India's Green Revolution 2.0

Trends Shaping India's Climate-Tech Sector

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FSG REIMAGINING SOCIAL CHANGE

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OVERVIEW

India's climate-tech sector is a vibrant ecosystem where environmental imperatives, the forces of innovation, and market dynamics coalesce. As the country grapples with the challenges associated with climate change, the sector is playing a critical role in shaping a more sustainable and resilient future for the Indian economy.

The evolution of the climate-tech sector is also significant for its potential to address social and equity issues. Initiatives in renewable energy and sustainable agriculture have the capacity to uplift rural communities, providing access to clean energy and improving livelihoods. As India strives for inclusive and sustainable development, the climate-tech sector becomes a catalyst for positive social impact, aligning economic growth with environmental and social well-being.

The growth of the sector is indicative of a transformative approach that balances economic development with environmental stewardship, setting an example for sustainable development on a global scale. Investments supporting the development and deployment of innovative climate technologies are helping India transition to cleaner energy sources, improve resource efficiency, and implement sustainable practices in various industries to meet climate commitments.

This report tracks the trajectory of investments in India's climate-tech sector in recent years, analyzing funding stock and flows across the sub-sectors in climate-tech. Exploring emerging trends and potential business models in the sector, it also offers insight into the future outlook for each sub-sector and delves into the implications for key stakeholders such as start-ups, legacy companies, government, and investors.

Investments in the climate-tech sector

Investments in India's climate-tech sector have experienced significant growth, reflecting increasing interest from both domestic and international investors. Despite a temporary setback in 2020 due to the economic disruptions induced by COVID-19, which led to a 42% reduction in funding compared to 2019, the sector has demonstrated resilience, registering an overall funding increase of 29% from 2019 to 2022 (*see Figure 1*). This growth culminated in a record total investment exceeding US$5 billion in 2022, a milestone signifying a robust vote of confidence in the sector's potential for impact.

The investment surge in the sector can be attributed to several key factors. Primarily, there has been a significant rise in awareness among citizens, businesses, and governments regarding the importance of embracing sustainable practices. Additionally, the government has steadily enhanced incentives in the sector, sparking interest among investors. These interconnected factors have collectively fueled the sector's growth.[1]

However, the investment momentum waned by the end of November 2023, with the sector attracting only 57% of the total investments garnered in 2022. This deceleration was driven by a decline in late-stage investments, attributed to valuation cuts and a discernably pronounced investor focus on profitability.[2]

Meanwhile, in a broader context, global climate-tech financing also witnessed a notable upswing, with a growth of over 108% from 2019 till the end of 2022, despite fluctuations. While investments reached a record high of US$ 73 billion in 2021, there was a significant decline in 2022 due to a hike in global interest rates and heightened caution by investors amid mounting uncertainty. The US Federal Reserve, which had maintained interest rates near zero since the onset of the COVID-19 pandemic, rolled out nine rate hikes between March 2022 and March 2023 to tackle rising inflation, diminishing the capacity and inclination of venture capital (VC) funds for investment. In particular, 2022 saw a steep reduction in funding for climate-tech solutions in mobility and transport, a segment that typically accounts for a significant portion of the global climate-tech funding.

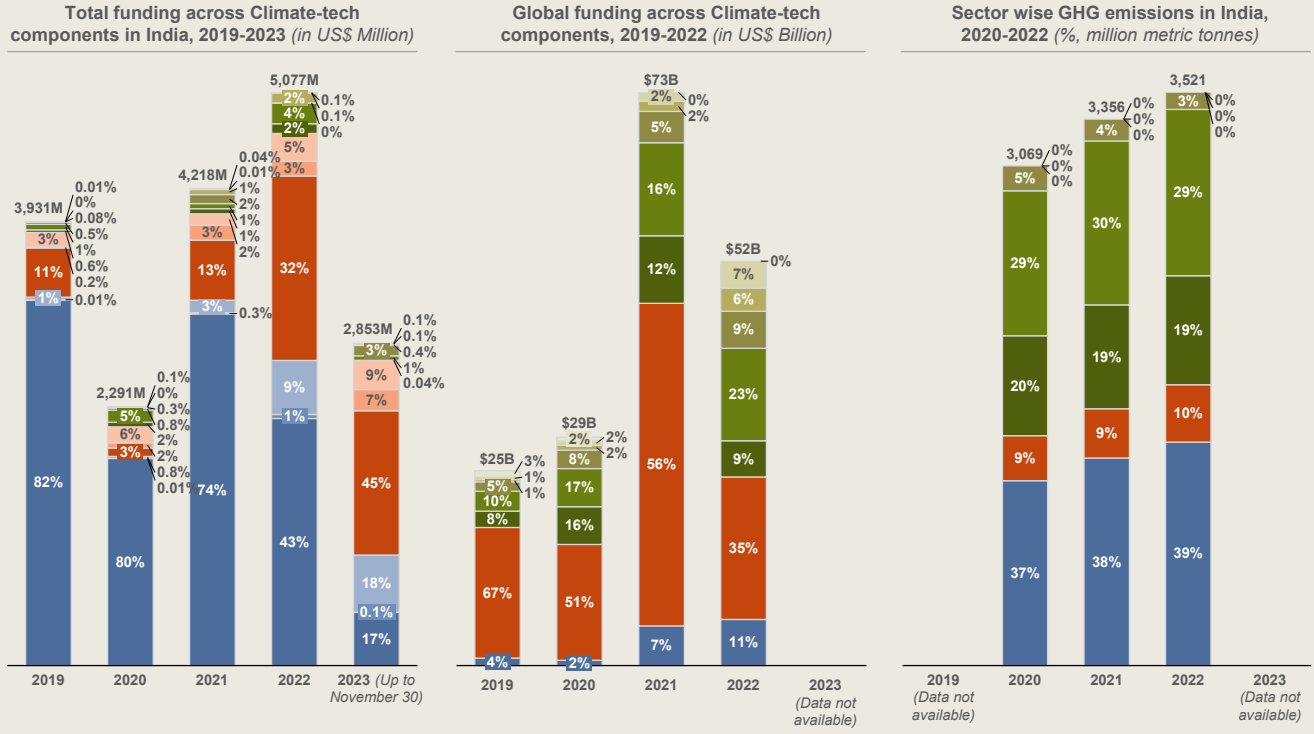
While the general trajectory of the climate-tech sector shows an upward trend, there are distinct variations within specific sub-sectors[3], which are explored in greater detail in the paper (*see Figure 1*). Notably, investment activity has been driven primarily by significant funding in the mobility and energy sub-sectors, which collectively represent over 94% of the total climate-tech investments in India from 2019 till November 2023. This dominant trend underscores the critical focus on these areas within the broader climate technology field. They are followed by the industry, manufacturing, and resource management sub-sector, garnering close to 2% of total investments over the same period, and the built environment and food, agriculture, and land use sub-sectors, each of which secured slightly over 1% of the total funding. The financial services sub-sector received less than 1% of the total climate-tech funding. Greenhouse gas (GHG) capture, removal, and storage, as well as climate change management and reporting, are nascent sub-sectors that received a negligible share of the investment pie.

