phase-II, credits generated/ traded in the compliance market will be tagged as mandatory Carbon Credit Certificates (m-CCCs), which would be the sole compensation instrument for obligated entities to meet GHG emission intensity targets.

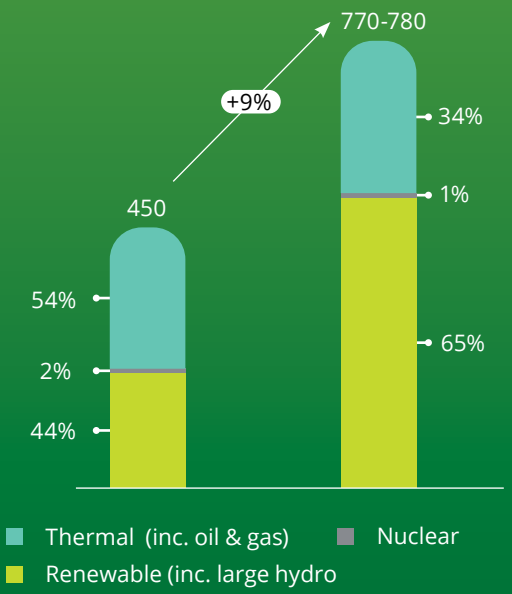
[16]Energy Saving Certificates

Investment opportunities

Renewable energy

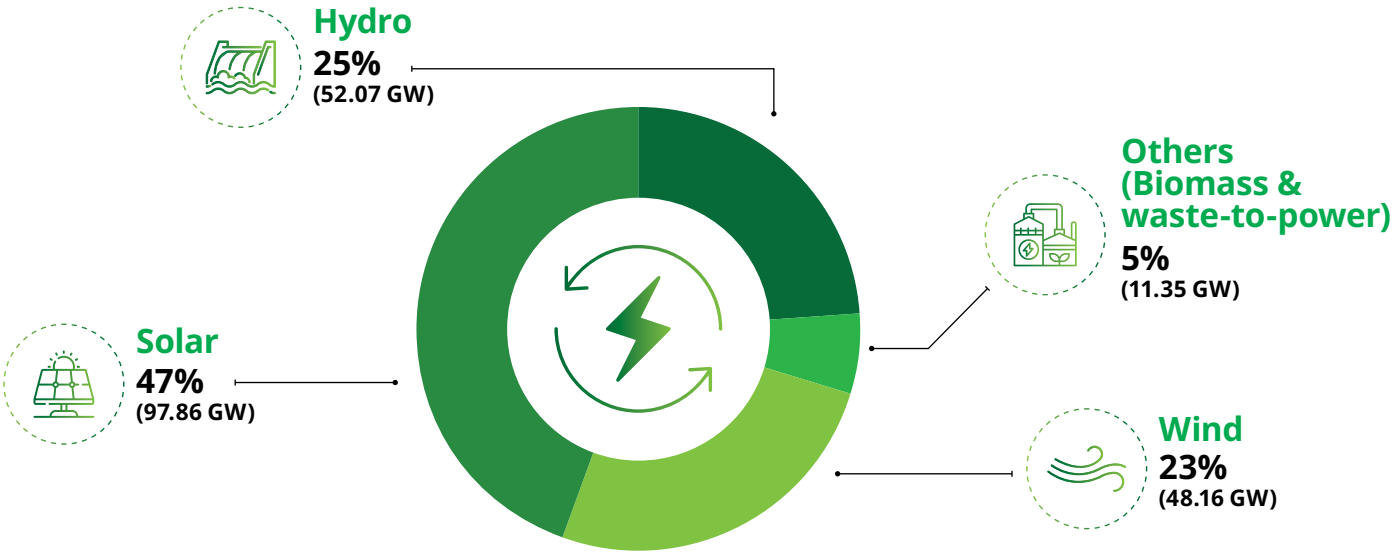
India has set ambitious targets for renewable energy adoption as part of its commitment to address climate change and reduce its carbon footprint. By 2030, it aims to achieve 500 gigawatts (GW) of installed renewable energy capacity. This goal forms a significant part of India's broader strategy to increase the share of non-fossil fuel energy capacity in its energy mix, to about 50 percent[17] of its total electric power installed by 2030.

Figure 1: Power sector landscape in India[18]



[17]MNRE (PIB notification dated 24th March'22)
[18]Ministry of New and Renewable Energy: https://mnre.gov.in/physical-progress, https://npp.gov.in/dashBoard/cp-map-dashboard, Crisil Report

Current Capacity of Renewable Energy (GW)



Growth drivers of the sector

Key factors that will drive the growth include:

Robust growth of electricity demand
Due to higher economic activities, electricity generation has grown from 1,373 billion units (FY20–21) to 1,734 billion units (FY23–24). The electricity demand is estimated to reach ~1,908 billion units by 2026–27.[19]

NDC targets
India's target of 500 GW of installed renewable energy capacity by 2030 also drives the demand for renewable energy.

Cost competitiveness of renewable technologies
Technological advancements have significantly reduced the capital investment required for solar and wind projects over time. This has resulted in reduced solar and wind tariffs, making these sources currently the cheapest generation sources in India. As the costs of renewable energy continue to decline, adoption by Indian consumers is accelerating, making the sector increasingly attractive to investors.

Well-defined roadmap supported by favourable policy framework
Through enforcement of Renewable Purchase Obligation under the Electricity Act (2003), the Central/State Regulatory Commission has laid out a year-wise consumption target for specific technologies – solar, wind and hydro for the obligated entities such as discoms, open access consumers and captive power plants, creating a mandatory demand for RE and resulting into a stable market for RE projects.

[19]https://mnre.gov.in/policies-and-regulations/policies-and-guidelines/centre/#:~:text=The%20projected%20All%20India%20peak,Survey%20(EPS)%20Demand%20projections

Lucrative policies and regulations have acted as a catalyst for the development of the RE sector in the country, with some of the recent ones listed as follows:

PLI scheme for Solar PV (2021)
The PLI scheme for solar PV manufacturing, introduced under the Aatmanirbhar Bharat initiative, has an outlay of INR24,000 crore, offering Production Linked Incentives (PLI) to selected solar PV module manufacturers. The incentives are for five years after commissioning, based on producing and selling high-efficiency solar PV modules.

Green open access (2022)
This was notified in 2022 to promote the generation, purchase and consumption of green energy. It enables consumers to procure renewable energy through Open access from any developer, directly or through a trading licensee or power markets. The sourcing flexibility increases cost competitiveness in the market while improving the share of renewable energy in the power mix.

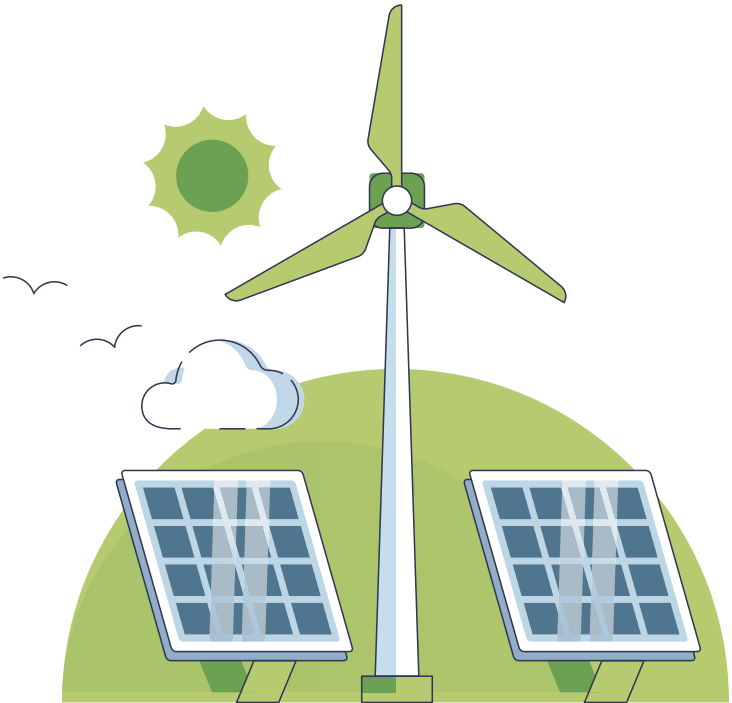
General network access regulations (2023)
This policy framework aims at open access to the inter-state transmission system, with the concept of "One-Nation One-Grid One-Frequency." It simplifies and speeds the process of providing flexible and non-discriminatory open access. The entities eligible to apply for the grant of connectivity to the nodal agency are generating stations, captive generating plants, standard energy storage systems and renewable power park developers.

PM Surya Ghar-Muft Bijli Yojana (2024)
The scheme is designed to offer free electricity to households across India. It provides subsidies to help households install solar panels on their rooftops, covering up to 40 percent of the installation costs. The scheme has an outlay of INR75,021 crore (~US$9 billion) and will be implemented until FY26–27.

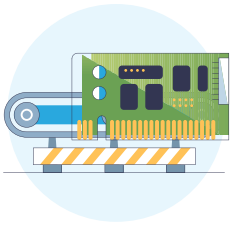
Investment scenario

India will have to add 300 GW of RE capacity over the next six years to bridge the gap between the announced target of 500 GW RE capacity and the current 209.44 GW RE installed capacity. Capacity addition, associated grid integration and expansion requirements will require significant investments.

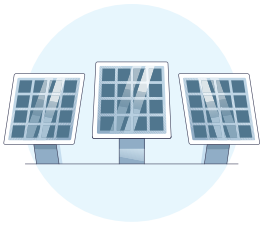
Currently, the investment opportunities in the RE sector are categorised into three segments: Advanced components manufacturing, Power generation and Power Transmission & Distribution (PT&D).



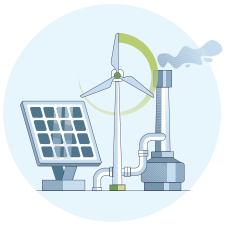
India has attracted investments in these opportunities from numerous institutions, including corporate-backed Indian and MNC players, PE funds and entrepreneur-backed new entrants.



Advanced components manufacturing
In FY23, India's cumulative PV module manufacturing (nameplate) capacity surpassed 38 GW and is estimated to reach 110 GW by 2026.[20] Simultaneously, India is shaping into a global export hub for key wind power components such as nacelle and wind turbines, mainly. These areas are pivotal in driving the renewable energy sector and can offer attractive investment opportunities.



Power generation
To achieve the said targets, investment of ~US$200–250 billion in capacity addition[21] are expected by 2030. Solar projects are expected to attract almost 50 percent of the total investments in this space. Additional opportunities of investment worth ~US$100–150 billion are expected to come by 2035 based on different pathways India can take for achieving net zero by 2070



Power Transmission and Distribution (PT&D)
Renewable energy projects can face significant headwinds due to grid connection backlogs. India is progressing with its grid expansion, having added 180,000 kilometres[22] of new transmission lines in the past decade, marking a 60 percent increase. Companies that offer technology and equipment for national transmission and distribution projects provide investment opportunities.

JVs and alliances: Harnessing collaboration advantages

Multiple investments in the sector have come in through various routes: Direct investments, JVs and acquisitions. Various policy initiatives introduced by the Indian government have propelled private players to enter the renewable energy space, including Indian conglomerates, MNCs and private equity funds. Public sector enterprises are also playing a significant role in forging energy collaborations through necessary technical and financial support by the government for projects in these areas.

[20]https://static.pib.gov.in/WriteReadData/specificdocs/documents/2023/sep/doc2023915253001.pdf
[21]Deloitte Analysis
[22]https://www.morganstanley.com/ideas/india-renewable-energy-investing-opportunities

Biofuels

As of December 2023, India imports about 85 percent of its crude oil requirement[23] and about 46 percent of its natural gas requirement.[24] As the world's third-largest energy consumer,[25] it faces increasing pressure to secure its energy future while addressing environmental concerns. This has prompted India to explore innovative solutions, particularly in the biofuels sector:

The government has introduced blending targets for various biofuels, with certain mandates mandatory and others indicative.

It has implemented the Ethanol Blended Petrol (EBP) Programme across the country, wherein Oil Marketing Companies (OMCs) are required to blend petrol with ethanol. The government has set a target of 20 percent ethanol blending in petrol under the EBP programme by Ethanol Supply Year (ESY)[26] 2025–26. Moreover, a pilot study to achieve 27 percent ethanol blending is also underway.[27] India's average ethanol blending has increased from 1.53 percent in ESY 2013–14 to more than X percent in ESY 2023–24.[28]

The government has announced a mandatory blending of Compressed Biogas (CBG) in the CNG (transport) and PNG (domestic) segments of the City Gas Distribution (CGD) Sector. CBG Blending Obligation (CBO) target has been kept as 1 percent of the total CNG/PNG consumption for FY25–26 and is expected to reach 5 percent by FY28–29.[29]

It has also announced indicative targets for other biofuels:

- SAF blending targets set for international flights from India (indicative): 1 percent by 2027 and 2 percent by 2028
- Target of 5 percent blending of biodiesel in diesel has been proposed by 2030

Under the methanol economy programme, testing of M15 (petrol blended with 15 percent methanol) has been conducted. Research and testing of 15 percent methanol in diesel are ongoing.

[23]https://sansad.in/getFile/lsscommittee/Petroleum%20&%20Natural%20Gas/17_Petroleum_And_Natural_Gas_23.pdf?source=loksabhadocs#:~:text=%E2%80%9CIndia%20imports%20about%2085%20per,all%20the%20public%20sector%20companies
[24]Oil ministry's Petroleum Planning & Analysis Cell (PPAC)
[25]https://www.investindia.gov.in/sector/renewable-energy
[26]Ethanol Supply Year; ESY19 to ESY22 – Ethanol supply period was December to November. From 1 Nov 2023, ESY period is changed to November to October so ESY23 covers only 11 months (Dec 2022 to Oct 2023)
[27]https://pib.gov.in/PressReleasePage.aspx?PRID=1931020
[28]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2043042
[29]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1979705

Bioethanol

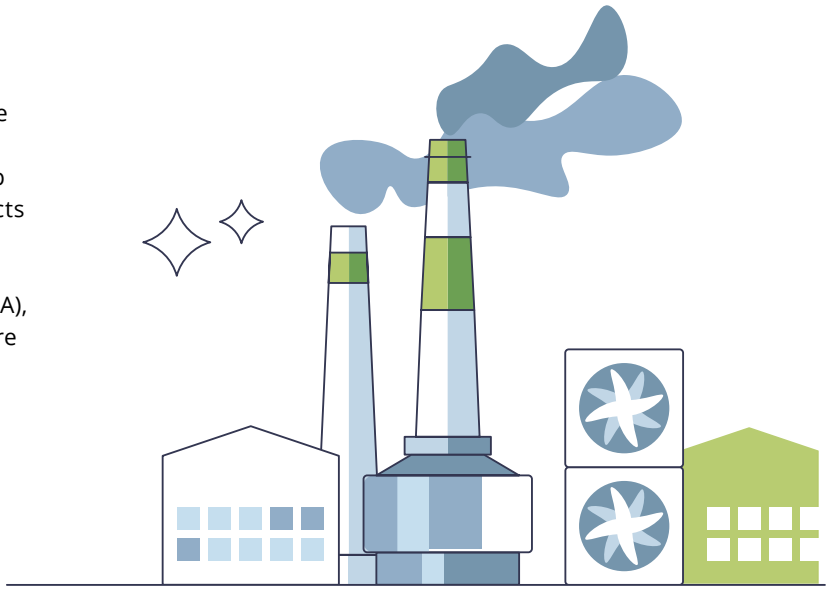
Under the EBP programme, the government mandates blending ethanol with petrol, aiming to achieve 20 percent blending by ESY 2025–26. This initiative aims to create a cleaner fuel alternative, reduce petroleum imports and enhance energy security by using agricultural produce, ultimately increasing farmers' income. India has achieved more than 13 percent blending in ESY 2023–24 YTD.[30] In ESY 2024, India is projected to consume ~8 million metric tonnes of ethanol, encompassing fuel and non-fuel uses[31] and annual consumption is expected to reach ~13 million metric tonnes by 2030,[32] factoring in the impact of growth in vehicle parc and EV adoption on petrol demand.

India's present approach to biofuel production is dominated by first-generation (1G) feedstocks (e.g., sugarcane, maize and rice). The government is also focusing on second-generation (2G) bioethanol produced from lignocellulose feedstocks such as agricultural residue, bagasse and bamboo to mitigate food security concerns. The government has launched the PM JI-VAN Yojana Scheme to promote advancements in 2G bioethanol produced from lignocellulosic biomass. Government scheme under PM JI-VAN yojana is providing Viability Gap Funding subject to a maximum of 20% of the project cost or INR 5 crore for every 10 lakh liters summed to biorefinery's annual name plate capacity, whichever is lesser for commercial plants setup and INR 15 crore financial assistance for demonstration projects

Prices of ethanol supplied from sugar-based feedstocks are approved by the Cabinet Committee on Economic Affairs (CCEA), and prices of ethanol supplied from grain-based feedstocks are decided by Public Sector Undertaking (PSU) OMCs.