Emissions realities and funding disparities

Aligning climate-tech investments with the need for emissions reduction in sectors contributing significantly to greenhouse gas emissions offers the potential for both environmental impact and economic growth. The energy sector is the largest contributor to GHG emissions in India, accounting for approximately 40% of emissions. Climate-tech companies in the energy sector have garnered the majority of the country's climate-tech funding over the years.

Following closely, the industry, manufacturing, and resource management sector contributes around 30% of GHG emissions, while food, agriculture, and land use accounts for approximately 20% of emissions. However, despite these sectors' significant contributions to GHG emissions, they have received only a small proportion of climate-tech investments, collectively representing about 4-5% of the total investments over the analysis years. This dissonance between emissions and financial support raises critical questions about the alignment of investment strategies with environmental priorities, necessitating a reevaluation of resource allocation for more impactful outcomes.

FIGURE 1: INDIAN AND GLOBAL FUNDING LANDSCAPE ACROSS CLIMATE-TECH COMPONENTS, AND SECTOR-WISE GHG EMISSIONS, FOR CALENDAR YEARS 2019-23



Components

- Energy — Generation, Storage, Management
- Mobility and Transport — Manufacturer, Supporting infra, Services
- Food, agriculture & land use
- Industry, manufacturing & resource management
- Built environment
- Financial services
- GHG capture, removal and storage
- Climate change management & reporting

Key investees

adani Renewables, ReNew Power, greenko, MYTRAH, OLA ELECTRIC, ATHER, TATA ev, UPL, Cropin, stellapps, ecoZen, String, Shriram epc Engineering the future, LOHUM, dr DETECT, recykal, abomberg, ottomate, dp drink prime, Transcon, Jai Kisan, AEREM, TURNO, VIDYUT, THREE WHEELS UNITED, URAVU, carbon clear, MAITHRI, CLIMES, Blue Sky Analytics, skymet, ambee, varaha

Note: The analysis pertains to calendar years (CYs) 2019 – 23. For CY 2023, the data analyzed was till November 30. More deals may have been recorded later that year as investors tend to publish annual reports at the end of the calendar year.
Source: FSG Analysis based on Tracxn (CY19-23), Dealroom data, CEEW, ourworldindata.org, and IEA

1 Energy

As India grapples with the challenges of meeting its growing energy demand, yet curbing emissions from its energy sector, climate-tech solutions are playing a transformative role in its approach to energy security. The growth of India's green energy sector is the lynchpin for fostering a resilient and sustainable energy ecosystem for the future.

In our analysis of investment in the sector, we have segmented the funding into three distinct sub-categories – **energy generation, energy storage,** and **energy management**. While the first encompasses energy generation companies, like Adani Green Energy and ReNew Power, the second focuses on energy storage, featuring companies like Cygni Energy and Matter Energy that specialize in non-EV related battery technologies and thermal energy solutions for grids. The third sub-category encompasses energy management, with firms like Serentica Renewables and Inox Green Energy specializing in smart grid management and sophisticated monitoring and management systems for industrial hubs.

Investments in the Energy sector

The total climate-tech funding in India's energy sector fell in 2022 and 2023 due to global economic challenges and a fall in the average deal size

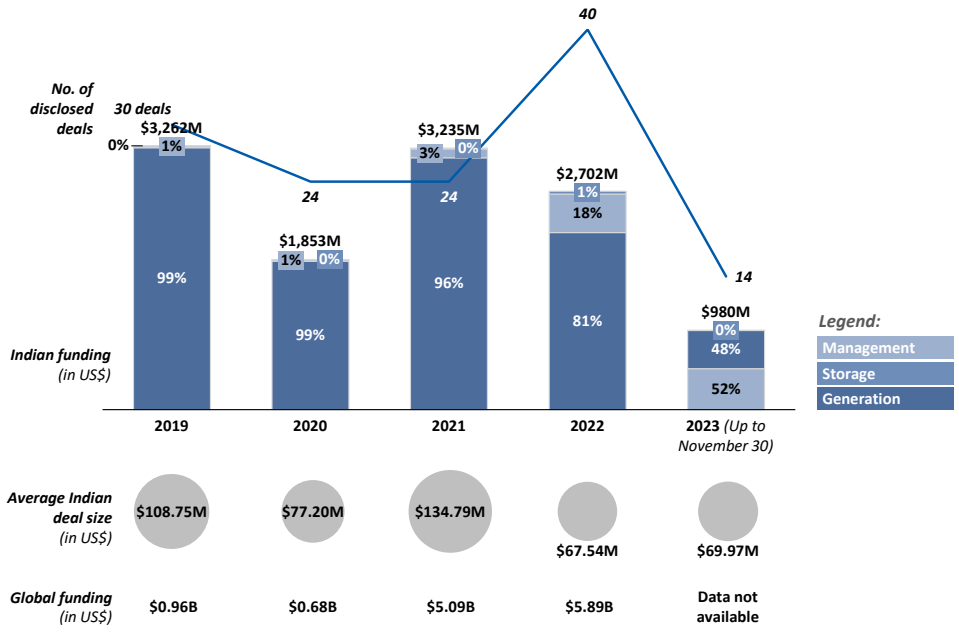
The green energy sector in India has witnessed significant investment fluctuations over the years. It attracted its highest investments totaling US$ 3,262 million in 2019, when two companies (ReNew Power and Mytrah) accounted for approximately 70% of the funding (*see Figure 2*). While the domestic green energy sector faced a 43% decrease in investments between 2019 and 2020, the global green energy sector also faced a decline of 29% in investments during the same period, primarily due to the economic impacts of the COVID-19 pandemic. This is also evident from the diminished number of deals and average deal size. The domestic sector recorded a 20% decrease in the number of deals and a reduction of 29% in the investment amount per deal compared to the figures from 2019.

However, India's green energy sector displayed remarkable resilience, rebounding with a substantial 75% surge in investments from 2020 to 2021, reaching a noteworthy US$ 3,235 million. This can be attributed to the post-IPO round raised by Adani Green in 2021, which accounted for 77% of funding in the sector that year.

The sector witnessed a decline in 2022 and 2023 as investments fell, with 2022 recording deals worth US$ 2,702 million, a 16% decrease from the previous year, and 2023 recording total deals of US$ 980 million, just about 36% of the total amount raised in 2022. This can

be attributed to the global economic challenges and the fall in average deal sizes; the total funding dropped in 2022 despite 40 deals that year compared to just 24 in 2021.

FIGURE 2: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE ENERGY SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

The energy generation segment emerged as the focal point for investments, securing approximately 94% of the total investments in the green energy sector from 2019 to 2022. This can be ascribed to India's policy initiatives aimed at enhancing renewable capacity, the remarkable cost competitiveness of solar energy—anticipated to surpass traditional coal-fired power by 2030 even when coupled with battery storage—and the escalating demand for energy. Conversely, the energy storage and energy management segments are still in the early stages of attention, encountering obstacles like substantial upfront costs, technological limitations, and regulatory complexities.[4]

The energy generation segment secured 94% of total investments in India's green energy sector from 2019 to 2022

The energy sector is the biggest contributor to India's GHG emissions, responsible for around 38% of the country's total emissions. Between 2019 and 2022, the green energy sector secured an average 74% share of climate-tech investments. While this outsized investment favors the energy sector, it leaves other emissions-intensive sectors lacking adequate funding.

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Key trends in the Energy sector

The energy sector in India is undergoing a dynamic transformation, shaped by both government initiatives and industry-driven innovations. These transformative trends not only shape the nation's energy future but also offer a highly encouraging landscape for the advancement of climate-tech in the energy sector.

The National Green Hydrogen Mission aims to achieve a green hydrogen production capacity of at least 5 MMT per year

The government is actively steering India's energy sector transition by focusing on renewables like green hydrogen, solar energy, and wind energy, digitizing energy management services, and promoting the circularity of waste-to-energy processes.

In line with its clean energy strategy, the **government is actively promoting the production and use of green hydrogen (GH2).**[5] It has introduced various policies and guidelines to achieve this aim, such as the Green Hydrogen Policy, the National Green Hydrogen Mission (NGHM), and Niti Aayog's report on Harnessing Green Hydrogen. The NGHM aims to achieve a green hydrogen production capacity of at least 5 MMT per year. The government also intends to create a framework to distribute incentives of ₹ 1,300 crore (US$ 157 million). The goal is to support 3.6 million tons of GH2 capacity over the next three years, with the incentive amount per kilogram of GH2 decreasing annually.

The government is pushing for self-sufficiency in high-efficiency solar PV module manufacturing and roof-top solarization

The **government is pushing for self-sufficiency in high-efficiency solar PV module manufacturing and roof-top solarization** to transition to renewables. Through various schemes like the Production Linked Incentive (PLI), Scheme for National Programme on High-Efficiency Solar PV Modules, Domestic Content Requirement (DCR), and customs regulations, it is promoting local manufacturing of solar photo voltaic modules.[6] The country's cumulative solar module manufacturing capacity more than doubled from 18GW to 38GW between 2022 and 2023 and is estimated to reach 100GW in the next 3-5 years.[7] To this end, the Interim Union Budget for FY25 announced plans for the roof-top solarization of 1 crore households.[8]

Complementing the thrust on solar energy, the **government is ramping up wind energy generation** for its green energy transition. Between April 2022 and January 2023, the electricity produced from wind energy projects in the country was 64.54 billion units. The government has set a target of harnessing 140 GW of installed wind energy capacity by 2030.[9]

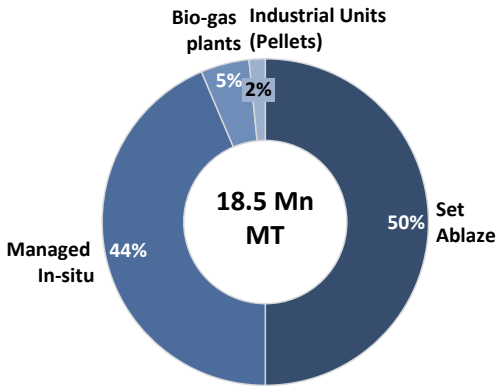
For its energy management digitization push, the government aims to install 250 million smart meters by 2025

While challenges remain, the **government's promotion of energy management digitization through smart meters**[10] is making headway, with a significant number sanctioned, ordered, and installed across the county. The government aims to install 250 million smart meters by the end of 2025. Under the National Smart Grid Mission

launched in July 2021, as many as 230 million smart meters have been sanctioned till July 2023, of which 36.5 million smart meters have been ordered. States across the country have installed 6.7 million smart meters.

Simultaneously, **government support for waste-to-energy initiatives[11] is powering a shift towards circularity in the energy sector.** At the forefront, the Ministry of New and Renewable Energy (MNRE) is implementing the Waste to Energy (WTE) Program under the umbrella of the National Bioenergy Program. The WTE program is backed by a substantial budget outlay of ₹ 600 crore (US$ 72 million) for the period FY 2021-22 to FY 2025-26, representing a significant commitment to converting waste into a renewable energy source.

FIGURE 3: PADDY STRAW CONSUMPTION DISTRIBUTION 2022



Government support for waste-to-energy initiatives is powering a shift towards circularity in the energy sector

The underutilization of agri-waste is also a growing concern. India generates 500 MT of agri-waste annually and burns 20% of it.[12] Punjab, one of the largest producers of agri-waste, generates 18.5 million tonnes of paddy straw annually (*see Figure 3*). About half of this is managed responsibly through in-situ (mixing the residue in the soil) and ex-situ (used as fuel) methods. The rest is burned, contributing to severe air pollution in North India, especially during winter, raising health concerns.

In order to address this concern, governmental authorities are actively encouraging thermal power plants to adopt agricultural waste as a sustainable fuel source. The National Green Tribunal (NGT) has specifically mandated that thermal power plants incorporate stubble pellets, constituting 5-10% of their total fuel consumption.[13]

Companies are investing in sustainability to reduce risks associated with climate change and align with the demands of conscious consumers

Amid these forward leaps, **corporate commitment to emissions reduction and de-carbonization** is gaining momentum. With growing awareness of the interconnectedness of sustainability and business success, the private sector's role in climate action is increasing. Companies are investing in sustainability to reduce the risks associated with climate change and align with the demands of a conscious

consumer base. Eight of the country's top ten companies by market capitalization have set net-zero targets that are to be achieved between 2030 and 2050.[14] Moreover, 79 companies in India have committed to reducing GHG emissions under the Science-Based Target Initiative (SBTi).[15]

The lack of reliable last-mile infrastructure for electricity transmission to rural households remains a concern

Meanwhile, however, significant challenges persist in the energy sector. A major concern is the **lack of reliable last-mile infrastructure for electricity transmission to rural households**, leading to a range of issues including low electricity voltage, restricted hours of availability, no power during late evening and night hours, and unreliable or poor connections.[16] Although the government declared that every village in the country had gained access to electricity by April 28, 2018, several villages were considered electrified even if only 10% of their households had such access.[17]

Additionally, the quality of electricity supplied to households is poor due to financial strains faced by power distribution companies.[18] The Saubhagya scheme has failed to incentivize DISCOMs to refine their electricity supply as it does not consider households' inability to pay.[19] Although initiatives like the Ujwal DISCOM Assurance Yojana (UDAY)[20] scheme aim to alleviate debts and aid failing DISCOMs, a pressing need for further action remains.

Future outlook for the Energy sector

Looking ahead, the future of climate-tech in India's energy landscape holds exciting prospects. The energy sector in the country is at a crossroads, poised to make significant strides in the pursuit of sustainable and clean energy solutions. There are several key focal points that highlight this promising future.