In FY24, India had an installed ethanol production capacity of ~10.9 MMTPA, with sugar accounting for ~65 percent of this capacity and grain-based production accounting for ~35 percent.[33] The capacity is forecasted to increase to ~15 MMTPA by 2030[34] to maintain the 20 percent blending mandate with EV penetration increasing to 30 percent. This will translate into an investment outlay of ~US$2–4 billion[35] over the next five years. Bioethanol production capacity is forecast to reach ~19.5 MMTPA by 2035, with a total investment outlay of ~US$4–6 billion.[36] The government's push for grain-based ethanol drives interest in large-scale grain-based capacities and dual-feed plants.

The domestic market is primarily fragmented, with 130+ ethanol producers, and the top 10 players have ~ a 20 percent market share.[37] Midsized firms focused on bioethanol and co-generation and large-scale diversified companies across end-to-end value chains producing bioethanol and derivatives.



[30]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2043042
[31]Indian Sugar and Bioenergy Manufacturers Association, Niti Aayog
[32]Deloitte Analysis
[33]https://pib.gov.in/PressReleasePage.aspx?PRID=1988727
[34]Deloitte Analysis
[35]Deloitte Analysis
[36]Deloitte Analysis
[37]Deloitte Estimates based on chinimandi, financial presentations of listed players and primary research

Methanol

Under Niti Aayog's Methanol Economy Programme Roadmap, the government aims to reduce India's dependence on crude oil imports by substituting 10 percent of crude imports with methanol by 2030. The roadmap also envisions the adoption of methanol across various sectors, including transportation and cooking fuel.

In FY23, India's installed methanol production capacity was 0.474 million tons, whereas actual production was 0.069 million tonnes.[38] All methanol plants in India are based on natural gas or naphtha.[39] Other feedstocks for producing methanol include coal, agricultural residues and CO2 from industrial processes.

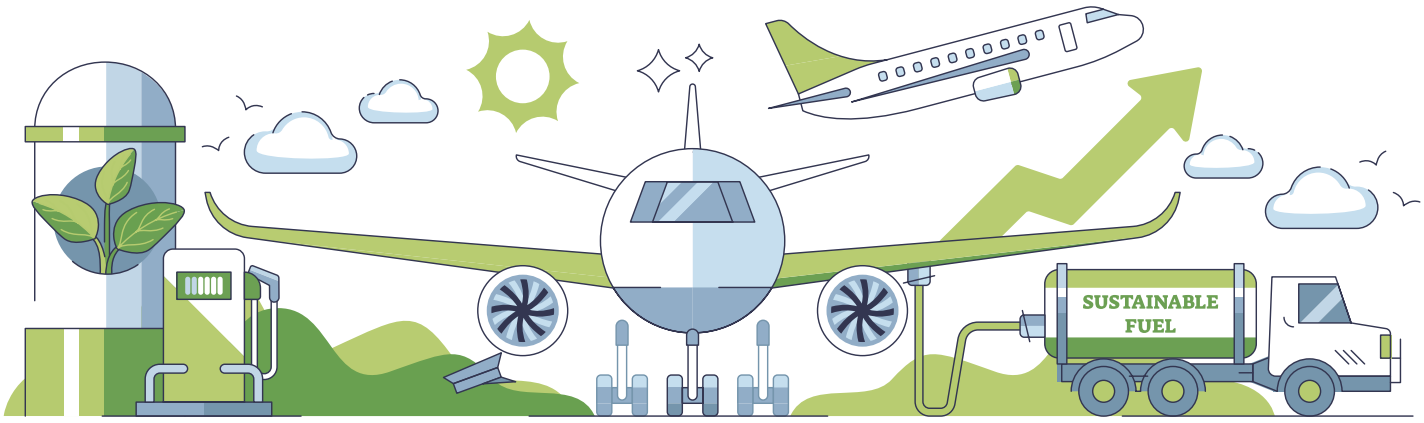
India's methanol industry is still in a nascent stage. Several PSUs and emerging players in the private sector are developing pilot projects to convert high-ash Indian coal into methanol. India has substantial potential for biomass conversion to methanol due to the abundant availability of agricultural residues, and there is growing interest in producing green methanol derived from agricultural residues.

Green methanol can also be used in the shipping sector as a low-carbon fuel. It is a promising alternative and can help the shipping industry transition to a more sustainable future.

Sustainable Aviation Fuel (SAF)

The civil aviation industry has emerged as one of the fastest-growing industries in India. A rising proportion of middle-income households, infrastructure buildup at leading airports and a supportive policy framework have positively pushed the aviation sector. The current demand for Aviation Turbine Fuel (ATF) stands at ~8 million tonnes[40] for FY24 and is forecast to register ~11 percent CAGR until FY30. The share of aviation in India's transport emissions is also expected to double from ~5 percent currently to ~10 percent by FY30.[41]

Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is a global offsetting scheme whereby airlines and other aircraft operators offset any growth in CO_2 emissions above baseline (85 percent of 2019 CO2 emissions from international civil aviation). India stands at a pivotal juncture in the journey towards the adoption of Sustainable Aviation Fuel (SAF), one of the key levers to decarbonise aviation, which is expected to contribute 53–66 percent[42] in achieving the net-zero targets for the aviation sector. Establishing SAF production facilities in India presents a significant opportunity to meet emission targets, create additional jobs and augment farmer income.



[38]https://chemicals.gov.in/sites/default/files/Reports/annual_report_english.pdf
[39]https://dst.gov.in/sites/default/files/Survey%20Report%20Production%20of%20Methanol.pdf
[40]https://ppac.gov.in/consumption/products-wise
[41]https://www.ceew.in/sites/default/files/ceew-research-transport-energy-use-carbon-emissions-decarbonisation.pdf
[42]https://www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/nz-roadmaps.pdf

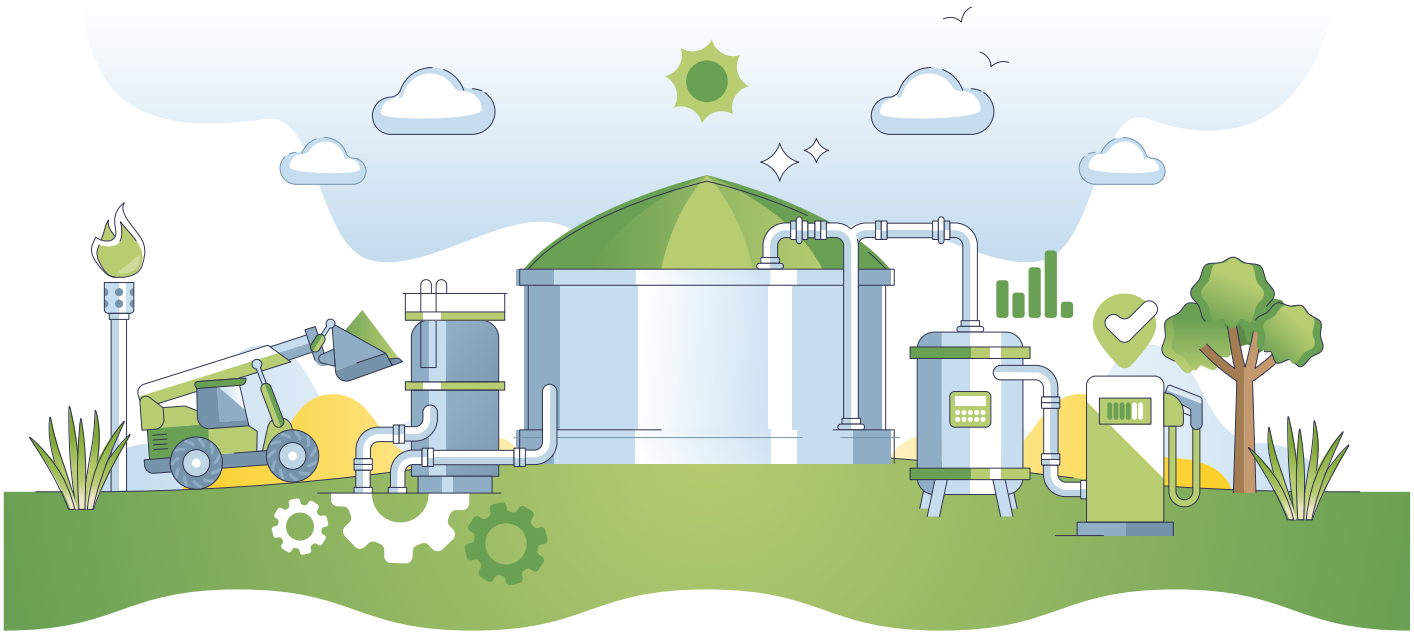
Currently, India has set indicative SAF blending targets for international flights (1 percent by 2027 and 2 percent by 2028). Globally, countries have adopted ambitious blending mandates. The EU has laid a clear roadmap until 2050 for using SAF and synthetically produced SAF. Per the EU roadmap, 34 percent SAF blending is required by 2040.[43] Leading international aviation bodies have also declared net-zero targets to drive demand for SAF, IATA, representing over 300 airline members, has also committed to achieving a net-zero target by 2050.[44]

In the aviation sector. India has the potential to produce 8–10 million tonnes of SAF based on its feedstock availability by 2040, of which India can aim to produce 2–3 million tonnes by 2030. These 2–3 million tons of production capacity will far exceed the potential domestic demand of 0.7–0.8 million tonnes of SAF at a 5 percent SAF blending, resulting in a significant export opportunity. Such capacity addition by FY30 will require a capital outlay of US$18–22 billion.[45] For India to achieve its full potential of 8–10 million tons of SAF, overall capital investment of US$70-85 Bn would be required. Cost economics would vary depending on the feedstock and technology used.
Currently, there are no commercial-scale SAF production facilities in India. However, several OMCs and biofuel manufacturers, in association with technology players, are planning investments in this space.

Compressed Biogas (CBG)

CBG is produced using anerobic given India's substantial biomass resources, producing CBG can drive substantial environmental and economic benefits, the production of CBG is influenced by factors such as technology and feedstock quality. The feedstocks for biogas production encompass a diverse range of waste and biomass sources, including agricultural residues, cattle dung, sugarcane press mud, municipal solid waste and Napier grass.[46]

The Ministry of Petroleum and Natural Gas (MoPNG) launched the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative for production of CBG. The 'SATAT' scheme encourages entrepreneurs to set up CBG plants, produce & supply CBG to OMCs for sale as automotive & industrial fuels.



[43]https://centreforaviation.com/analysis/reports/eu-parliament-approves-sustainable-aviation-fuel-mandate-up-from-2-in-2025-to-70-in-2050-661409
[44]https://www.iata.org/en/programs/sustainability/flynetzero/
[45]https://www.iata.org/en/programs/sustainability/flynetzero/
[46]https://static.investindia.gov.in/s3fs-public/2023-06/ETAC_2023_FINAL_PRINT_1.pdf

Policies and regulations introduced by the government and the shift towards clean energy have fostered the landscape for compressed biogas in the country:

1

Blending mandate: After FY25, blending will be mandatory to promote the production and consumption of CBG. The CBG Blending Obligation (CBO) targets are set at 1 percent, 3 percent, 4 percent and 5 percent for FY26, FY27, FY28 and FY29, respectively.

2

By-products: CBG plants producing Fermented Organic Manure (FOM) and Liquid Fermented Organic Manure (LFOM) as byproducts and not discharging any wastewater are classified under the white category for pollution clearance. They have also been included under the Fertiliser Control Order of 1985.

3

Favourable policy landscape: MoPNG has issued guidelines for co-mingling CBG with natural gas in the City Gas Distribution (CGD) network. In addition, the Petroleum and Explosives Safety Organisation (PESO) has issued a notification stating that no separate approval or licence is required for the sale of CBG if an entity already holds a licence for selling CNG and vice-versa.

4

Incentives to producers: Have been established in several states to coordinate with various departments to provide state-specific enablers for CBG plants. The RBI has included CBG projects under priority sector lending which enables better credit access for potential producers.

Investment opportunities in the CBG sector

The CNG demand is expected to stand at 95–110 MMSCMD by 2030 and 145–210 MMSCMD by 2035, from the current demand of 44 MMSCMD, assuming that the share of natural gas in the energy basket[47] and the number of CNG pumps[48] would increase gradually. Assuming a 5 percent CBO in 2030, the demand for CBG in FY30 is expected to range between 4.9 and 5.4 MMSCMD.

The investment landscape for CBG production in India is promising, driven by robust government initiatives. This sector offers substantial economic potential, with an estimated investment requirement of US$25–30 billion[49] by 2030 and US$45–60 billion[50] by 2035. The availability of diverse feedstock sources enhances the feasibility of CBG projects.

Major corporate investments and state-level projects further underscore the sector's viability. CBG production presents a stable and attractive investment opportunity, and is supported by long-term revenue contracts and priority sector lending benefits.

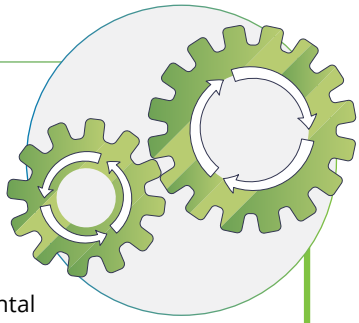
Additionally, there are several financial schemes and incentives aimed at promoting the establishment of CBG plants. These initiatives are designed to mitigate the financial burden on producers and encourage CBG adoption. These include the National Bioenergy Programme, the GOBAR-Dhan Scheme,[51] Financial Assistance for Parali Collection Machinery and Market Development Assistance.[52] Many OMCs and players in the private sector have already entered this space or are planning to do so.

[47]CAGR of 12% to reach 15% in 2030 from 6.7% in 2023. Assuming a more conservative CAGR of 8% from 2030 to 2035
[48]Number of CNG pumps in 2022 – 5040, Target CNG pumps in 2032 – 18336. Average Annual CNG Sale per Pump = ~7700 Tons
[49]Deloitte Analysis
[50]https://gobardhan.co.in/whats-new/Waste_to_Energy_Program%20revised%20guidelines.pdf
[51]https://www.india.gov.in/spotlight/gobardhan-galvanizing-organic-bio-agro-resources-dhan
[52]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1986252

Decarbonising hard-to-abate sectors: A strategic approach

Decarbonising hard-to-abate sectors, such as steel, cement, power, refining, chemicals, mining and aluminium, presents significant challenges due to the inherent carbon intensity of their production processes. Achieving net-zero emissions in these sectors requires a combination of innovative technologies and strategic investments. The potential pathways for decarbonisation are across five key categories: operational efficiency, low-carbon power or fuel usage, advanced electrification, biofuels or bio-based feedstocks or green hydrogen and Carbon Capture Utilisation & Storage (CCUS).

Operational efficiency



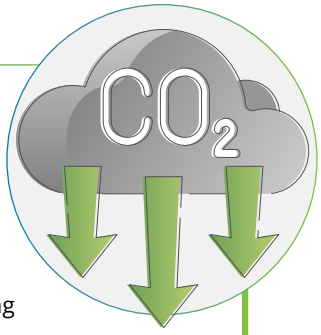
Operational efficiency remains a foundational approach to reducing emissions across hard-to-abate sectors. This involves optimising existing processes to reduce energy consumption and emissions without significant capital investments.

In steel and cement production, optimising blast furnace operations and improving energy efficiency in cement kiln operations can lead to immediate, albeit incremental, reductions in carbon intensity. For instance, increasing the efficiency of the Blast Furnace-Basic Oxygen Furnace (BF-BOF) route, responsible for ~70 percent of global steel production, can reduce emissions. Similarly, in cement production, optimising kiln operations and integrating waste heat recovery systems can enhance efficiency.

The smelting process, in particular, offers significant opportunities for operational efficiency improvements in aluminium production. Optimising the Hall-Héroult process and implementing advanced heat exchangers can reduce energy consumption and emissions. Enhancing refining processes, particularly in the Bayer process, can also produce more efficient alumina.

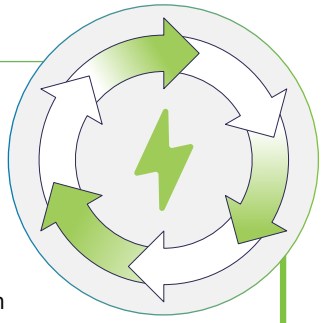
Operational efficiency in mining can be achieved through better fleet management, optimised blasting techniques and more efficient equipment. These incremental improvements in haulage and processing can lead to notable reductions in emissions. Energy efficiency measures in the power sector include expanding gas-based plants using advanced turbines and upgrading existing steam and gas turbines, which can also result in significant efficiency gains. Key initiatives in refining include fuel gas desulfurisation, installation of ceramic coatings in furnaces for better heat transfer and replacing steam tracing with electric tracing. Other measures, such as installing Pyrogel coating on critical hotlines, upgrading catalysts and optimising crude preheat, also contribute to increased operational efficiency. Continuous efficiency improvement is crucial in the chemicals sector. Initiatives such as advanced chemical recycling help optimise operations.