Potential for Green Hydrogen to revolutionize multiple sectors

Green Hydrogen has the potential to decarbonize several sectors, including transportation, shipping, and steel

India has announced a target of energy independence by 2047 and net-zero emissions by 2070. Green hydrogen is expected to play a substantial role in achieving these goals. To this end, the central government has launched the National Green Hydrogen Mission to make India *aatmanirbhar* (self-reliant) through clean energy and to serve as an inspiration for a global transition towards clean energy. It plans to achieve this by creating demand for green hydrogen, piloting green hydrogen projects and hubs, implementing strategic interventions for the energy transition, and developing infrastructure and an enabling policy framework.

The need for Green Hydrogen is rapidly increasing due to its potential to decarbonize several sectors, including transportation, shipping, and steel. Green hydrogen can replace traditional fossil fuels in transportation that contribute significantly to greenhouse gas emissions. It can also be used in industry for the production of ammonia, methanol, and steel, which

is currently heavily reliant on fossil fuels. Additionally, Green Hydrogen can be used as a backup energy source for renewable energy plants, providing a constant and reliable source of energy.[21]

Legacy companies such as Tata and Ashok Leyland have started testing hydrogen-powered heavy-duty trucks and buses. India's oil refiners, such as IOCL, HPCL, and BPCL, are already building green hydrogen production and storage facilities across the country. Private players like RIL, Adani Group, and Tata Steel are also preparing roadmaps to transition to green hydrogen in the coming years.[22]

Start-ups like NewTrace and Ohmium have started working on electrolyzers and management systems to manufacture green energy.[23] Ossus Biorenewables uses proprietary bioreactors to convert organic carbon in industrial effluents to green hydrogen and has already started partnering with industrial plants to produce 30 kgs of green hydrogen per day from each plant.[24]

Time of Day (ToD) tariff structure for electricity in India[25,26]

The ToD tariff approach involves charging varying electricity rates based on the time of day. It offers consumers the opportunity to reduce their bills by adjusting their energy usage patterns and can help power systems utilize resources more efficiently. Installation of smart meters will play a pivotal role in facilitating ToD tariff adoption.

The Government of India's amendment to the Electricity (Rights of Consumers) Rules, 2020, introducing ToD tariff, reflects a commitment to this transformative strategy. The ToD tariff structure is set to introduce dynamic pricing, with rates to be 20% lower during solar hours (duration of eight hours in a day as specified by the State Electricity Regulatory Commission) and 10-20% higher during peak hours (night hours when households use heavy electrical appliances like air conditioners).

Installation of smart meters will play a pivotal role in facilitating Time of Day tariff adoption

Legacy companies will have to adapt to the new infrastructure, including installing and integrating smart meters. This could involve significant changes to their existing systems and processes. For example, in the US, companies like Google, Ecobee, Emerson, and Honeywell are designing smart thermostats that are preprogrammed to meet individual customer preferences.[27] Companies may need to adjust their operations to align with the peak and off-peak hours defined in the ToD tariff structure.[28,29]

Scope of peer-to-peer (P2P) energy trading in India[30,31]

The peer-to-peer (P2P) energy trading model establishes an online marketplace where prosumers and consumers engage in direct electricity trading, eliminating the need for intermediaries and allowing for transactions at mutually agreed prices. This approach fosters increased deployment of renewable energy and enhances grid flexibility.

Several enabling factors have paved the way for the successful implementation of P2P energy trading in India. The presence of distributed renewable energy resources, coupled with a robust digitalization infrastructure and a conducive regulatory framework, forms the bedrock for the growth of P2P trading.

The presence of distributed renewable energy sources, robust digitalization infrastructure, and a conducive regulatory framework form the bedrock for the growth of P2P energy trading

The expansive potential for commercialization in P2P energy trading renders it an exceptionally attractive space for start-ups. For example, in Bangladesh, a company called SOLshare operates as a P2P trading platform, connecting local consumers through small-scale mini-grids. Other P2P trading platforms are gaining traction around the world, like Brooklyn Microgrid (US), Centrica plc (UK), Piclo (UK), Lumenaza (Germany), sonnenCommunity (Germany), Transactive Energy Initiative (Colombia) and Vandebron (Netherlands).

The government also acknowledges the significance of P2P energy trading. The blockchain-based P2P trading pilot initiative in Uttar Pradesh reflects this. It was launched in 2020 and spearheaded by the India Smart Grid Forum (ISGF) and Powerledger. The pilot garnered widespread interest from numerous distribution companies across India, subsequently inspiring the replication of similar initiatives in states such as Delhi and West Bengal.

Need to prioritize the development of grid-scale storage[32]

As India strives to achieve 50% of its energy requirements from renewable sources by 2030, the escalating penetration of renewable energy has heightened the strain on the already burdened transmission and distribution grid. This underscores the urgent need for solutions that enhance the flexibility of power systems, and the development of grid-scale storage emerges as a strategic imperative.

Anticipating the growing need for energy storage, the government is poised to institute comprehensive policies to bolster energy storage capacity in India. In line with this commitment, the National Electricity Plan 2023 outlines a projection for the energy storage capacity, targeting 41.65 GW from Battery Energy Storage Systems (BESS) by 2029-30. This commitment is underscored by the Union Cabinet's approval of viability gap funding (VGF) amounting to ₹ 3,760 crore (US$ 453 million), covering up to 40% of the capital cost. This financial support aims to encourage private players to actively contribute to the establishment of Battery Energy Storage Systems.

Legacy companies play a crucial role in fostering the development of grid-scale storage solutions in India, and some have already taken significant strides

Legacy companies play a crucial role in fostering the development of grid-scale storage solutions in India, and some have already taken significant strides in this direction. Notably, the Power Grid Corporation of India Limited (PGCIL) has commissioned a pioneering 1 MW/0.5 MWh pilot project in Puducherry, integrating Advanced Lead-acid and Li-ion (LFP) technologies.[33] The National Thermal Power Corporation Limited (NTPC) has released

tenders for 1,000 MWh of battery storage capacity. These endeavors by legacy companies underscore their active engagement in contributing to the advancement of grid-scale storage solutions in the Indian energy landscape.[34]

Potential of Vehicle-to-Grid storage solution[35]

The essence of a Vehicle-to-Grid (V2G) storage system lies in its ability to empower EV users to contribute to grid stability. Through this system, users can permit the grid to discharge their vehicle batteries when required, particularly during instances of a spike in local demand. In return, users typically receive compensation, either in the form of lower EV charging rates or direct payments for the electricity fed back into the grid. This symbiotic relationship between EVs and the grid not only optimizes energy usage but also fosters a collaborative approach to addressing peak demand challenges.

The Vehicle-to-Grid storage system presents an enticing opportunity for start-ups to craft innovative business models

The V2G (Vehicle-to-Grid) storage system presents an enticing opportunity for start-ups to craft innovative business models in the burgeoning energy sector. A wave of start-ups, both domestic and international, is actively developing grid-scale energy storage solutions, signaling a vibrant ecosystem poised for growth.

In the Indian context, Sheru, an energy software company, stands out with its pioneering efforts in crafting a V2G bidirectional battery-swapping system designed to balance demand dynamics effectively.[36] On the global front, a diverse array of start-ups is making significant strides in this domain. Green Energy Wallet, a US-based startup, harnesses blockchain technology to facilitate energy transactions. Similarly, V2G EVSE from the UK focuses on Bi-Directional Charging Stations. Collectively, these start-ups epitomize the innovation and potential inherent in the V2G storage system, offering a glimpse into the future of sustainable energy solutions.[37]

Rising adoption and deployment of biofuels[38]

India's rapid emergence as a prominent biofuels producer and consumer results from a combination of well-coordinated policy measures, strong political support, and abundant feedstock availability. The National Biofuels Policy of 2018 comprehensively covers various aspects of the biofuels field and sets a vision for developing the sector. Multiple initiatives like the ethanol blending program for 1G ethanol, the Pradhan Mantri Jaiv Indhan - Vatavaran Anukool fasal awasesh Nivaran Yojana (PM JI-VAN) for 2G ethanol, the biodiesel purchase policy for biodiesel, and the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme for compressed biogas (CBG) are actively promoting biofuel production and utilization in the country.

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The International Energy Agency (IEA) projects that by 2028, global biofuel demand will reach 200 billion liters. Renewable diesel and biojet fuel are expected to contribute nearly half of this growth, with the remainder coming from ethanol and biodiesel.

The launch of the Global Biofuels Alliance (GBA) on September 9, 2023, on the sidelines of the G20 summit, further underscores India's commitment to biofuels. Initiated by India, the alliance includes Singapore, Bangladesh, Italy, the US, Brazil, Argentina, Mauritius, and the UAE as founding members. As of January 2024, the GBA has expanded to include 22 member countries and 12 international organizations. The GBA's primary goal is to expedite the adoption of sustainable biofuels, aligning with international and domestic efforts to expand sustainable biofuel supplies to stay on track with a net-zero trajectory.

Opportunity to harness India's offshore wind energy potential

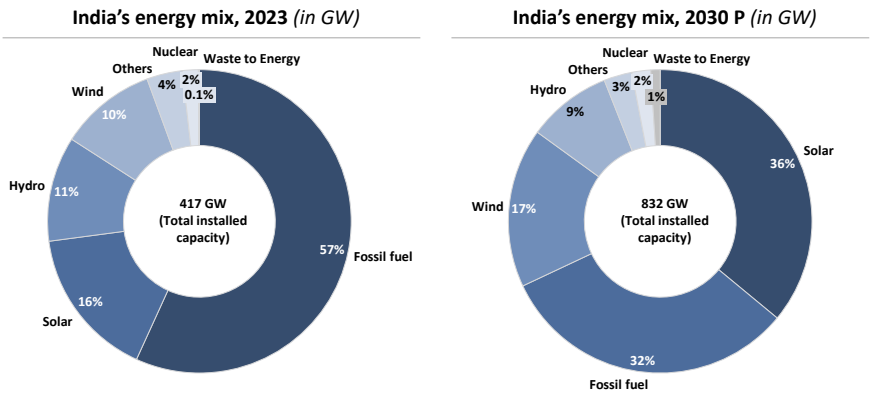
India's extensive coastline offers potential for 195 GW of offshore wind energy

India is gearing up to harness 140 GW of installed wind energy capacity by 2030, with a significant portion (30 GW) coming from offshore wind.[39] The extensive 7,600 km coastline offers potential for 195 GW of offshore wind energy, with an ability to provide utilization factors of more than 50-55%. The government's push for offshore wind energy is evident from the Ministry of New and Renewable Energy's announcement regarding the launch of a 4GW tender for offshore wind power off the coasts of Tamil Nadu and Gujarat.[40] As declared in the interim Union Budget FY25, the government aims to provide viability gap funding (VGF) for 1GW of offshore wind power.[41]

India currently relies on fossil fuels for 57% of its energy but aims to reduce this to 32% by 2030

India currently relies on fossil fuels for 57% of its energy but aims to reduce this to 32% by 2030 (*see Figure 4*). The nation has set ambitious targets, including lowering carbon intensity by 45%, achieving 50% renewable electric power by 2030, and reaching net-zero carbon emissions by 2070. The goal is to install 500 GW of renewable energy capacity by 2030.[44]

FIGURE 4: INDIA'S CURRENT[42] AND PROJECTED[43] ENERGY MIX (2023- 2030)



The government's emphasis on wind energy is catalyzing a strategic shift among legacy energy companies towards leveraging wind power. Tata Power has unveiled plans for a substantial investment of ₹ 750 billion (US$ 9 billion) in wind energy infrastructure.[45] Meanwhile, the Adani group, through its subsidiary Adani Wind Energy, stands as India's leading wind energy player, boasting a portfolio of 20 GW.[46]

Wind energy presents a compelling and lucrative market opportunity for investors, as evidenced by the burgeoning market growth and the influx of current investments. Over the next five years, the market is poised to witness the installation of 0.85 to 1.75 GW of wind power capacity.[47] The industry anticipates attracting investments ranging from ₹ 10,000-15,000 crore (US$ 1.2 – 1.8 billion) solely for enhancing equipment manufacturing capacity. This investment is projected to catalyze an additional influx of ₹ 70,000-80,000 crore (US$ 8.4 - 9.6 billion) into complementary sectors such as transmission, storage, and services.[48]

Enhancing the efficiency of waste-to-energy plants using advanced technologies like plasma gasification, hydrothermal carbonization (HTC), and refuse-derived fuel[49]

Among technologies that can increase the efficiency of waste-to-energy plants, plasma gasification stands out for its ability to handle various waste types, including hazardous waste, while significantly reducing waste volume. A plasma-gasification-based hazardous WTE plant in Pune with a capacity of 700 TPD showcases the commercial use of this technology for waste disposal.

Advanced technologies like plasma gasification, hydrothermal carbonization, and refuse-derived fuel can enhance the efficiency of waste-to-energy plants

Similarly, hydrothermal carbonization (HTC) can process diverse waste types, reduce waste volume, and generate fuel for boilers or gasifiers. However, research and development (R&D) regarding the effective implementation of HTC in India is still underway.

Refuse-derived fuel (RDF), produced by the shredding and drying of municipal solid waste (MSW), is a fuel source for industrial processes, such as cement kilns, and power plants. India boasts multiple RDF-based WTE plants, including Delhi's Timarpur-Okhla Waste Management Company Limited and Ghazipur WTE Power Plant, Hyderabad's plant set up by Greater Hyderabad Municipal Corporation (GHMC) and Ramky Enviro Engineers Limited, and Bengaluru's plant managed by BBMP.

The government has a pivotal role in advancing the efficiency of waste-to-energy (WTE) plants through comprehensive measures. Its commitment is reflected in policy formulations, exemplified by the Urban Development Policy in India, which strategically targets the creation of garbage-free cities. Providing crucial financial support, the Ministry of New and Renewable Energy extends central financial assistance to project developers and service charges to implementing/inspection agencies, fostering the successful commissioning of WTE plants.[48]

Legacy companies, start-ups, and MSMEs collectively pave the way for the adoption of advanced technologies in the realm of waste management. A notable example is Asia Bio-energy Pvt Ltd (ABIL), a Chennai-based company that pioneers the application of "biogas induced mixing arrangement (BIMA)" technology in a 5.1 MW Municipal Solid Waste (MSW)-to-energy project. In Vadodara, UPL Environmental Engineers Pvt Ltd takes the lead with their cutting-edge gasification technology, boasting an impressive destruction efficiency of 99.9% and emissions well below prescribed thresholds.[49]

Potential for HVDC transmission to play a significant role in the adoption of renewable energy[52]

On the horizon of climate-responsive technology in India's energy landscape lies a transition from High Voltage Alternating Current (HVAC) transmissions to High Voltage Direct Current (HVDC) transmission systems, at least for specific use cases. This shift is underpinned by the inherent advantages of HVDC, presenting a compelling alternative for optimizing power transmission over long distances.