Low-carbon power or fuel usage



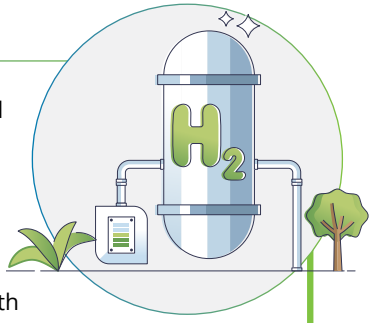
The transition to low-carbon power sources is critical for decarbonising energy-intensive industries. Replacing fossil fuels with low-carbon alternatives such as natural gas or using renewable energy sources such as solar and wind can significantly reduce emissions. Transitioning from coal-based processes to natural gas-based Direct Reduced Iron (DRI) processes in steel production and substituting coal with alternative fuels such as biomass in cement kilns can drastically reduce emissions. Shifting from coal and natural gas-powered grids to renewable energy sources such as hydro, wind and solar is essential for reducing emissions in aluminium smelting operations. Additionally, hydrogen-based calcination in refining offers a green alternative to traditional fossil fuel-based methods. Renewable energy sources such as solar and wind and energy storage solutions are critical for reducing emissions in mining operations. In refining, adopting renewable energy, replacing fuel oil with natural gas and using natural gas in unit furnaces and hydrogen manufacturing units are key strategies for reducing emissions. Fuel switching to blue and green hydrogen and implementing advanced recycling processes help minimise emissions in the chemicals sector.

Advanced electrification



Electrification of industrial processes using renewable electricity can dramatically reduce carbon footprints. Using renewable energy-powered Electric Arc Furnaces (EAFs) in steel production can significantly reduce emissions. In cement production, emerging technologies are exploring electrified clinker production, though challenges remain due to high-temperature requirements. Advanced electrification strategies, such as multi-polar cells and electric calcination, are essential for reducing emissions in the aluminium industry. The integration of mechanical vapour recompression can further reduce emissions during alumina production. Electrification in mining extends to Battery-Electric Vehicles (BEVs) and processing activities powered by renewable electricity. However, significant investment in on-site renewable generation and storage solutions is necessary to electrify off-grid operations. Electrification efforts in refining and chemicals include electrifying turbine drives of unit compressors and pumps, as well as furnaces and re-boilers, which are vital steps towards reducing emissions.

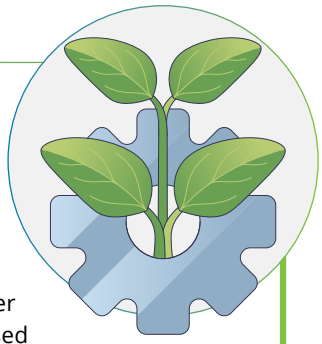
Biofuels, bio-based feedstocks and green hydrogen



Biofuels and bio-based feedstocks offer a pathway to decarbonise sectors that rely heavily on carbon-intensive inputs. Hydrogen-powered DRI technology in steelmaking and bio-based feedstocks in refining present sustainable alternatives to traditional processes. Hydrogen calcination in the aluminium industry and using biofuels in ancillary processes, such as anode production, can significantly reduce emissions.

Hydrogen-powered haulage vehicles and advanced biofuels are being developed as potential solutions for reducing emissions in mining operations, though challenges remain regarding technology readiness and infrastructure. Green hydrogen and biomass & ammonia cofiring initiatives in the power sector are gaining traction. Green hydrogen, biomass co-firing in coal-fired boilers and replacing natural gas with compressed biogas in unit furnaces are vital strategies for reducing carbon emissions in refining. Transitioning to bio-based organic building blocks, green hydrogen and industrial bio-based operations helps reduce carbon footprints in the chemicals sector.

Carbon Capture Utilisation or Storage (CCUS)



CCUS technologies are pivotal for mitigating emissions in sectors where complete decarbonisation is challenging. These technologies capture CO2 emissions from industrial processes and store them underground or utilise them in other applications. In steelmaking, CCUS can capture emissions from blast furnaces and cement kilns. Inert anode technology and CCUS integration in smelting and refining operations offer a pathway to near-zero carbon aluminium production. CCUS technologies for capturing methane emissions from coal mining and on-site processing activities are being developed, though scaling these solutions to commercial levels remains challenging. CCUS innovations in the power sector involve capturing carbon from power plants and converting it into green fuel for a wide range of applications, such as serving as a base material for the chemical industry, storing renewable electricity and being a transportation fuel. In refining, initiatives such as producing 3G ethanol from off-gas and using synthesised air technology for post-combustion capture are emerging as CCUS applications. CCUS, turquoise hydrogen production and waste heat capture are essential components for reducing emissions in the chemical sector.

Decarbonising hard-to-abate sectors requires a holistic approach that integrates multiple strategies across operational efficiency, low-carbon power usage, advanced electrification, bio-based alternatives and CCUS. Operational efficiency improvements are essential, as they are often viewed as business as usual and investments required are incremental in nature. Investment potential lies in transformative technologies such as renewable energy, green hydrogen, biofuels or bio-based feedstocks, CCUS and advanced electrification, which require substantial capital investment and industry collaboration. As companies prioritise these innovative solutions, the path towards a low-carbon future becomes clearer, with significant opportunities for reducing emissions in hard-to-abate sectors such as steel, cement, power, refining, chemicals, mining and aluminium.

Green hydrogen and its derivatives

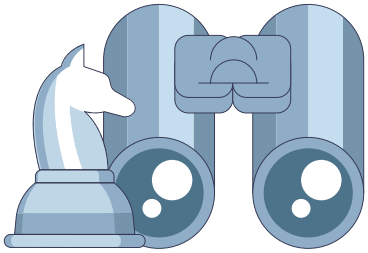
India is one of the largest consumers of hydrogen globally, with consumption of ~5–6 MMT in 2023; fertilisers and refining account for ~95 percent of the country's overall consumption.[53] The green hydrogen market is poised to gain momentum, primarily driven by the imperative to replace the existing demand for grey hydrogen, driven partly by the requirements of hard-to-abate sectors and energy transition scenarios globally. India has abundant Renewable Energy (RE) resources, which provide a strong foundation for producing green hydrogen.

Hydrogen, under normal conditions, is a highly volatile and flammable gas with low volumetric density, making it costly and technically demanding to transport in large industrial quantities. Given these challenges, derivatives such as green ammonia and green methanol present more practical alternatives for exporting hydrogen.[54]

India launched the National Green Hydrogen Mission in 2023 to boost green hydrogen manufacturing. The mission aims to achieve 5 MMTPA of green hydrogen production in India in FY30. There have been two capacity auctions totalling 0.86 MMTPA of green hydrogen capacity. However, projects are yet to go live.

[53]Investment Landscape of Green H2 in India, SAREP May 2023
[54]Green H2: Energizing the path to net zero; Deloitte's 2023 global Green H2 outlook

India's ambitious push towards Green hydrogen is driven by its goal of achieving energy independence by 2047 and fulfilling its decarbonisation commitments, including net zero by 2070.



Policy support and strategic vision: The National Green Hydrogen Mission is central to this effort. The target to produce atleast 5MMT of Hydrogen annually by 2030 aligns with India's current hydrogen demand and positions the country to capture emerging export markets, potentially reaching 10 MMTPA. The national government has earmarked US$2.2 billion for the mission, with US$1.6 billion to incentivise green hydrogen production and ~US$600 million for electrolyser manufacturing. Additional drivers include the waiver of ISTS for green hydrogen/ammonia production, which is anticipated to improve project viability by lowering the costs of RE and electrolyser plants.[55]

Demand outlook

Global hydrogen demand touched 95MMT in 2022, but the usage remained concentrated in traditional sectors such as refining and fertilisers.[57] The uptake of hydrogen in new applications – critical for the clean energy transition – remains minimal, representing less than 0.1 percent of global demand. The IEA's projections based on current investments estimate a global green hydrogen production of 28MMT by 2030, highlighting the need for policy support and sustained investment.

India's demand for green hydrogen is expected to grow over the next decade. In an optimistic scenario, driven by domestic industries decarbonising their operations, such as steel, heavy transport and shipping, demand could reach or exceed the 5 MMTPA target by 2030. In a more ambitious scenario, factoring in export markets, this could reach 10 MMTPA.[58] However, achieving these targets depends on substantial investment in infrastructure.

Export opportunities: Many countries globally are planning to use green hydrogen for reducing emissions in hard to abate sections. The EU RE Directive mandates 42 percent of industrial hydrogen to be green by 2030, increasing to 65 percent by 2035.[56] Major import markets such as Japan and Korea are looking at using ammonia for co-firing in coal power plants – providing a significant export opportunity.

Investment opportunities

Several investment opportunities arise across the green hydrogen value chain, considering the targets taken and the infrastructure required to achieve them. In terms of electrolyser capacity, it is estimated that India will need 60–100 GW[59] by FY30, which can potentially lead to an investment opportunity of ~US$20–25 billion rising up to ~US$35–40 billion in FY35. In addition, the investment required to set up the complementary ammonia production and storage capacity is estimated to be US$9 billion[60] by FY30. The renewable energy needed to sustain this infrastructure will cost ~US$67 billion in FY30 and rise to ~US$99–120 billion in FY35. Potential investment opportunity across the green hydrogen value chain in India in the areas reviewed could be ~US$100 billion by 2030 and ~US$145–170 billion by 2035, including investment required for setting up RE.

[55]https://assets.bbhub.io/professional/sites/24/BNEF_New-Energy-Outlook-India-2023.pdf
[56]https://www.taylorwessing.com/en/insights-and-events/insights/2024/01/implications-of-red-iii-directive-for-businesses-and-investors
[57]IEA Global Hydrogen Review 2023
[58]https://assets.bbhub.io/professional/sites/24/BNEF_New-Energy-Outlook-India-2023.pdf
[59]https://invest.up.gov.in/wp-content/uploads/2024/07/India_210724.pdf
[60]https://sarepenergy.net/wp-content/uploads/2023/05/GREEN-HYDROGEN-FINAL-Version.pdf

Current scenario

Electrolyser manufacturers

Indian companies are forming JVs with global players to establish gigafactories and use international expertise. New firms are also entering the market with smaller-scale projects catering to specific industry needs in India.[61,62]

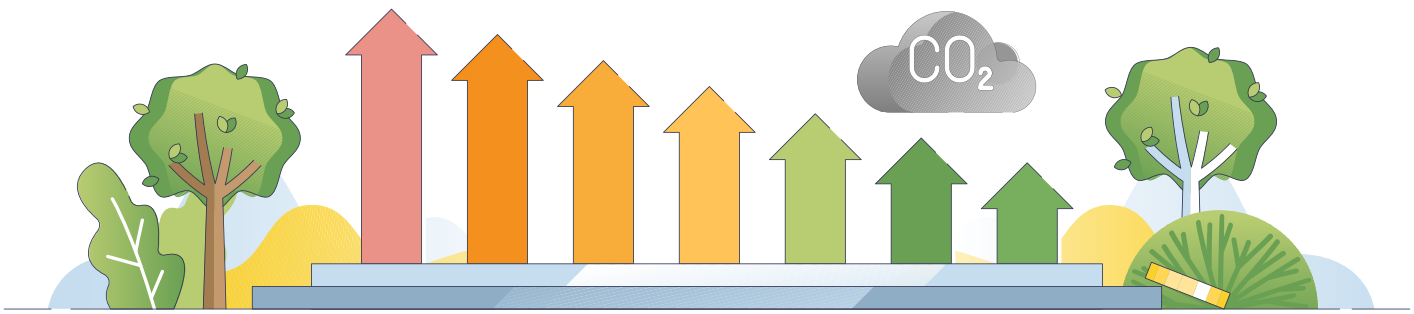
Green hydrogen producers

Specialised RE players are integrating green hydrogen production into their operations using excess electricity during low-demand periods to optimise resource utilisation. Major conglomerates are also entering the green hydrogen market, with large Indian private players leading efforts to produce green hydrogen at scale, investing in solar power projects, electrolyser production and hydrogen-powered vehicles.

Consumers and infrastructure developers

Consumers of green hydrogen span across industries, from refineries and chemicals to transportation. Large corporations are transitioning to green hydrogen to meet sustainability targets and reduce carbon footprints.

Moreover, Companies are also investing in the infrastructure needed to store and distribute hydrogen.



[61]https://www.manufacturingtodayindia.com/jakson-green-gears-up-for-green-hydrogen-revolution/
[62]https://www.moneycontrol.com/technology/ohmiums-rs-2000-crore-green-hydrogen-electrolyser-gigafactory-launched-near-bengaluruarticle-12773433.html

Energy Storage Solutions (ESS)

Context

At COP26 in November 2021, India announced to reach 500 GW of non-fossil energy capacity by 2030. Solar (grid and rooftop) and wind energy dominate the domestic renewable sector. However, the RE power supply is intermittent and variable. Energy storage solutions store energy and help stabilise the grid during peak times ensuring uninterrupted power supply.

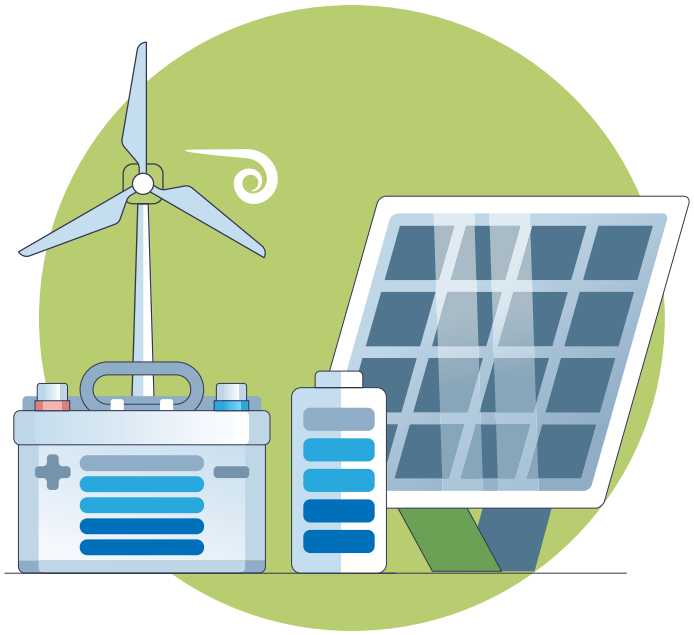
There are different types of energy storage technologies present in the market from mechanical to thermal, based on the process of energy conversion utilised. Mechanical ESS includes pumped hydro storage, compressed air energy storage and flywheel technologies, while batteries constitute the electrochemical storage solutions. Hydrogen fuel cells are classified as chemical storage solutions, while supercapacitors are electrical storage options. Thermal storage solutions include sensible (molten salt, chilled water), latent (Ice storage, phase change materials) and thermochemical storage solutions.

Current state of ESS in India

India has a potential of 119 GW of pumped hydro storage.[63] Currently, 4.7 GW is under operation, while 4 GW is under construction. Construction is yet to start on 3.6 GW of concurred projects, whereas 60 GW of projects are under survey and investigation.[64] Thermal storage solutions are in the nascent stage of development. "India One is an R&D project with 16 hrs of thermal storage supporting the round-the-clock (RTC) operation of a 1 MW solar thermal plant in Rajasthan.[65] International power companies are also collaborating with power utility firms in India to develop thermal energy storage solutions.

As of March 2024, India had a total installed capacity of 0.2 MW in electrochemical storage/Battery Energy Storage Systems (BESS).[66] Solar PV, combined with BESS, accounted for 90 percent of these installations.

Overall, BESS and pumped storage are the common commercially deployed energy storage technologies available. Other technologies are in the experimental stage, and their commercial viability is yet to be successfully tested in a grid-scale setup.