Balancing the advantages of HVDC transmission with economic considerations will likely shape India's future energy transmission

HVDC excels in efficiency for long-distance bulk power transmission, with lower losses (2-3%) than HVAC (5-10%). However, the need for terminal converter stations makes HVDC more expensive. Balancing HVDC advantages with economic considerations will likely shape India's future energy transmission.

Even though the costs involved make it difficult to replace the entire HVAC transmission infrastructure with HVDC, the technology presents a unique opportunity for integrating remote renewable energy into the grid with minimal losses. HVDC can quickly compensate for fluctuations in power levels, making it the ideal technology for stabilizing irregular power flows, such as those generated by wind farms. HVDC transmission is already being used in Europe, the US, and other countries to connect offshore wind energy with the main grid.

Legacy companies like Hitachi Energy and General Electric (GE) T&D India are actively exploring opportunities in the HVDC power transmission space. By 2025, four substantial High Voltage Direct Current (HVDC) projects will be tendered: Bhadla-Fatehpuri, Leh-Ladakh, Khavda, and Barmer-Jabalpur.[53]

Summary of key trends in the Energy sector

- The government is actively promoting the production and use of green hydrogen (GH2)
- The government is pushing for self-sufficiency in high-efficiency solar PV module manufacturing and rooftop solarization to transition to renewables
- Complementing the thrust on solar energy, the government is ramping up wind energy generation for its green energy transition
- While challenges remain, the government's promotion of energy management digitization through smart meters is making headway, with a significant number sanctioned, ordered, and installed across the county
- Government support for waste-to-energy initiatives is powering a shift towards circularity in the energy sector
- Corporate commitment to emissions reduction and de-carbonization is gaining momentum
- A major concern is the lack of reliable last-mile infrastructure for electricity transmission to rural households

Summary of future outlook for the Energy sector

- Green Hydrogen has the potential to decarbonize multiple sectors, including transportation, shipping, and steel
- The ToD tariff structure is set to introduce varying electricity rates in India based on the time of day
- Several enabling factors have paved the way for the successful implementation of peer-to-peer (P2P) energy trading in India
- With renewable energy penetration growing, the development of grid-scale storage to enhance the flexibility of power systems is a strategic imperative
- The Vehicle-to-Grid (V2G) storage system presents an enticing opportunity for start-ups to craft innovative business models in the burgeoning energy sector
- The production and consumption of biofuels is expected to increase as key obstacles are addressed
- India is gearing up to harness 140 GW of installed wind energy capacity by 2030, with a significant portion (30 GW) coming from offshore wind
- Advanced technologies like plasma gasification, hydrothermal carbonization (HTC), and refuse-derived fuel can increase the efficiency of waste-to-energy plants
- A transition from High Voltage Alternating Current (HVAC) transmissions to High Voltage Direct Current (HVDC) transmission systems presents a unique opportunity for integrating remote renewable energy into the grid with minimal losses

2 Mobility and Transport

The mobility and transport sector in India has become a focal point of climate-tech innovation and investment. With a burgeoning population and rapid urbanization, the demand for efficient, sustainable transportation solutions has grown rapidly in the country. This is reflected in investor affinity for green solutions in mobility and transport.

EV manufacturing has consistently attracted substantial investments, typically accounting for around 70-80% of climate-tech funding for mobility and transport solutions

In our analysis of funding within the sector, we have segmented the funding into three sub-categories – **Electric Vehicle (EV) manufacturers** like Ola Electric and Mahindra Electric Automobile Ltd, **supporting infrastructure** developers such as Battery Smart and SUN Mobility for EV charging, and **service providers** including start-ups like FleetX for EV fleet management. EV manufacturing has consistently attracted substantial investments, typically accounting for around 70-80% of climate-tech funding for mobility and transport solutions. The only exception was in 2020, wherein companies offering services for EVs received a majority (~54%) of the climate-tech funding in mobility and transport, and EV manufacturers received relatively lower funding, potentially on account of the COVID-19 pandemic.

Investments in the Mobility and Transport sector

While growth in the mobility and transport space in India's climate-tech sector has been robust, it faced a setback when investments fell by 54% between 2019 and 2020 (*see Figure 5*). A broader reduction in global funding on account of the COVID-19 pandemic was one of the key drivers, which led to smaller investments and fewer mega deals.

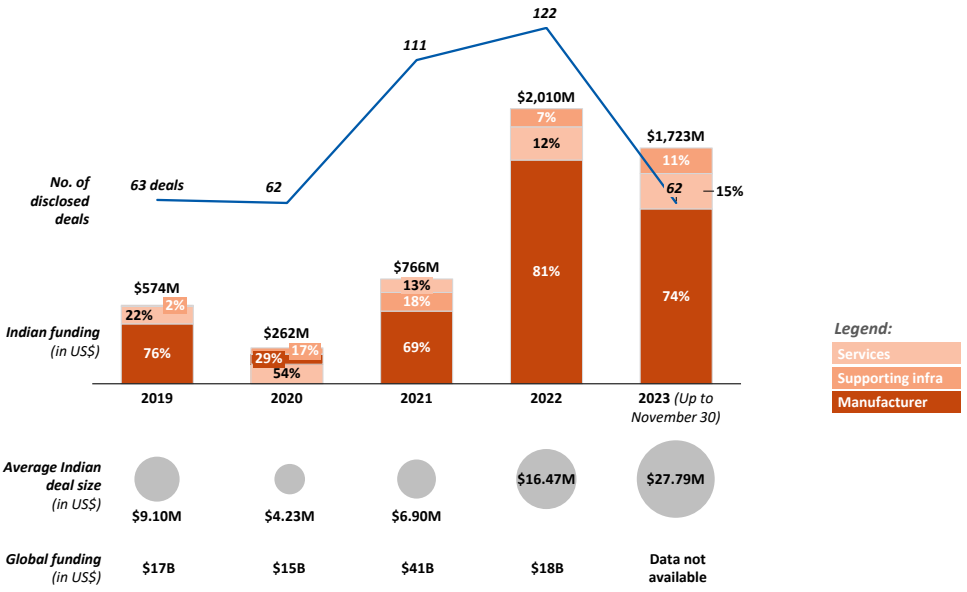
Apart from the pandemic-induced slump in 2020, climate-tech funding in India's mobility and transport sector has largely witnessed steady growth year-over-year, with a peak in 2022

There was a resurgence in 2021 on the back of a few major deals – Ola Electric raised over US$ 300 million, and GMW and Sun Mobility raised US$ 50 million each. These deals accounted for over half of the domestic funding in 2021, leading to a 192% increase over the preceding slump year.