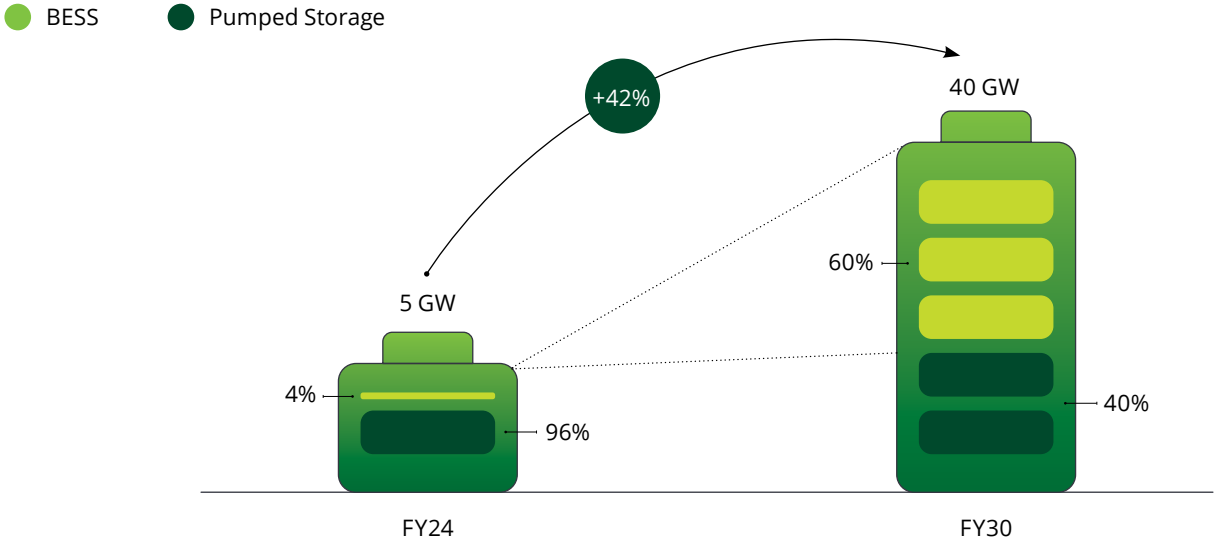


[63]https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1930831
[64]https://www.pib.gov.in/PressReleasePage.aspx?PRID=2040582
[65]https://solarimpulse.com/companies/india-one-solar-thermal-power-plant#
[66]https://www.mercomindia.com/product/india-energy-storage-landscape

Capacity and investment until FY30

India's current ESS capacity is ~5 GW and is estimated to post a 42 percent CAGR to 40 GW in FY30. The following chart represents the estimated ESS capacity buildup until FY30:[67]

Figure 2: Current and projected ESS capacity in India



The capex required to set the technologies varies as follows:[68]

1. Pumped hydro storage: It varies based on project size. On average it is ~US$6.5 million/MW
2. BESS: It comes in various sizes of 2-, 4-, 5- and 6-hour energy storage configurations. The 4- and 6-hour sizes will be common in FY30. The average capex required is ~US$7 million/MW.

The total capex needed to achieve the FY30 target aggregates to ~US$270 billion in FY30. This investment will be worth ~US$600 billion in FY35.[69]

[67]https://cea.nic.in/wp-content/uploads/irp/2023/05/NEP_2022_32_FINAL_GAZETTE-1.pdf
[68]https://cea.nic.in/wp-content/uploads/irp/2023/05/NEP_2022_32_FINAL_GAZETTE-1.pdf
[69]Deloitte Analysis

Growth drivers and competitor archetypes

The demand for ESS is driven by the following factors:

Firming the RE output
RE sources have cyclical outputs of peak and low to no generation. This intermittent supply causes disturbance on the load side. ESS can help in smoothening the output and making it firm and dispatchable.

Reduction in network cost
It helps reduce peak generation by integrating more electricity within the same grid, thereby, avoiding network upgrades.

Regulatory push
The government policies favouring RE capacity addition and the ambitious target of 50 percent energy consumption powered by RE in FY30 will need a robust ESS network to support the RE round-the-clock power infrastructure. Additionally, RPO regulation and subsequent energy storage obligations, released in 2022, make it mandatory to support the established RE capacity with storage capacities.

RE+BESS creates a business case for energy/RE players to provide peak power support and RE RTC solutions to utilities and existing C&I clients. Consequently, the market is dominated by leading RE players, including energy companies and large conglomerates. Other new energy companies and RE developers plan to enter the market through strategic collaborations and acquisitions. The pace of RE project growth in India, fuelled by the government's regulatory push and domestic production of key RE technologies, makes the ESS sector an attractive investment opportunity.

Water sector for climate solutions

The water management value chain begins with water sourcing and ends with recycling/reuse, and emerging technology, policy and financing are transforming this value chain into an instrument for the mitigation of climate change and energy transition. Water sourcing includes surface and groundwater extraction, desalination, rainwater harvesting and water transfer projects. Water treatment focuses on purification through filtration, sedimentation, disinfection, coagulation and Reverse Osmosis (RO). In water distribution and supply, the main activities involve pipeline management, leak detection, water storage and pumping systems to ensure effective water delivery. Water use and conservation emphasizes agricultural, industrial and household water use, as well as smart irrigation and conservation programmes. Wastewater collection and treatment handles sewer networks, stormwater management and treatment processes from primary to tertiary levels. Finally, water recycling and reuse focuses on recycling treated water for agriculture, industry, sludge treatment and irrigation, promoting sustainability and reducing overall water demand. Cause-effect relationships between climate change, energy transition and water management are being recognised globally.

Effective water management is crucial for meeting several Sustainable Development Goals (SDGs), particularly SDG 6 (clean water and sanitation), SDG 13 (climate action) and SDG 7 (affordable and clean energy).[70] Improving water-use efficiency in energy production has the potential to reduce global water withdrawals by 25 percent, contributing significantly to SDG 7. Advanced wastewater treatment technologies are essential in reducing carbon emissions. Traditional wastewater treatment processes are energy-intensive and a significant source of methane. Implementing efficient irrigation methods such as drip and sprinkler systems can reduce water usage by up to 50 percent. Climate change and energy transition have direct and quantifiable impacts on water security in India, and vice versa.

Erratic monsoon patterns, with a 30 percent increase in extreme rainfall events, have led to severe droughts and flooding in states such as Maharashtra and Tamil Nadu, directly impacting agriculture and drinking water supplies.[71] The accelerated melting of Himalayan glaciers, which have lost 23 percent of their ice mass since 1975, further threatens long-term water availability.[72] Improving water-use efficiency in existing thermal power plants can also cut water usage by 30–50 percent, emphasizing the importance of investing in water-efficient technologies.[73] Rapid urbanisation, projected to increase city populations to 600 million by 2030, combined with agriculture's continued demand for water, drive targeted investments in urban water management, rainwater harvesting and modern irrigation techniques such as drip irrigation to address the challenges of climate change and growing energy needs. These challenges have been recognised by India's policymakers, and the National Water Mission, under the National Action Plan on Climate Change (NAPCC), has set specific targets for increasing water use efficiency by 20 percent and promoting water conservation.[74] The demand-supply gap in India will continue to widen at an accelerating rate.

The 2030 Water Resources Group estimates that the gap between water demand and supply in India could reach a staggering 56 percent by 2030, amounting to a shortfall of 700–800 Billion Cubic Metres (BCM)[75] per year. Irrigation is expected to continue demanding the highest share (~70–80 percent) of the total demand, while demand drivers such as increasing urbanisation and industrialisation, shifts in consumption trends, growing aquifer recharge demands and increasing groundwater depletion rates are expected to push India's water demand beyond the reach of traditional water management methods.[76]

The World Bank estimates that India will need to invest an additional US$291 billion by 2030 to meet its water demand,[77] which includes investment in developing core water infrastructure, such as laying pipelines and additional civil work, apart from costs associated with dynamic water management methods, which entail higher unit costs. NITI Aayog's Composite Water Management Index states that the traditional water supply infrastructure, including reliance on groundwater, dams, canal irrigation and flood irrigation, will not continue to scale with the demand. To mitigate this crisis, new methods of water sourcing, treatment, distribution, use, wastewater treatment and recycling are being introduced.[78] Considering that the traditional methods will not be able to meet all the supply requirements, financing of new water management methods with higher unit costs is gaining traction. The perception of water is poised to shift from a social utility towards a priced commodity, bearing the full cost of a complex water infrastructure required to meet the evolving needs of the fastest-growing economy in the world.[79]

[70]FUNDING A WATER-SECURE FUTURE- An Assessment of Global Public Spending
[71]NITI Aayog, Composite Water Management Index
[72]2030 Water Resources Group Report
[73]Charting our Water Future Report, 2030 Water Resources Group
[74]Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), Government of India
[75]AMRUT Scheme Report, Ministry of Housing and Urban Affairs
[76]Global Innovation Lab for Climate Finance, India
[77]India Water Stewardship Report, Global Water Partnership
[78]Climate and Energy Transition Finance Initiative (CETFI)
[79]Composite Water Management Index 2.0, NITI Aayog

The roadmap for private sector investment in water management is being laid out through an evolving policy ecosystem and innovative financing frameworks.

Evolving Indian ecosystem

The Government of India (GoI) has long relied on a suite of established financing mechanisms to address the country's water management. Central budget allocations have been pivotal, funding key initiatives such as the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) for enhanced irrigation and the National Rural Drinking Water Programme (NRDWP)[80] to ensure safe water access in rural areas. The Viability Gap Funding (VGF) scheme has been instrumental in enabling critical yet financially demanding projects, such as large-scale irrigation and water treatment infrastructure. The Jal Jeevan Mission has mobilised a mix of central and state funds to advance universal rural tap water connectivity. Additionally, the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) supports vital water conservation projects, while Externally Aided Projects (EAPs) have used international financing for expansive initiatives such as river basin management and urban water supply enhancement.

PPPs are the current mainstays of private capital in water management

More than 55–60 percent of the private capital invested in the Indian water management market is through PPP projects.[81] Accordingly, the government has introduced the Public-Private Partnership Appraisal Committee (PPPAC) to streamline the approval process for PPP projects. This initiative has simplified the regulatory framework for private investors, and consequently, India ranks first in Asia for investment and business climate and second in Asia for innovative financial instruments[82] in PPP engagements. While PPPs still offer the single greatest mode of private capital infusion into the Indian water management market, but India is steadily moving beyond PPPs to emphasize innovative and privately sourced capital.

Beyond PPPs:

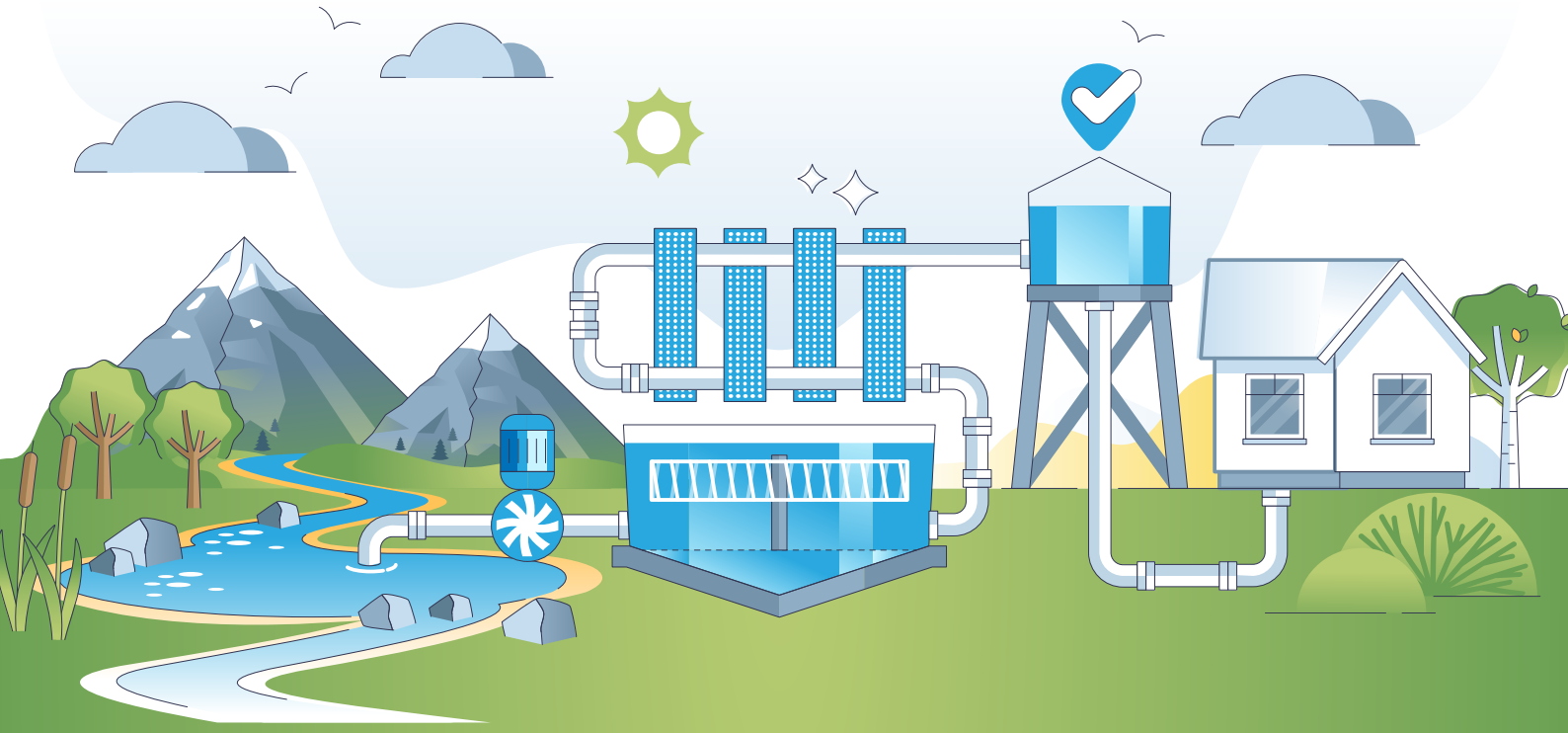
The Water Resources Group (WRG) and Climate and Energy Transition Finance Initiative (CETFI) are working to devise frameworks that encourage private investment through green bonds, de-risking of investments and other innovative financing frameworks. The Global Innovation Lab for Climate Finance has developed several blended finance instruments that have mobilised over US$2 billion in private investment for climate-related projects worldwide. These instruments are being adapted to the water sector in India by CETFI to attract the necessary capital for large-scale water infrastructure projects and technological innovations. India has already issued several green bonds, raising billions of dollars for renewable energy and other sustainability projects. As of 2023, India had issued a total of US$21 billion in green bonds, including significant fund allocations to water management projects.[83] Specifically, water-related projects have become increasingly important, representing about 12 percent of the total green bond issuance in India by 2023.

[80]India Green Bond Issuance Report 2023
[81]National Infrastructure Pipeline, Government of India
[82]Rabobank Irrigation Investment Strategy
[83]IFC Investment Outlook in Indian Water Sector

The Indian Water Management Market: This is a vast, untapped market with enabling governance, market size and financing mechanisms in place.

Category	Water sourcing	Water treatment	Water distribution and supply	Water use and conservation	Wastewater collection and treatment	Water recycling and reuse
Estimated market size by 2030	US$5–7 billion	US$10–12 billion	US$20–25 billion	US$4–5 billion	US$15–20 billion	US$6–8 billion
Total	**US$ 60–75 billion**					

While 75–80 percent of the water management funds have historically come from government funding, private sector investments are being seen as the next step in meeting the burgeoning demands. The scale of the private investment opportunity in India is apparent from the fact that India demands the most freshwater in the world (>700 BCM annually) and per capita consumption (in litres/capita/day) (lpcd) is projected to increase from current 140 lpcd to 220 lpcd by 2030. Massive budget outlays exceeding US$100 billion are being expended under more than 2000 water management projects under the National Infrastructure Pipeline. The private sector's participation is being encouraged to implement and finance these projects. By 2030, new investment opportunities amounting to more than US$60–75 billion exist across the entire water management value chain, for meeting domestic residential, industrial and agricultural demands.

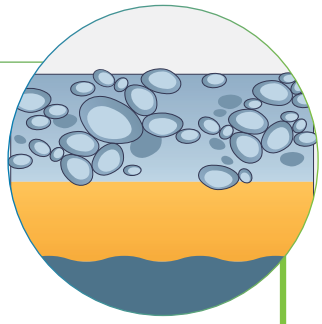


The continuing demands of agriculture

India's growing irrigation needs are expected to fuel its freshwater water demand and constitute the greatest opportunity for businesses.

Irrigation management and micro-irrigation efficiency improvements are among the most important interventions in India's long-term water management strategy. The total irrigation demand is expected to reach 900–1,000 BCM by 2030 (from the current ~670 BCM), The sector is witnessing a paradigm shift with the growing adoption of precision technologies, particularly drip irrigation and low-pressure membranes.[84] The potential market for irrigation management in India is estimated at US$2.4 billion by 2030, while the low-pressure membrane market could potentially reach US$0.5–1 billion by 2030. Investments in this domain are driven by private sector players, financial institutions, venture capital and impact investing firms, highlighting the financial community's recognition of the sector's growth potential.The government's Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), growing awareness of water scarcity, increasing demand and the rising adoption of precision farming technologies are the primary drivers of this market.

An emerging market

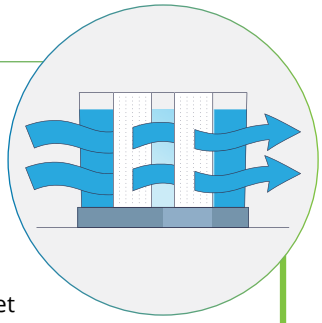


Water and Wastewater (WWW) treatment constitutes an attractive opportunity because the AMRUT scheme focuses on a city-level circular water economy and non-revenue water.