The trend continued in 2022 as funding surged to new heights of US$ 2,010 million on the back of multiple high-value deals, led by Tata Passenger Electric Mobility securing US$ 500 million. Similarly, by the end of November 2023, India's mobility and transport sector had already secured 86% of the record funding it had raised the previous year with Ola Electric raising 40% of the funding, signaling a trend similar to the previous year despite the headwinds in the funding space.

Climate-tech funding in India's mobility and transport sector has largely witnessed steady growth year-over-year, aside from the pandemic-induced slump in 2020, culminating in a peak in 2022. In contrast, globally, funding in this segment has experienced notable volatility, with downturns in both 2020 and 2022 punctuated by a record investment of US$ 41 billion in 2021. The significant decline in 2022 was a consequence of the global economic challenges, including inflation, declining valuations, and rising interest rates, along with geopolitical conflicts, all of which had a considerable impact on private markets.

FIGURE 5: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE MOBILITY AND TRANSPORT SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

Amid this global economic uncertainty, India demonstrated remarkable economic resilience, successfully sustaining its growth trajectory despite global headwinds. This indicates a resilient expansion in this segment of India's climate-tech sector outside of pandemic influences, while the global trend shows greater susceptibility to fluctuations.

While the mobility and transport sector in India's climate-tech landscape has attracted significant investments, accounting for about 29% of the total climate-tech funding in the country, its contribution to GHG emissions is relatively lower, at 9-10% of India's total emissions. This disparity suggests a potential misalignment between the substantial funding this sector receives and the pressing need for emissions reduction in sectors with higher emissions.

While the mobility and transport sector garners about 29% of the total climate-tech funding in India, its contribution to GHG emissions is relatively lower, at 9-10% of India's total emissions

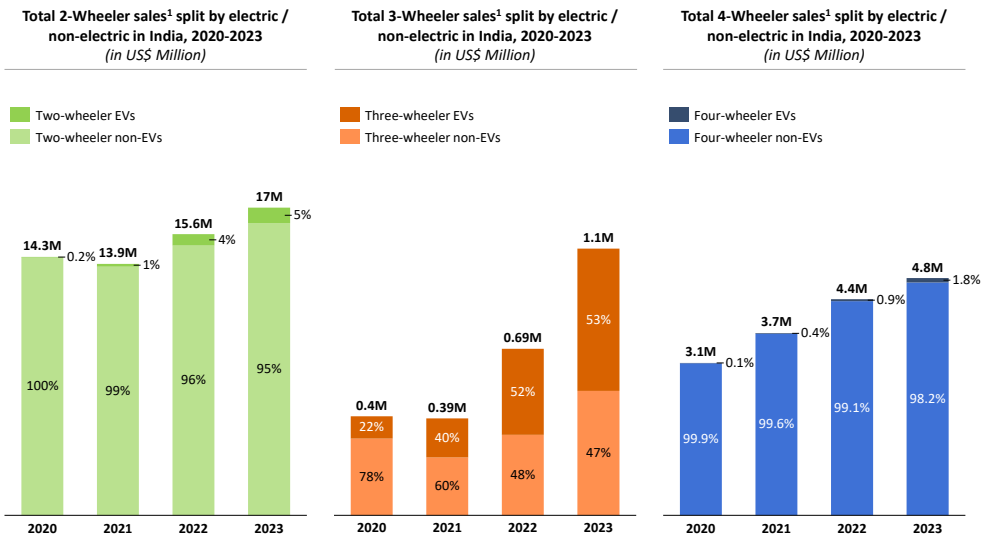
Key trends in the Mobility and Transport sector

From the surge in electric vehicle adoption to government initiatives promoting electrification, the rise of shared mobility, and the transition towards electric last-mile delivery, several key trends are redefining the future of mobility and transport in India and propelling the growth of climate-tech.

With a projected 49% CAGR between 2022 and 2030, the domestic EV market is targeting 10 million annual EV sales by the decade's end, the majority of which will be two-wheeler and three-wheeler vehicles

The **increasing adoption of EVs, led by two-wheeler (2W) and three-wheeler (3W) vehicles**, is at the forefront of the mobility and transport sector's sustainability transition in India. With a projected 49% compound annual growth rate (CAGR) between 2022 and 2030, the domestic EV market is targeting 10 million annual EV sales by the decade's end,[54] the majority of which will be 2W and 3W vehicles. For the calendar year 2023, 5% of the total 2W vehicles sold and 53% of the total 3W vehicles sold were electric, as opposed to ~1.8% in the 4W segment[55] (*see Figure 6*). This increase in the adoption of 2W and 3W electric vehicles is driven by factors such as highly competitive total costs of ownership (TCOs) and the minimal requirement for public charging infrastructure, as home charging is sufficient for everyday use. Creative and compelling EV options that match the performance of internal combustion engine vehicles (e.g., horsepower, acceleration), and early logistics and delivery fleet adoption due to Government of India incentives are also key drivers of adoption.[56]

FIGURE 6: PENETRATION OF 2W AND 4W EVS IN THE INDIAN MARKET[52]



Note: 1. Each registration in the Vahan Sewa database has been considered as a sale; 2. Each category includes vehicles used for public, personal, and commercial usage
Source: FSG Analysis based on Vahan Sewa Dashboard, Ministry of Road Transport and Highways, Government of India

Beyond their use in passenger mobility, adoption of EVs in last-mile delivery, especially two-wheelers, has been increasing in India

Beyond their use in passenger mobility, **adoption of EVs in last-mile delivery**[57] - especially two-wheelers - has also been increasing. India aims to achieve a 30%

adoption rate of EVs among private cars, 70% among commercial vehicles, and 80% among two- or three-wheelers by 2030[58] . By 2025, EVs could constitute approximately 25-30% of all last-mile delivery fleets in India. The private sector will have a crucial role in this transition, and several major companies are actively electrifying their fleets. Amazon India plans to have 100,000 EVs in its delivery fleet by 2030, Zomato has announced 100% fleet electrification by 2030, and Big Basket aims for 70% electrification by 2024. This presents a significant market opportunity for the EV ecosystem.