The sporadic spatial and temporal distribution of water resources in the country calls for localised community and business involvement in water management solutions, and this has led to the development of city level circular economy and focus on Integrated Water Management Systems (IWMS). Towards this end, ~US$5–6 billion have been allocated under the AMRUT scheme towards circular water economies and WWW treatment.

WWW treatment in India is being redesigned to function on a city-level circular water economy, with efforts to bring non-revenue water down from 40–50 percent to 20 percent. The WWW treatment market size currently stands at ~US$8 billion and is projected to reach 25–32 billion by 2030.[85]

Future opportunity



Desalination is a crucial frontier in India's water security strategy and is a scalable, profitable business.

As water scarcity becomes an increasingly pressing issue in India's rapidly urbanising coastal cities, desalination has emerged as a vital solution. Over the past few years, significant technological advancements have driven down the unit cost of desalination from US$0.60–0.73 per cubic metre to less than US$0.5 per cubic metre, making it more economically viable. By 2030, the desalination market in India is projected to reach US$4.3 billion, reflecting the critical role it will play in the nation's water management strategy. Leading Indian companies are spearheading this sector, with their efforts being supported by major investors, including global infrastructure funds. By 2030, the Indian desalination market alone is expected to reach US$5–7 billion, while rainwater harvesting and aquifer recharge systems could constitute an additional US$4–7 billion market.

[84]Aavishkaar Venture Management Services Annual Report 2023
[85]Tata Cleantech Capital Investments in Desalination

Digital systems and platform for climate solutions

India's holistic approach focused on regulations, infrastructure, capabilities and innovation has created a self-reinforcing and sustainable digitisation wave. India is in the middle of a nationwide digital transformation journey, focused on building a digitally empowered society and a knowledge economy. National flagship programmes such as Digital India, Smart City Mission, Startup India and BharatNet are forging a robust and dynamic ecosystem of digital public infrastructure, goods and services. Internet access has quadrupled in a decade from ~300 million subscribers in 2014 to more than 950 million subscribers in 2024.[86] India is one of the fastest in the world in implementing 5G infrastructure. India has adopted a distinctive and innovative strategy by making strategic investments in Digital Public Infrastructures (DPIs) such as UPI, Aadhaar and DigiGov, which aim to create open, scalable, secure and standardised systems. This approach has catapulted the country to become the third-largest digitalised country in the world. These transformative advancements are the result of the government's strategic and relentless focus on: (a) building a robust and accessible data infrastructure, (b) instituting cutting-edge regulations and standards frameworks, (c) elevating digital capabilities across industries, government and academia, and (d) cultivating a thriving and dynamic innovation ecosystem.

The GoI has taken several policy initiatives to use the expanding digital capabilities in India to create new possibilities for innovative digital services and products for reducing carbon emissions and integrating sustainability principles. Unlike the global north, the countries in the global south have a unique "wicked problem". The global south has an imminent need to grow the economy at a rapid pace and improve socio-economic outcomes with respect to poverty levels, income, health and education, among others and at the same ensure that climate action and their respective targets are met.

The government aims to resolve this conundrum of conflicting and opposing goals through the two-pronged approach of digitisation and decarbonisation of the economy. The National Action Plan on Climate Change (NAPCC) outlines several key missions, such as the National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat and National Water Mission, among others, aimed at addressing climate change through digital innovations. In addition to the programmes launched under NAPCC, additional national initiatives such as Smart City Mission, AMRUT, Digital India and Startup India also prioritise the development of digital solutions for climate risk mitigation, planning and monitoring. Each programme drives India's digital metamorphosis for creating impact across major carbon emissions contributing sectors. Per a recent World Economic Forum study, digital solutions can potentially reduce carbon emissions by 20 percent by 2050. In the future, given the political stability and commitment towards both sectors, the digitisation for the decarbonisation market in India is expected to grow its contribution towards climate change and economic growth.

The national-level policy initiatives are catalysing digital climate technology markets across sectors such as energy and utilities, infrastructure, industry, logistics and transportation, which together contribute more than 90 percent of the total emissions in the country.[87]

The energy and utilities sector is witnessing demand for solutions focusing on the reduction of energy leakages and improving energy efficiency. India's push towards integrating digital solutions in the energy sector across the value chain of generation, transmission and distribution is strengthened by several national-level initiatives. For instance, the National Smart Grid Mission has planned a budgeted outlay of ~US$130 million[88] and focuses on modernising the power sector through the adoption of smart grid technologies. Its mission is to lead investments in smart grid infrastructure and SCADA systems for 100 smart cities, roll out a nationwide advance meter and develop 20,000 microgrids.[89] Until 2024, the mission had achieved more than 13 million smart meter installations.[90] Under the programme, an additional 25 million smart meter installations are planned. The government has also set up Energy Efficiencies Services Ltd., which is leading the implementation of programmes such as the Smart Meter National Programme and Building Energy Efficiency Programmes, which integrate digital innovations at scale across the sector. Given the national policy thrust, India's digital solutions market for the energy sector has matured rapidly over the last decade to become a vibrant and competitive landscape, driven by escalating demands for grid modernisation, energy efficiency and demand management.

[86]Tata Cleantech Capital Investments in Desalination
[87]IEA Data Sevices
[88]National Smart Grid Mission website
[89]National Smart Grid Mission
[90]National Smart Grid Mission Dashboards

The infrastructure sector is experiencing a surge in demand for digital solutions for optimising building and infrastructure construction, operations and maintenance to reduce emissions across key segments of the value chain: Emissions from India's infrastructure sector are expected to reach more than 90 gigatonnes of carbon dioxide equivalent between 2020 and 2070[91] under a business-as-usual scenario. This projection surpasses the carbon budget allocated for the entire country. Given the high carbon emissions share of buildings and the construction sector, several national and regional initiatives have been undertaken to promote the adoption and certification of green buildings. The National Building Codes 2016 issued guidelines for prioritising green buildings for optimising the construction and facilities management sector. The Ministry of Housing and Urban Affairs offers extra FAR 1–5 percent, 5 percent for projects of more than 3,000 sqm plot size to incentivise green buildings[92]. The Climate Smart Cities Assessment Framework launched by MoHUA in 2019 emphasized guidelines for the promotion of green buildings and digital solutions for infrastructure across all 100 smart cities through the integration of green building recommendations of National Building Codes 2016 and compulsory green building minimum ratings as part of city development control regulations. Additionally, the framework incentivises cities to promote the adoption of green buildings by increasing the ratio of the built-up area of green buildings to the occupant load per 100 sqm, as mentioned in the model building by-laws for each of the building types. Popular green building ratings systems in India, such as IGBC, GRIHA, LEED, BREEM, EDGE and USGBC, incentivise digital solutions such as connected building energy management, building information modelling, resource flow monitoring and automated workforce optimisation. This highlights the critical need for robust strategies to reduce emissions and enhance sustainability within the sector.

Logistics and transportation decarbonisation initiatives in India are being augmented through digital platform solutions that improve fuel efficiency, overall traffic optimisation and maximising operations throughput: Mobility services and solutions, whether for moving people or goods, contribute 13 percent of the total emissions of the country.[93] The sector's decarbonisation efforts comprise synergistic investments across various initiatives, such as promoting EVs, enhancing public transport and improving fuel efficiency. Digital solutions are pivotal to India’s decarbonisation strategy in the transport sector. They optimise logistics for the vast network of trucks and goods vehicles, potentially slashing fuel consumption by up to 15 percent. Smart traffic management systems in congested cities such as Mumbai and Delhi can cut emissions from idling vehicles by 10–20 percent.[94] Digital platforms also support the rollout of EVs by enabling efficient charging infrastructure and route planning, which is critical as India aims for EVs to comprise 30 percent of new vehicle sales by 2030.[95] These digital advancements are essential for meeting India's ambitious targets, including a 20–25 percent reduction in transport sector emissions by 2030, by boosting efficiency and promoting sustainable practices. Transportation digitisation is the top-most priority in urban India. National investments through the Smart City Mission into the digitisation of transportation services are accelerating smart mobility to deliver an efficient and sustainable system. Mobility and network infrastructure have the largest share of projects and investments. “Smart Mobility”, including smart roads and integrated public transport had almost 24 percent of the total projects and the highest percentage (21 percent) share of total investments.[96]
In addition to the urban sector, the logistics sector, including railways, airports and ports, is substantially investing in digital technologies. The modernisation of railway stations through the Amrit Bharat Station Scheme with digital solutions such as smart lighting, automated ticketing and energy-efficient systems is expected to be a critical component in Indian Railway’s aspirations to become net zero by 2030.

[91]Council of Energy Environment and Water
[92]India Green Building Market Maturity Snapshot, IFC, World Bank
[93]International Energy Association Data Services
[94]Potential of Intelligent Transport Systems to reduce greenhouse gas emissions in road freight transport, ERTICO, ITS Europe
[95]Ministry of Transport, GoI, Press Release
[96]Smart City Mission Progress, Localizing Sustainable Development Goals 2023

Indian industries are showing surging demand for Industry 4.0 adoption, with more than two-thirds of Indian manufacturers transforming supply chains. Under the National Action Plan on Climate Change (NAPCC), several incentives have been established to help industries manage and reduce climate emissions. These include the Perform, Achieve and Trade Scheme, part of the National Mission for Enhanced Energy Efficiency (NMEEE), which provides incentives through energy savings certificates for industries that achieve energy efficiency improvements. Additionally, the energy efficiency financing platform has been set up to provide a platform for industries to access funding and technical support for implementing energy-saving measures, thus reducing emissions. Additionally, the pressure on industries to adopt more sustainable practices is intensifying from multiple fronts, including employees, consumers, government bodies, investors, regulators and the local communities where businesses operate. Given this systemic push, industry leaders are implementing pioneering transformations through the integration of Industry 4.0 and Industry 5.0 across supply chain operations. Indian companies are investing in digital solutions such as telematics and real-time analytics to monitor and manage energy consumption, which helps in cutting emissions across their manufacturing processes. Certain cement players are employing AI-driven analytics and a centralised business command and control centre to optimise kiln operations and reduce fuel consumption, showcasing the practical application of digital technologies in reducing industrial emissions.

National policies and market trends across energy, utilities, transportation, infrastructure and industry are creating a surge of investment opportunities in cutting-edge digital and platform solutions.

The Indian market is witnessing multiple opportunities across key digital solutions for top carbon-emitting sectors. Cumulatively, this market is valued at US$20 billion.[97] The rapidly scaling climate tech investments from global and domestic VCs encourage various start-ups to participate in this market and drive the speed and scale of innovations.

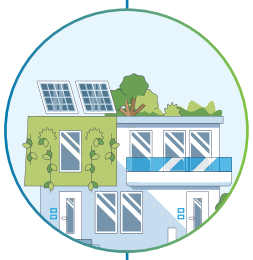
Digital energy and utilities solutions

This includes several organisations such as state electricity regulatory commissions, power distribution companies and large industrial and commercial users. Smart city authorities are implementing solutions in the areas of smart grids, energy management systems, smart meters, energy forecasting tools, renewable energy management platforms, energy analytics and reporting tools. These solutions are getting integrated across multiple projects in smart cities, industrial complexes, power generation and transmission units. The total market size for these solutions was US$1–2 billion in 2023. It is expected to post ~20 percent CAGR over the next five years.[98] Leading global players are expanding their presence to support private and government stakeholders. They face strong competition from major Indian corporations. The market is further galvanised by innovative start-ups and MSMEs using cutting-edge technologies such as AI/ML, IoT and cloud computing, creating state-of-the-art solutions. Several JVs and collaborations for capability enhancement in collaboration with cloud computing and telecom companies are also being witnessed in the market. This dynamic environment fuels rapid technological advancements and intensifies market competition.

Smart transportation systems

Smart traffic management systems with capabilities of route analytics, intelligent route optimisation, smart parking and traffic network optimisation are being implemented across 100 smart cities, which can achieve significant emissions reduction by managing congestion in cities. The immediate market size for ITMS is ~US$300 million in 50 out of 100 smart cities, which can be penetrated in the next five years. Additionally, a long-term market of more than US$2.5 billion exists in 400 additional cities[99] prioritised by government schemes such as the Smart City Mission and AMRUT. Leading global OEMs are active in this segment. Additionally, the transportation and mobility sector has received a disproportionately high share of climate technology investments in the country at ~30 percent of total investments.[100] This has encouraged several start-ups to provide solutions in route analytics, smart parking, logistics optimisation and other areas.

[97]Cumulative market size for energy, transportation, building and infrastructure, and smart factories, as obtained from research estimates of multiple independent agencies
[98]Data compiled from research studies done by independent market research firms
[99]DPRs by multiple smart cities, SCM data on implementation status of ITMS in cities. Independent research reports on market growth rate for ITMS
[100]Financial Express

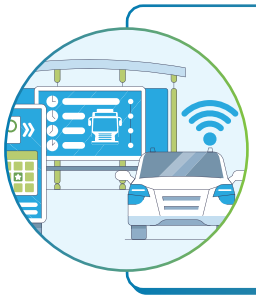


Smart building and infrastructure solutions

Digital solutions in areas of smart building technologies, HVAC systems, digital twins, building information models smart lighting, etc., can achieve 20–30 percent reduction in carbon emissions[101] from residential, industrial and commercial buildings and infrastructure. The plethora of policy incentives is encouraging players in the real estate sector to invest in digital solutions for achieving sustainable and green building certifications and ratings. Prop tech start-ups, along with global OEMs, are spearheading this movement with AI- and IoT-powered solutions that optimise energy management, improving building efficiency and cutting energy use. Additionally, with the advent of connected building technology, various institutions are converting industrial, social and residential developments into smart precincts and campuses. Some of the key smart precinct developments include GIFT City Gujarat, university campuses and private sector developments in various metropolitan cities of India. Additionally, the smart building market will also witness tailwinds from the newly launched industrial smart cities in 2024 with an investment of US$280 billion by the government. Per a recent study by the National Real Estate Development Council (NAREDCO), commercial green buildings alone will generate US$ 11 billion, with residential projects contributing US$28 billion to this burgeoning market by 2025. The digital solutions component, as part of the total green building market, is estimated at US$8–9 billion in 2025.[102]

Smart factory systems

Major carbon-emitting sectors manufacturing units in sectors of cement, iron and steel, etc., are investing in industrial IoT solutions, digital twin systems, advanced process control systems and energy management systems in India. The total market size in this domain is US$4–6 billion and is registering ~14 percent CAGR.[103]



Integrated Command and Control Centres (ICCCs)

Since 2015, under the Smart Cities Mission, ICCCs have been a core component in the implementation of smart cities to improve their performance with respect to sustainability. ICCCs focus on transport management, waste management, water management and environment monitoring use cases. ICCCs have already been implemented in 100 smart cities. The momentum and the demand are strong for scaling these systems to the top 100 AMRUT 1 cities beyond the SCM cities which can have a potential market size of US$1.5 billion.[104]

Environment monitoring systems: India is enhancing its forecasting and environmental monitoring capabilities. It is expected to have a comprehensive Doppler Weather Radar Network that will offer more precise predictions of extreme weather events. Investments are also being made in satellite technology and machine learning to provide detailed flood alerts, while AI is being employed to detect wildfires and issue timely warnings. Additionally, substantial resources are being allocated to improve weather modelling systems, integrate real-time data from various sources and develop advanced analytics platforms to support decision-making and disaster preparedness.

[101]Estimations quoted and verified by leading solutions providers such as Johnson Controls, Schneider Electric, Honeywell, etc
[102]Estimates based on India's Smart Homes research done by NAREDCO
[103]Research and Markets
[104]Smart City Mission, Deloitte Analysis, Global ICCC market growth rate has been assumed

Circular economy and waste management

India's waste management sector is at the cusp of a transformation. With a population exceeding 1.4 billion and rapid urbanisation, the country generates over 62 million tonnes of Municipal Solid Waste (MSW) annually—a figure expected to triple by 2030.[105] This massive volume of waste is not just a challenge but a resource waiting to be tapped. The global shift towards sustainability, along with India's accelerated path to becoming a US$5 trillion economy, are some of the key factors fuelling a rising demand for cutting-edge waste management solutions.

Addressing waste management as a central pillar of India's climate action plan and its commitments under the Paris Agreement.

The waste management sector can bolster India's bid to achieve its target for net zero emissions by 2070,[106] especially on its commitments under SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action). The threat from waste is exacerbated further when mismanaged, and India's waste management sector is largely informal, with severe environmental, climate and health implications. As of 2021, India was the third-largest contributor to global GHG emissions and the sixth-largest contributor to waste-related GHG emissions.[107] Landfills, where most waste ends up, are notorious for emitting methane—a greenhouse gas that is 25 times more potent than carbon dioxide over a 100-year period.[108] The decomposition of organic waste in these landfills leads to a significant release of methane, contributing to global warming and exacerbating climate change. Therefore, a renewed look towards waste management across the value chain – waste collection, transport, treatment and disposal – is critical for taking the sustainable route for India's development.

India is ushering into a new era of waste management based on the restorative and regenerative principles of circular economy.[109]

The government has laid a strong foundation for addressing waste management challenges and adopting the principles of a circular economy through initiatives across the waste management value chain, especially through comprehensive coverage under the National Mission on Sustainable Habitat, NAPCC, where waste management forms one of its five key pillars.[110] The mission identifies waste management as a priority area for reducing emissions and promoting sustainability through the adoption of the 3R Principle—reduce, reuse and recycle.[111]

Recognising the strong co-dependence of each stage of the value chain, the government launched the Swachh Bharat Mission (SBM) in 2014. The mission identifies scientific waste collection as a prerequisite for efficient waste processing. For instance, mixed waste with a high proportion of organic waste has a low calorific value, resulting in sub-optimal energy generation.[112] Therefore, SBM focuses on addressing challenges across the value chain, catalysing investments in waste management infrastructure, from waste segregation at the source to the development of waste processing plants. Consequently, the processing rate of municipal solid waste has improved significantly, rising from 68 percent in 2020 to 78.46 percent in 2024.[113] The Atal Mission for Rejuvenation and Urban Transformation (AMRUT), with a capital outlay of US$11 billion, focuses on processing wastewater, recycling and reusing.[114] Another key initiative is the Solid Waste Management Rules 2016, which mandates the segregation of waste at the source and promotes the use of technology for waste processing.[115]

The government is steadily pushing for innovation and the development of technology for waste management. The Waste to Wealth Mission launched in 2021 by the government aims to identify, develop and deploy technologies to treat waste for energy generation, recycling materials and extraction of resources of value.[116] In 2015, the Department of Science & Technology launched its Waste Management Technologies (WMT) programme to develop waste management technologies that can be adopted in small and medium-scale enterprises to improve their productivity and global competitiveness.[117]

Despite these efforts, the scale of the waste problem is immense, and government initiatives alone are insufficient

[105]Ministry of Housing and Urban Affairs (MoHUA); ITA Dept. of Commerce, US Government (2023)
[106]Press Information Bureau (2023)
[107]Climate Watch Data 2021
[108]Environment Protection Agency, US Government
[109]Ellen MacArthur Foundation
[110]National Action Plan on Climate Change (NAPCC) - National Mission on Sustainable Habitat 2021-30, Ministry of Housing and Urban Affairs, Govt. of India
[111]National Mission on Sustainable Habitat 2021-30, Ministry of Housing and Urban Affairs, Govt. of India
[112]Centre for Science and Environment (2020)
[113]Press Information Bureau (2024)
[114]Press Information Bureau (2021)
[115]Press Information Bureau
[116]Office of Principal Scientific Adviser, Government of India
[117]Department of Science & Technology, Govt. of India

to comprehensively tackle the challenge. It is also critical to note that waste management falls under the jurisdiction of the local government, which often lacks the financial and technical prowess for developing and deploying innovative waste management solutions. As is evident, the waste management sector requires substantial investment in infrastructure, technology and innovation to achieve the desired outcomes. This is where private investment becomes crucial. The private sector brings in the necessary capital, innovation and operational efficiency to transform waste management into a sustainable, profitable industry.

A joint effort by the public and private sectors in waste management can propel the growth of a circular economy, where waste is not just disposed of but transformed into valuable resources. Private investment is crucial for bridging the gap between government initiatives and the actual on-ground implementation of sustainable waste management practices. To foster private participation, the government has taken several steps to make the waste management sector more attractive to investors. The government has been actively promoting Public-Private Partnerships (PPPs) in waste management projects, offering a win-win solution as it uses the efficiency and innovation of the private sector while ensuring that public interests are safeguarded.

To make waste management projects financially viable, the government has introduced Viability Gap Funding (VGF), which provides financial support to projects that are otherwise economically unfeasible.[118] This funding mechanism is particularly useful for large-scale infrastructure projects, such as waste-to-energy plants and recycling facilities, where the initial capital expenditure is high. Moreover, the Ministry of New and Renewable Energy offers central financial assistance to project developers on the successful commissioning of waste-to-energy plants.[119] The government has also introduced various tax incentives and subsidies to encourage private investments in waste management. For example, companies investing in waste-to-energy projects can avail of tax holidays and capital subsidies under the Income Tax Act.[120] These efforts are accelerating the shift towards a circular economy, making the waste management sector more attractive than ever for private investments.

India currently has 94 opportunities in the solid waste management sector worth ~US$2 billion, including projects such as waste-to-energy plants, bio-methanation plants, bio-mining, e-waste management facilities, integrated wastewater management and smart solid waste equipment.[121] The entire waste management value chain is expected to experience significant growth in the next decade.[122] For investors, the shift towards a circular economy presents a dynamic and scalable market opportunity. As the global focus on sustainability intensifies, India is emerging as a key player in the circular economy, offering a range of investment avenues from waste-to-energy projects to advanced recycling technologies.

India's leading business houses have recognised the potential of the waste management sector and have made significant investments to drive the circular economy. Large private conglomerates in India are driving innovation in the e-waste management and waste-to-energy segments using cutting-edge technologies.[123] Companies are also investing in collaborations and initiatives aimed at improving plastic waste collection and recycling infrastructure in India, contributing to the circular economy and reducing environmental pollution.[124]

India is witnessing growing investment trends in e-waste management, plastic waste processing, Waste-To-Energy (WTE) plants and biomethanation.

[118]Press Information Bureau (2020)
[119]Ministry of New and Renewable Energy
[120]Waste Management in India: Tax Benefits and Incentives to Drive Sustainable Practices - First Green Consulting, India
[121]India Investment Grid, DPIIT, Govt. of India
[122]ITA Dept. of Commerce, US Government (2023)
[123]Blue Planet (2024)
[124]Hindustan Unilever Limited

In 2024, India's waste management market was estimated at ~US$13 billion and is expected to post a CAGR of more than 6 percent between 2024 and 2030.[125] Some of the key areas exhibiting promise are as follows:

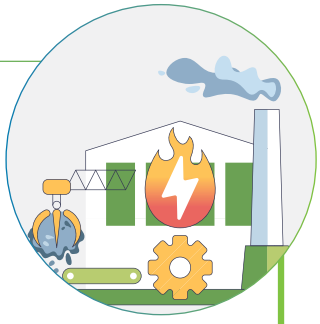
E-waste processing

India is the second-largest producer of e-waste globally, generating over 3 million tonnes of e-waste annually.[126] Rapid technological adoption and the burgeoning electronics market are estimated to drive the growth of the e-waste sector at ~10 percent over the next decade.[127] E-waste contains valuable materials such as gold, silver and rare earth metals, making it a lucrative sector for recycling and recovery. This sector has seen interest from private players and government institutions. For instance, Bhabha Atomic Research Centre (BARC) has developed energy-efficient and cost-effective e-waste recycling technologies, which are ready for commercialisation and transfer to e-waste management companies. The AGNIi Mission, under the Office of the Principal Scientific Adviser to the Government of India, is actively supporting BARC in bringing these technologies to market.[128]

Plastic waste processing

India is the third-largest generator of plastic waste, accounting for over 9 million tonnes annually, of which only 60 percent is recycled.[129] In the next 10 years, plastic waste is expected to grow by 200 percent, offering a unique problem statement as well as an opportunity.[130] Estimates suggest that the plastic recycling industry will reach US$7 billion by 2033. Private investors are already capitalising on the high volumes of plastic waste generated by setting up recycling facilities and developing innovative technologies for efficient waste processing. Moreover, in 2021, India became the first Asian country to launch a Plastics Pact, aiming to make 100 percent of its plastic packaging reusable or recyclable and recycle 50 percent of its plastic packaging by 2030.[131]

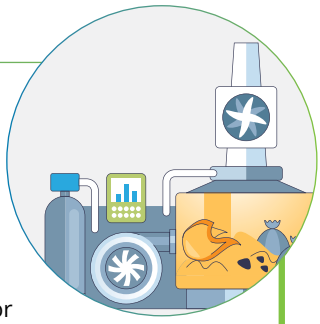
Waste-to-energy plants



Estimates suggest that India has the potential to generate 5,690 MW of power from industrial and municipal waste, but as of May 2023, the installed capacity was only 556 MW, highlighting significant untapped potential.[132] While traditional incineration remains the most common method of WTE processing in India, it is also less efficient due to the burning of unsegregated waste with low calorific value. India has 12 operational waste-to-energy plants. For instance, some WTE plants sort and treat solid waste before incineration to improve plant efficiency and reduce environmental impact. Newer technologies such as Refuse-Derived Fuel (RDF) are being adopted by companies for processing mixed waste to remove non-combustible materials, improving the calorific value of energy generation.[133]

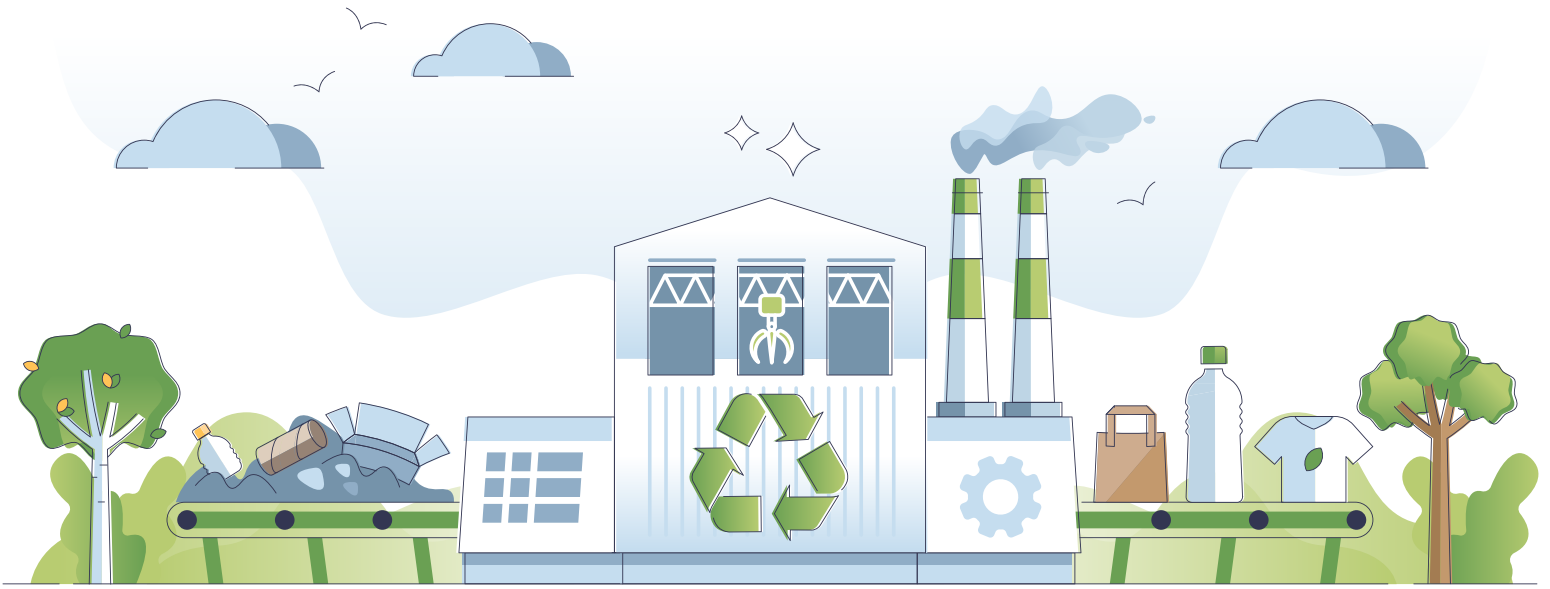
[125]Mordor Intelligence
[126]Business Today (2021)
[127]UKRI Innovate UK – www.iuk.ktn-uk.org; Ministry of Electronics and Information Technology (www.meity.gov.in); www.techsciresearch.com
[128]Invest India (2022)
[129]Plastic Waste Management - Swachh Bharat Mission (2019)
[130]Invest India
[131]UKRI Innovate UK - www.iuk.ktn-uk.org
[132]Economic Times (2023)
[133]EAI Consulting

Investment in industrial solid and liquid waste processing



India generates 6.2 billion litres of untreated industrial wastewater daily, with only 60 percent of it treated by 194 Common Effluent Treatment Plants (CETPs).[134] Industries such as textiles, chemicals and auto components primarily contribute to industrial wastewater. With water scarcity rising, demand for wastewater recycling and reuse is increasing. The adoption of Zero Liquid Discharge (ZLD) technology is a promising solution. The government has prioritised wastewater management with 97 CETP projects underway, offering significant private investment opportunities.[135] As industries face stricter environmental regulations, investing in wastewater treatment is essential for sustainability and industrial growth.

India is not just responding to the challenges of waste management; it is actively transforming them into opportunities for economic growth and environmental sustainability with a positive social impact. The confluence of government initiatives, private sector investments and a robust regulatory framework is sure to position the country as a global leader in the waste management sector. India is unlocking the potential of a circular economy, turning waste into wealth. Investors have a unique opportunity to be part of this transformative journey, contributing to a cleaner and greener future.



[134]Indian Council of Agriculture Research (ICAR) 2020
[135]India Infrastructure (2021)

Sustainable transport infrastructure

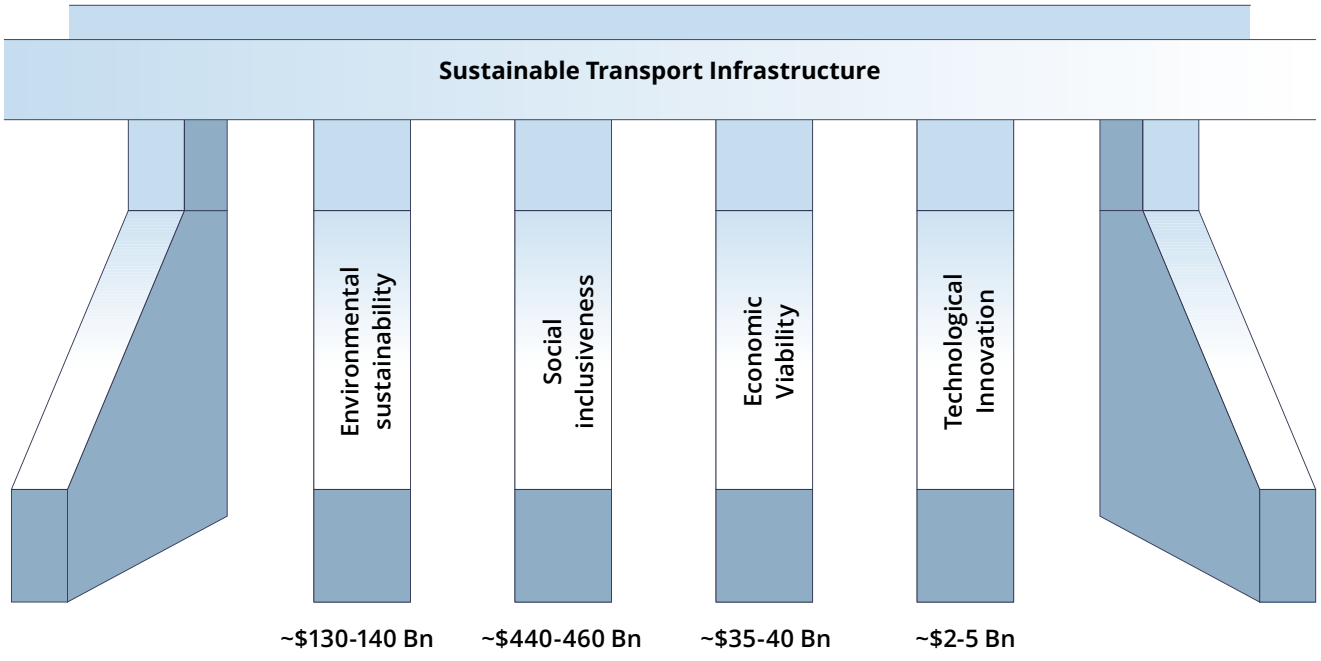
Unlocking India's future through focus towards sustainable transport infrastructure

India's transport sector is a cornerstone of its economic development, playing a pivotal role in driving growth and mobility across the country. With its extensive network of roads, railways and growing air and sea links, the sector has significantly contributed to the country's economy and directly employs about 10 percent of the country's working population.[136] As India gears up to become the third-largest economy by 2027 with a projected GDP of US$5 trillion,[164] the transport sector is expected to be a key driver fuelling economic growth.

However, despite these achievements, several challenges hinder the sector's sustainability and efficiency. The transportation sector, responsible for about 14 percent[138] of the country's GHG emissions, underscores the need for change. Passenger and freight emissions would increase by 1.5x and 3x, respectively, between 2020 and 2052.[139] With the current population of 1.4 billion rising mobility demand is straining infrastructure, leading to congestion, pollution and declining living standards. As cities are set to house 600 million people by 2036,[140] passenger and freight demand will likely increase by 2.3x and 4x, respectively, between 2020 and 2052.[141] If this trend persists for the next few decades, the average carbon emissions from India's transport sector will nearly double, rising from 271 kg CO2 to 448 kg CO2 per capita. This underscores the need for a strong focus on sustainable transport infrastructure across the country to not only meet the rising demand but also drive the revolution towards sustainable transit.

Redefining the core pillars of sustainable transport infrastructure in India to pave the path for the sector's investment potential

Sustainable transport infrastructure refers to a system of transportation that prioritises environmental sustainability, social inclusivity, economic viability and technological innovation. In the Indian context, this also encompasses public transit systems such as buses, metros and non-motorised transport (NMT), including cycling and walking, alongside the growing adoption of EVs. The aim is to reduce emissions, minimise resource consumption and improve liveability in cities. The four key pillars of sustainable transport infrastructure are as follows:



[136]India Infrastructure (2021)
[137]https://www.tandfonline.com/doi/pdf/10.1080/01441648408716562#:~:text=In%20India%2C%20a%20sizeable%20portion,employed%20in%20the%20transport%20sector
[138]https://www.thehindu.com/business/Economy/india-to-become-third-largest-economy-with-gdp-of-5-trillion-in-three-years-finance-ministry/article67788662.ece
[139]https://climateactiontracker.org/documents/832/CAT_2020-12-09_Report_DecarbonisingIndianTransportSector_Dec2020.pdf
[140]Deloitte Estimation
[141]https://www.worldbank.org/en/news/opinion/2024/01/30/gearing-up-for-india-s-rapid-urban-transformation

Environmental sustainability

Environmental challenges hinder India's sustainable growth. Among the world's 20 most polluted cities, 14 are from India, severely impacting public health and liveability.[142] Due to air pollution, India loses about US$220 billion per annum, equivalent to 6.6 percent of the GDP.[143] India's reliance on fossil-fuel-powered vehicles impacts energy security. Switching to an alternative fuel could reduce India's oil dependency from 82 percent to 25 percent and cut the fuel import bill from US$112 billion to US$34 billion.[144] Furthermore, inadequate and fragmented transportation system coupled with a lack of active and green mobility infrastructure exacerbates pollution, congestion and a disintegrated mobility ecosystem.

To achieve environmental sustainability and promote sustainable transport, the following interventions are required:

- **Formulate policies for alternative fuel technology:** Invest in creating a robust infrastructure for alternative fuel technology (EV, hydrogen, blended fuel, etc.) to diversify clean energy solutions. This includes incentives for EV adoption and the development of charging infrastructure.
- **Promote active and green mobility:** Develop infrastructure to support cycling and walking. Change land use plans to make active mobility feasible and attractive.
- **Strengthen transit-oriented development policies:** Reduce vehicle dependency by promoting sustainable development through efficient land use near transit hubs.
- **Encourage multi-modal integration:** Develop seamless connectivity between buses, metros, trains and NMT to boost public transport efficiency and reduce private vehicle dependence. Integrated ticketing, real-time information and coordinated infrastructure will also streamline travel and make urban areas more sustainable and equitable, ensuring that residents benefit from improved transport options.

Social inclusiveness

About 18 percent of the Indian population depends on public modes of transportation for daily commuting.[145] A reliable and affordable transport system is one of the key aspects of social inclusiveness, but accessibility of the Indian transport system is limited, with urban areas suffering from congestion and rural areas lacking efficient connectivity. Road safety also remains a critical issue, with India reporting one of the highest rates of road accidents per capita. In 2022, India reported 4,61,312 road accidents, which claimed 1,68,491 lives.[146] Furthermore, public transportation systems are often overcrowded and underfunded. India has 1.2 buses per 1,000 people which is much below the benchmark for developing nations.[147] This results in inequitable access to transportation for marginalised populations, women and the elderly. Furthermore, the absence of multimodal integration reduces transport efficiency. Moreover, challenges in the transport ecosystem, such as the absence of robust benchmarks for monitoring and timely improvements, can hinder transport resilience. To promote social inclusiveness, the following interventions are required:

- **Increase public transit with improved accessibility:** Expand the public bus fleet, aiming for the recommended benchmark of 3–4 buses per 1,000 people, and ensure these buses are equipped with facilities for differently abled individuals and the elderly.
- **Improve safety and affordability:** Implement measures to improve road safety and introduce affordable fare structures, ensuring marginalised communities, including women and low-income groups, have safe and equitable access to public transport.
- **Prioritise investments in public transport:** Focus on developing inclusive public transit systems to enhance accessibility for all communities.
- **Enhance Public-Private Partnerships (PPP) to attract private sector investment:** Strengthen collaborations to modernise transport systems, especially in high-density and underserved areas, with a focus on inclusivity, safety and accessibility.
- **Build resilient infrastructure:** Invest in resilient transport infrastructure that can withstand environmental challenges, ensuring consistent service delivery in urban and rural areas. This will help provide equitable, reliable access to transportation for all segments of society, especially during natural disasters and adverse conditions.

[142] Deloitte Estimation
[143] https://www.iea.org/reports/transitioning-indias-road-transport-sector/executive-summary
[144] https://www.statista.com/topics/8868/passenger-transport-in-india
[145] https://www.worldbank.org/en/news/feature/2011/09/23/india-transportation
[146] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10089696/#:~:text=About%2018%%20of%20the%20Indian%20population%20depends,of%20transportation%20for%20daily%20commuting%20(UITP%202020a).
[147] https://morth.nic.in/sites/default/files/RA_2022_30_Oct.pdf

Economic viability

An affordable transit system is crucial in India, where a significant portion of the population relies on it for daily commutes. Public transportation is a lifeline for low- and middle-income groups who cannot afford personal vehicles. However, rising fares and inadequate services often push commuters towards private vehicles, increasing their cost of travel and exacerbating traffic congestion and pollution. To improve affordability and economic viability of public transit projects, several measures can be implemented:

- **Subsidies and financial support:** Government subsidies can help reduce operational costs, making fares more affordable for users. This can be funded through dedicated taxes or levies on private vehicle usage.
- **Public-Private Partnerships (PPPs):** Engaging private players in the development and operation of public transit can bring much-needed investment and efficiency. PPPs can help modernise infrastructure and ensure better service delivery.
- **Integrated ticketing systems:** Implementing a unified ticketing system across various modes of public transport (buses, metros, trains) can enhance convenience and reduce commuter costs. This integration can also streamline revenue collection and reduce fare evasion.
- **Investment in infrastructure:** Expanding and upgrading public transit infrastructure, such as dedicated bus lanes and metro networks, can improve service reliability and attract more users.

Technological innovation

Technological innovation plays a pivotal role in advancing sustainable transport infrastructure, yet India's adoption of such technologies remains limited compared with global standards. Key areas include battery technology, which needs improvements in energy density and cost; hydrogen fuel cells, supported by the National Hydrogen Mission but requiring significant infrastructure; and smart grid systems, to manage increased energy demand from EVs and renewables, which are yet to be fully deployed. Additionally, the Intelligent Transportation Systems (ITS) can optimise traffic flow and reduce congestion, but it has been implemented in limited capacity across the country. The global smart transportation market was valued at US$96.6 billion in 2020 and is projected to reach US$251 billion by 2030, posting a CAGR of 10.2 percent,[148] illustrating the significant investment potential of these technologies. However, high capital investments, extensive data management needs and the absence of standardised and uniform technologies pose significant challenges to the widespread adoption of these technological innovations in India.

To promote sustainable transport infrastructure through technological innovations, the following interventions are required:

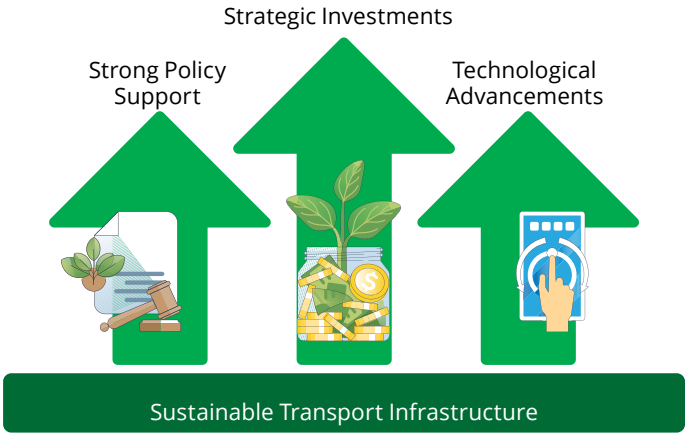
- **Invest in AI-driven smart infrastructure:** Develop infrastructure solutions empowered with AI to predict future travel demand and create personalised travel recommendations for users.
- **Integrate smart mobility:** Utilise smart mobility solutions in public transport, such as real-time data systems, digital ticketing and multimodal platforms to improve efficiency and user experience.
- **Develop EV management platforms:** Implement EV-specific apps and digital dashboards to provide real-time data on charging stations, vehicle performance and route optimisation, enabling better management and user convenience for EV owners.

[148]https://timesofindia.indiatimes.com/business/for-1000-people-just-1-2-buses-in-india/articleshow/65945392.cms

Capitalising policy, investments and innovative technology for sustainable transformation

To fully realise the potential of sustainable transport infrastructure, India must create an enabling environment. Key enablers for creating sustainable transport infrastructure include robust policy and regulation, investment in climate financing, and cutting-edge technology. Strengthening policies such as the National Electric Mobility Mission Plan (NEMMP) and FAME and introducing new initiatives for hydrogen fuel will be critical. Developing additional schemes that promote renewable energy integration and EV adoption while harmonising local regulations with national goals will help build climate-resilient and energy-efficient transport systems. Adoption of new policies, such as carbon pricing, will prove to be the game-changer.

Investment will play a crucial role, with access to private sector capital being essential for large-scale projects such as EV manufacturing and nationwide charging networks. Using financial instruments such as green bonds, climate funds and blended finance models can help attract private investment, driving the development of sustainable transport infrastructure. The financial landscape is gearing up to support the emerging advanced infrastructure. Banks, NBFCs and fintechs are beginning to provide tailored financing options and embracing emerging technology to create a sustainable future for India. Some of the other areas to be explored include:



Public policy

- Conducive policies to enable transition to sustainable and green transport infrastructure

Lighthouse Projects

- Support development of demonstration projects to test green technologies

Loans and VGF

- Provide capital for infrastructure through grants, subsidies, loans
- Develop accreditation standards for accessing climate finance

Innovative Financing

- Exploring innovative financing including private sector, merging and coupling financing of multiple initiatives in packages

Capacity Building

- Upskilling government and private sector on emerging techs, R&D, efficient planning concepts

Knowledge Management

- Developing a green infrastructure technologies database
- Develop platform to share experience among stakeholders

On the technological front, advancements in battery technology, hydrogen fuel cells, smart grid systems and Mobility-as-a-Service (MaaS) platforms will augment the transport infrastructure. Encouraging PPPs and fostering innovation in these areas will be key to transforming India's transport sector into a low-carbon, energy-efficient ecosystem. This will assist in propelling an expeditious and seamless transition towards greener energy, strengthening the country's commitment to achieve carbon neutrality by 2070.

India's path to sustainable transport infrastructure

India's push for sustainable transport infrastructure and electric mobility is key to challenges posed by rapid urbanisation and environmental concerns. Technological innovations are expected to reshape the future of the transport ecosystem. With strong policy support, strategic investments and technological innovation, India is poised to lead the global shift towards sustainable mobility, driving both economic growth and climate action. The continuous innovations and evolving business models will impact the movement of people and goods, enabling better access through sustainable infrastructure. The focus is to deliver solutions that amalgamate green technologies, digital technologies and innovation prowess to create sustainable transport infrastructure while attaining the vision of reducing the carbon footprint substantially.

Sustainable agriculture

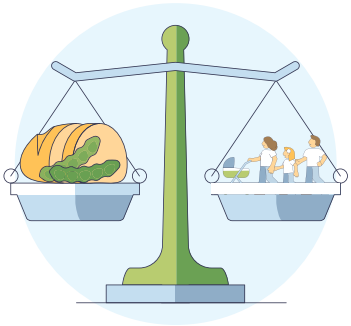
India's agricultural sector is the backbone of the economy, providing employment for nearly 50 percent of the population and contributing significantly to the country's wealth. Despite its critical role, Indian agriculture in India faces several challenges, including poverty, malnutrition and environmental degradation. To combat the situation and align with the Sustainable Development Goals (SDGs), the government has introduced various initiatives, such as the National Mission for Sustainable Agriculture (NMSA) and Pradhan Mantri Krishi Sinchai Yojana (PMKSY).[149] However, achieving the SDGs, particularly in agriculture requires a holistic approach that integrates socioeconomic factors, environmental sustainability and technological innovation.[150]

The United Nations SDGs framework places a strong emphasis on sustainable agriculture through SDG 2 (Zero Hunger). Clauses 2.3 and 2.4 of this goal underscore the importance of enhancing productivity, resilience and sustainability in agriculture.[151] [180] SDG 2.4 specifically advocates for increased investment in resilient agricultural practices. Sustainable agriculture is interlinked with other SDGs, including poverty reduction, climate change mitigation, water usage, gender equality and sustainable production and consumption.[153] In India, achieving SDG 2 is crucial, as agriculture is key to food security and rural livelihood. The government's focus on climate-resilient practices is essential to address both poverty and the challenges posed by climate change.[154]

India is on the brink of a sustainable agriculture revolution, with the increasing adoption of climate-resilient crop varieties and innovations such as zero tillage, agroforestry, precision farming, integrated pest management and drip irrigation. These advancements are reshaping the agricultural landscape, making it more resilient and sustainable.[155]

Agriculture significantly impacts the Indian economy, contributing nearly one-fifth of the national income and providing close to two-fifths of employment opportunities. According to an economic survey by the Ministry of Finance, agriculture supports the livelihood of about 42.3 percent of the population and contributes 18.2 percent of India's GDP at current prices.[156]

Factors influencing the market[157]



Increasing demand for food

Need to reduce the environmental impact

Regulatory support

[149]https://www.alliedmarketresearch.com/smart-transportation-market
[150]Ministry of Agriculture & Farmers' Welfare, Government of India. "National Mission for Sustainable Agriculture (NMSA)." Ministry of Agriculture & Farmers' Welfare, 2023.
[151]Singh, Sukhpal, and Anil Shishodia. "Challenges and Opportunities for Sustainable Agriculture in India." Journal of Cleaner Production, vol. 284, 2021, Article 124714. DOI: 10.1016/j.jclepro.2020.124714
[152]Chander, Mahesh, and Ram Pratap. "Sustainable Agriculture and the SDGs: An Overview with Special Reference to SDG 2 in India." Sustainability, vol. 15, no. 5, 2023, pp. 1110-1134. DOI: 10.3390/su15053110.
[153]Pingali, Prabhu, and Anaka Aiyar. "Achieving the SDGs through the Agricultural Transformation in South Asia: Interlinkages and Synergies." World Development, vol. 157, 2023, Article 106010. DOI: 10.1016/j.worlddev.2022.106010.
[154]Chander, Mahesh, and Ram Pratap. "Sustainable Agriculture and the SDGs: An Overview with Special Reference to SDG 2 in India." Sustainability, vol. 15, no. 5, 2023, pp. 1110-1134. DOI: 10.3390/su15053110.
[155]NITI Aayog. "SDG India Index & Dashboard 2020-21." NITI Aayog, Government of India, 2021.
[156]Singh, Ravi P., et al. "Advancements in Agroforestry Practices for Sustainable Agriculture in India." Agriculture, Ecosystems & Environment, vol. 318, 2022, Article 107508. DOI: 10.1016/j.agee.2021.107508
[157]Ministry of Finance, Government of India. Economic Survey 2022-23. Volume I, Chapter 7, 2023.

The Indian government has developed comprehensive policies at national and state levels to enhance the sustainable growth of the agriculture and food sectors. These policies aim to integrate strategies, innovations, technology and finance to promote sustainable agriculture practices.[158] Key policies are listed below:

Nationally Determined Contributions under Paris Agreement

Emphasises agriculture as a priority adaptation sector for the country.

Sub-Mission on Agricultural Mechanisation

Facilitates the adoption of drones for assessing crop damage, applying pesticides and fertilisers, and combatting locust invasions.

National Mission for Sustainable Agriculture

Enables sustainable agricultural practices in India through adaptation measures such as improved crop seeds, water use efficiency, pest management, nutrient management, access to Information, etc.

National Initiative on Climate Resilient Agriculture

Improves resilience and reduces climate vulnerability of the sector through strategic research and technology demonstration.

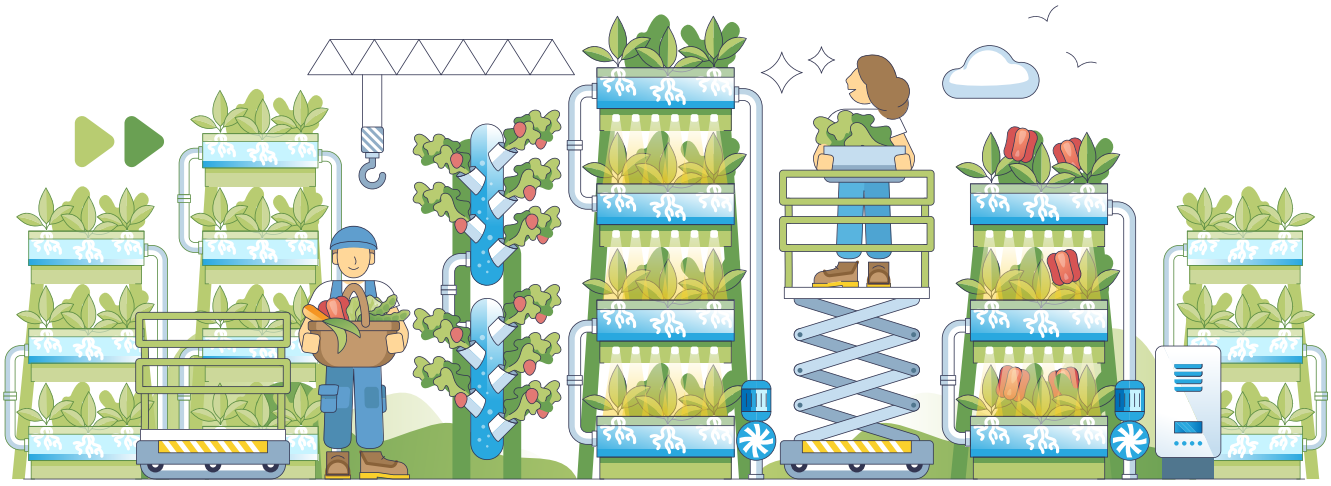
National Adaptation Fund for Climate Change

Focuses on enabling climate resilient agriculture across climate vulnerable geographies.

The Agriculture Accelerator Fund

Provides early-stage funding to Innovative Ag Techs, acting as a catalyst for Indian agtechs to scale.

Under optimistic scenarios, where policy support is robust, technology adoption accelerates and consumer awareness deepens, the demand for sustainable agricultural products could experience significant growth, potentially increasing by 15–20 percent annually.[159] In a more moderate scenario, gradual shifts in policy and steady market awareness would drive consistent demand growth, though at a slower pace. However, in a pessimistic scenario, factors such as policy stagnation or economic downturns could hinder growth to a more modest 5–10 percent annually.[160, 161]



[158]https://www.skyquestt.com/report/sustainable-agriculture-market
[159]Food and Agriculture Organization of the United Nations (FAO). "India: Agriculture Policies and Strategic Planning." FAO Country Programming Framework 2023-2027.
[160]OECD-FAO. "Agricultural Outlook 2023-2032." OECD-FAO Agricultural Outlook, 2023.
[161]Deloitte Insights. "The Future of Food: Complexities and Opportunities in the Sustainable Food System." Deloitte, 2021.

Investment potential

The Indian agricultural market is projected to grow by nearly 27 percent, from US$373 billion in 2024 to US$474 billion by 2029.[162] Government-backed accelerator programmes and policies promoting sustainable agriculture and climate-smart practices are fuelling investor interest in AgriTech ventures. These initiatives are designed to empower small-scale farmers by improving market access, providing better supplies, enhancing crop storage and facilitating access to financing. In addition to government support, charitable organisations and patient investors are actively contributing to these efforts, aiming to uplift the livelihoods of small-scale farmers and promote long-term sustainability in the sector.

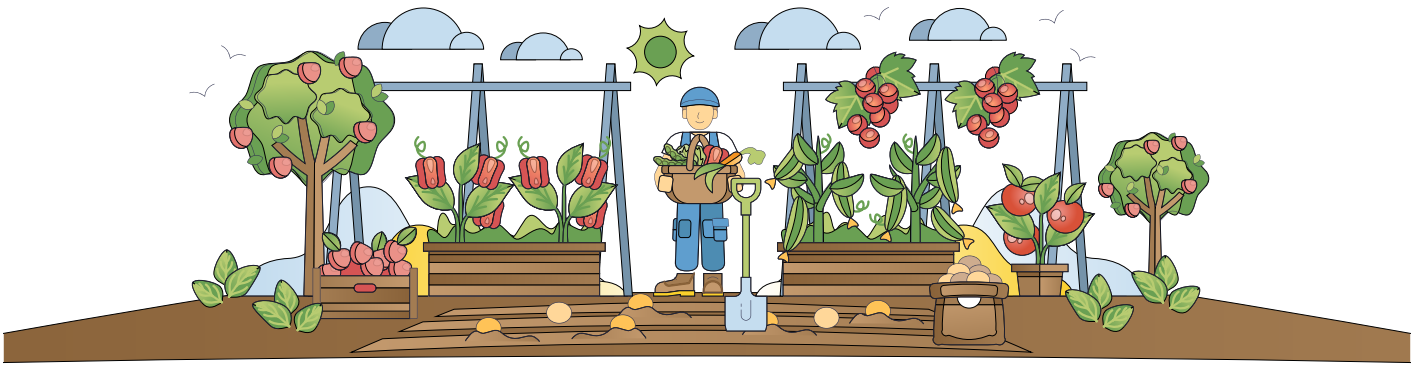
Growing demand for organic products	Export potential	Sustainable farming inputs
Projected to reach US$9.1 billion by 2025 with an annual growth rate of 10 percent.	Projected to reach US$320 billion by 2025 and post a CAGR of 25 percent	Expected to reach US$243.61 million by 2029, at a CAGR of 12 percent

Technology and innovation	Government support and initiatives
Projected to reach US$11.61 billion by 2025 at a CAGR of 13 percent	Schemes such as the National Food Security Mission (NFSM), PKVY and NMSA[163]

In 2022, while funding for downstream and midstream AgTech start-ups in India dropped by 37 percent and 65 percent, respectively, upstream categories (the production side of the agri-supply chain) saw a 50 percent increase, making India the second-largest market for agrifood tech start-ups after the US.[164] Venture capital in India has primarily targeted financing and technology to enhance agricultural practices and address challenges such as droughts, pests and flooding. The following provides a snapshot of the funding landscape:

Investment or funding suitability[165]	Early-stage equity and grant capital	Towards innovation-driven start-ups and SMEs
	Debt capital and de-risking mechanisms (e.g., credit guarantees)	Towards agri-focused NBFCs or commercial banks' lending to Agtechs, farmers and farmer collectives

Several government schemes such as the Organic Value Chain Development for Northeastern Region (OVCDNER)[166] and the National Agriculture Market (e-NAM)[167] have been established to promote sustainable agriculture and attract investment in the sector. These programmes aim to enhance market access, improve supply chains and encourage eco-friendly farming practices. On a global scale, initiatives such as the SDGs and the Paris Agreement align with these efforts, fostering international funding and collaborations that support sustainable agricultural practices and climate-resilient farming.



[162]World Economic Forum. "Shaping the Future of Global Food Systems: A Scenarios Analysis." World Economic Forum, 2020.
[163]https://www.mordorintelligence.com/industry-reports/agriculture-industry-in-india/market-size
[164]https://knometrix.com/wp-content/uploads/2024/02/Exploring-the-Sustainable-Agriculture-Market-Opportunity-in-India-Knometrix.pdf
[165]https://agrithority.com/india-has-potential-to-be-a-major-global-agriculture-player/
[166]https://www.climatepolicyinitiative.org/publication/green-investment-opportunity-in-india/
[167]https://asfac.assam.gov.in/portlet-innerpage/mission-objectives

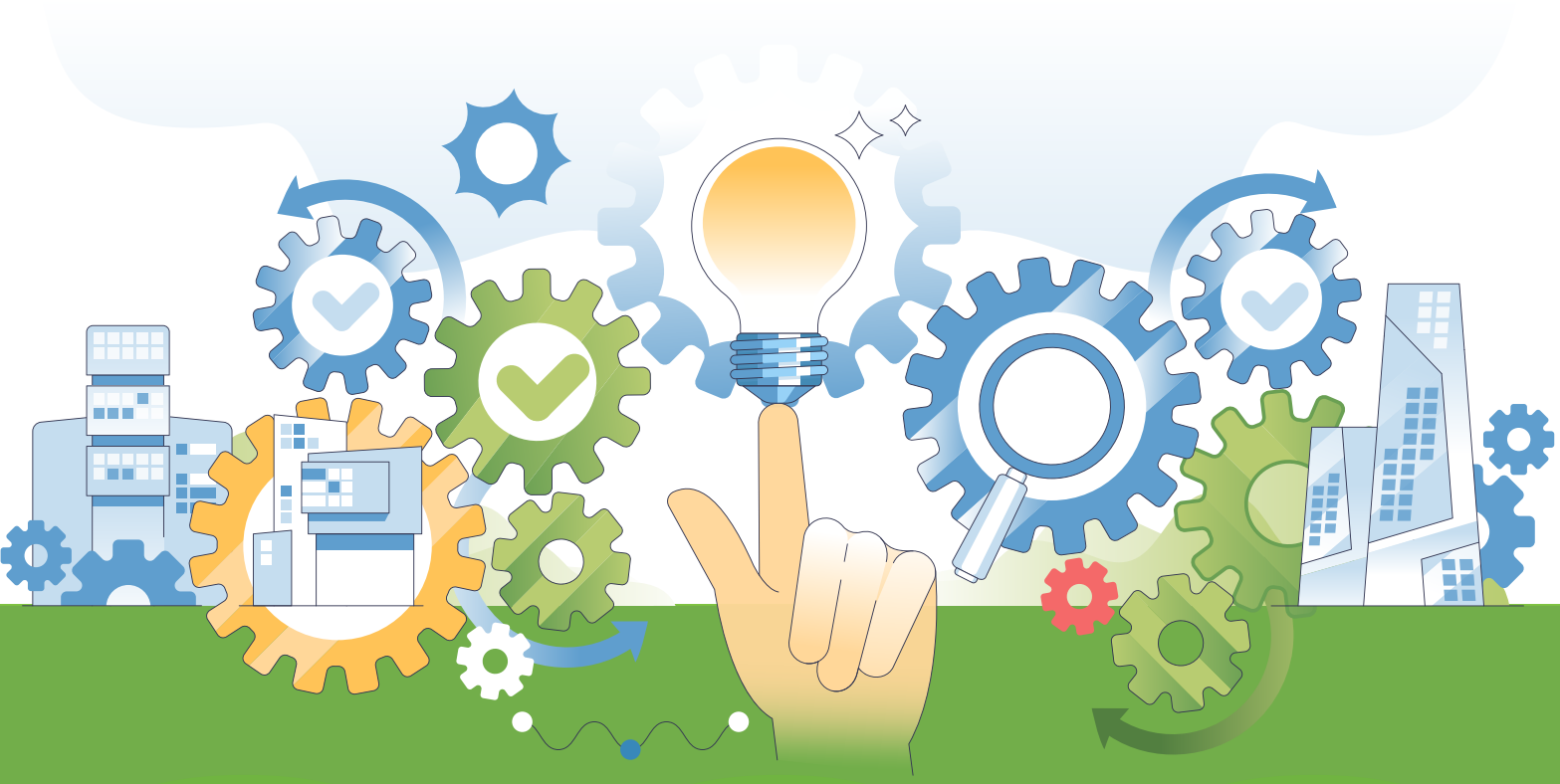
Current players/investment

Investments in the agricultural sector are increasingly centred on innovation, sustainability and scalability, attracting interest from tech-driven start-ups, established agribusinesses and multinationals committed to sustainable development. Technologies such as AI, ML and blockchain are playing a transformative role in improving agricultural production, reducing waste, minimising carbon footprints and boosting overall output.

This investment landscape features large companies in the agriculture and agro-processing sectors, cooperatives in the dairy and fertiliser sectors, and input providers in the fertiliser and biotechnology industries. In organic farming, leaders in the organic products sector are making strides, while precision farming is attracting companies focused on agricultural technology. Additionally, there are firms advancing drone technology, with IoT and AI innovations supported by agritech start-ups. As India grapples with challenges such as climate change, resource scarcity and rural poverty, targeted investments in sustainable agricultural practices are becoming increasingly vital.[168] These investments enhance agricultural productivity and resilience and contribute to broader development goals, enhancing poverty alleviation and food security.[169]

To capitalise on India's sustainable agriculture opportunities, investors should focus on projects aligned with government schemes supporting climate-resilient and sustainable practices. Exploring innovative financing models, such as blended finance combining public, private and philanthropic capital, can help de-risk investments in this space. Prioritising technology-driven solutions, including AI, IoT and blockchain, will boost farm productivity and sustainability. Additionally, supporting carbon farming initiatives offers the potential to tap into the growing carbon credit market by investing in sustainable land-use practices that sequester carbon. By embracing these strategies, investors can drive both profitability and positive environmental outcomes.

[168]https://static.pib.gov.in/WriteReadData/specificdocs/documents/2024/mar/doc202435319301.pdf
[169]World Bank. "India: Green Agriculture Project." World Bank, 2020



Conclusion

India's climate strategy embodies an ambitious vision that balances environmental stewardship with economic progress. Anchored by transformative policies and programmes, the country's roadmap for renewable energy, biofuels, decarbonisation and sustainable infrastructure reflects its determination to address climate challenges at scale.

However, this ambitious vision demands an infusion of US$1.5 trillion by 2030 across various areas. Targeted initiatives, such as the Production Linked Incentive (PLI) scheme for solar photovoltaic (PV) manufacturing and the Green Open Access initiative, democratise renewable energy access and foster growth. Programmes such as the PM Surya Ghar Muft Bijli Yojana empower millions with subsidised solar rooftop installations, ensuring equitable energy distribution. Additionally, there are opportunities for advanced energy storage systems, including Battery Energy Storage Systems (BESS) and pumped hydro.

Water security, agriculture and sustainable transport are also pivotal to India's climate resilience. Efficient irrigation, wastewater recycling and desalination projects will address key water-related challenges, including an estimated 56 percent demand-supply gap for 2030.

Sustainable agriculture practices such as precision farming, agroforestry and regenerative techniques strengthen food security while enhancing carbon sequestration and climate adaptation. India's sustainable transport agenda focuses on electrification, multi-modal transport systems and urban planning to curb rising emissions and congestion in rapidly urbanising areas. Investments in EV infrastructure, high-speed rail and public transportation networks position the country as a leader in low-carbon mobility.

Integrating digital platforms and AI-powered climate solutions streamlines operations across energy, water management, transport and agriculture, driving efficiency and sustainability.

India's climate response is not just an environmental imperative but an economic opportunity. It integrates clean energy, a circular economy, clean water, climate-resilient agriculture and sustainable transport infrastructure enabled by digital platforms and transformation.

India's strategic focus on biofuels complements renewable energy expansion. Using its abundant agricultural resources, the country achieved ethanol blending levels of over 13 percent in 2024, with plans to reach 20 percent by 2025–26. The PM JI-VAN Yojana and initiatives targeting second-generation biofuels underscore the commitment to reducing dependency on fossil fuels while ensuring food security. SAF production, projected to require investments exceeding US$75 billion by 2030, highlights a dual-purpose strategy of decarbonising aviation and uplifting agricultural communities through feedstock utilisation.

India's decarbonisation ambitions extend to hard-to-abate sectors such as steel, cement and refining, where innovations such as hydrogen-based Direct Reduced Iron (DRI) and Carbon Capture Utilisation and Storage (CCUS) are emerging as game-changing solutions. The National Green Hydrogen Mission, targeting 5 MMT of annual green hydrogen production by 2030, opens up US$100 billion in investment opportunities across production, infrastructure and end-use sectors. With its abundant renewable energy resources and policy backing, India is well-positioned to lead the global green hydrogen revolution.

Beyond energy, the country's sustainability agenda integrates infrastructure, water management and agriculture. Electrification, multi-modal transport systems and urban planning efforts address rising emissions and congestion, particularly in rapidly urbanising areas. Simultaneously, India is tackling its water challenges, including a 56 percent demand-supply gap projected by 2030, by advancing efficient irrigation, wastewater recycling and desalination projects, collectively valued at over US$75 billion.

Digital transformation plays a pivotal role in amplifying the effectiveness of these initiatives. Smart grids, AI-powered logistics and digital platforms streamline operations across energy, transport and agriculture. Programmes such as the Smart City Mission and AMRUT integrate sustainability into urban ecosystems, further reinforcing India's leadership in climate innovation.

India's multifaceted approach—encompassing renewable energy, advanced technology, sustainable practices and infrastructure—illustrates a clear, actionable strategy to combat climate change. By aligning policy ambitions with substantial investment opportunities, the country is creating a model for global climate leadership while fostering inclusive and sustainable development for its citizens.

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