The rise of shared mobility has also emerged as a key driving factor for sustainability in the sector. With increasing adoption among consumers, the shared mobility market is expected to reach US$ 42.85 billion by 2027 from US$ 11.05 billion in 2021, expanding at a CAGR of 25.3%.[59] Driven by factors like growing disposable income, inadequate public transport infrastructure, and the demand-supply gap, India's shared mobility sector is expected to reach nearly 15 crore users by 2025.[60]

The rise of shared mobility has emerged as a key driving factor for sustainability in the mobility and transport sector

Complementing this market-driven momentum, **government-led electrification of mobility** is also fostering an environment for widespread adoption of EVs. The Government of India aims to electrify 30% of the country's vehicle fleet by 2030, with significant budget allocation towards promoting clean energy vehicles. The FY24 Union Budget has allocated ₹ 51.72 billion (approximately US$ 631 million) towards its FAME-II scheme to subsidize and promote the adoption of clean energy vehicles, representing an 80% increase in budget allocation from previous years.[61]

Zooming out to the bigger picture, the **government's push on smart cities with smart mobility** is making headway. Aiming to develop 109 cities as smart cities, the Government of India launched the Smart City Mission (SCM) in June 2015.[62] The defining feature of a smart city is smart mobility – an approach marked by high flexibility, convenience, and clean and green technologies, promising citizens affordable, multiple modes of transportation, including rapid mass transit systems, on-demand mobility solutions, ride-sharing, vehicle-sharing, electric vehicles, biking, walking, and more. The government is promoting smart mobility through key initiatives like rail-based mass rapid transport systems (MRTS), light rail urban transit systems or Metrolite, bus rapid transport systems (BRTS), electric vehicle adoption, a national common mobility card (NCMC), and on-demand personalized rapid transport (PRT).[63]

The government is pushing for smart cities with smart mobility, an approach marked by high flexibility, convenience, and clean and green technologies

Future outlook for the Mobility and Transport sector

As India forges ahead in its commitment to sustainable development, the future outlook for climate-tech in the realm of mobility and transport appears promising, with a series of transformative trends poised to redefine the space.

These advancements will likely have varied impacts across different stakeholders, benefiting some while presenting challenges for others— while manufacturers may see new opportunities for innovation, and consumers could enjoy more choices and efficiency, traditional industries may need to adapt to the shifting landscape to stay relevant.

Middle-mile and long-haul electrification to lower the logistics industry's carbon footprint

An intriguing shift on the horizon is the focus on middle-mile electrification. While many companies have set targets to employ net-zero fleets by 2030, middle-mile logistics, often overlooked due to current EV constraints, is expected to gain significant attention. Notably, Heavy Goods Vehicles (HGVs), accounting for 2% of the total vehicles, are responsible for 43% of GHG emissions in the transportation sector.[64]

India's shift to freight electrification, with a focus on electric vehicles for logistics, has wider implications –the government is likely to develop policies that adapt to and support this green transition. NITI Aayog has already set up e-FAST, a platform designed to promote collaboration among government entities and private sector partners to develop strategies and actions for large-scale freight electrification. Meanwhile, the Ministry of Road Transport and Highways (MoRTH) plans to develop EV-friendly highways with extensive charging infrastructure across the country.

Companies that are poised to be early adopters of middle-mile electrification can leverage the market sentiment towards electrification and set themselves up in pole position in the market

Companies that are poised to be early adopters have a significant opportunity to leverage the market sentiment towards electrification and set themselves up in a pole position in the market. While some companies like Tata, Ashok Leyland, Infraprime, etc., have already launched electric freight trucks[65], other players, ranging from legacy companies like Mahindra to newer entrants such as Triton, are gearing up to introduce their own models.[66] Although widespread retail availability and significant commercial transactions are anticipated within the next couple of years, Eicher has already secured a notable agreement with Amazon to supply up to 1,000 trucks over the next five years.[67]

However, adoption is hindered by inadequate charging infrastructure – India significantly lags other geographies on charging infrastructure, with roughly 200+ EVs per commercial charging point, as compared to ~20 in the US and less than 10 in China.[68] The ecosystem suffers from a variety of issues, ranging from a lack of standardized charging protocols, leading to incompatibility between EVs and charging stations, to security and maintenance challenges at public chargers. Widespread use of the Bharat DC-001 standard, incompatible with current EV models, is resulting in underutilized charging facilities.[69] Companies like ElectricPe, developing EV charging platforms, will have to build scaled partnerships with key stakeholders, and greater capital and financing will have to be directed towards the same.

Potential of new business models like Mobility as a Service

One of the most promising prospects for the future of mobility in India is the adoption of Mobility as a Service (MaaS), which integrates various forms of mobility services into a single, user-friendly platform.[70] It can not only curb emissions but also alleviate other negative externalities, such as congestion, air pollution, social exclusion, and excess consumption of space.[71]

The key driver behind MaaS's readiness in India is the widespread growth of smartphone adoption and mobile internet usage. With an estimated 1,341 million smartphone users by 2030, India presents a large potential market for MaaS.

The start-up ecosystem is poised for a boom in innovation, with MaaS offering fertile ground for developing new technologies and services. India already has a significant number of start-ups in the landscape, ranging from ride-hailing apps like Ola, Rapido and Blusmart, to other novel applications such as Bounce, a dockless bike rental start-up, and carpooling services like Quickride. Start-ups are expected to develop new business models and applications and lead the way in app development, data analytics, and user interface design, which are vital components of a successful MaaS platform.

The start-up ecosystem is poised for a boom in innovation, with Mobility as a Service (MaaS) offering fertile ground for developing new technologies and services

The Government of India is actively supporting MaaS development. It is not only providing financial incentives for deploying electric and hybrid vehicles, and investing in developing smart city infrastructure[68], but also aims to directly integrate MaaS into existing transport networks, ensuring it complements public transportation systems. Towards this end, the Ministry of Housing and Urban affairs has collaborated with the government of Germany and set up a framework for implementing MaaS in Indian cities.[72]

Multiple cities and municipal transport operators have incorporated elements from MaaS ecosystems into their mobility networks. For example, Surat has launched an "Intelligent Transit Management System" (ITMS) to efficiently manage its transportation network. ITMS combines the Bus Rapid Transit System (BRTS), city bus services, a Vehicle Location System (VLS), and a Passenger Information System (PIS).[67]

Sustainable fuel alternatives to replace conventional fossil fuels[73]

The Indian government is taking several proactive steps to reduce emissions from fossil fuels. This includes targets for blending 20% ethanol in gasoline and 5% biodiesel in diesel. Such initiatives aim to reduce the carbon intensity of traditional fuels, promoting more sustainable alternatives.

The government has rolled out several initiatives aimed at reducing the carbon intensity of traditional fuels, promoting more sustainable alternatives

Moreover, India's green hydrogen and ammonia policy aims to scale up green hydrogen production to 5 million metric tons (MMT) by 2030, offering the potential for a cleaner

energy source and reduced carbon emissions. The government has also introduced a biofuel policy which aims to enhance biofuel availability, boost domestic production, establish 2G bio refineries, develop new biofuel feed stocks and technologies, and integrate biofuels with mainstream fuels.[74]

This transition must be supported by industry, with companies manufacturing and deploying vehicles that can run on alternative fuels, complemented by companies that process and manufacture the said fuel. We are already witnessing the first foray – vehicle manufacturers, like Maruti Suzuki and Ashok Leyland in collaboration with IIT Delhi and IOC, are focusing on flex-fuel vehicles that can run on various blends of gasoline and ethanol.[75] Similarly, legacy energy firms like Indian Oil are pivoting towards an increased focus on established alternative fuels like CNG[76], while a range of start-ups like Jap Innogy and Aganvay Technologies are exploring novel composition and production processes.[77]

Greater adoption of four-wheeler (4W) EVs

Falling production costs due to a maturing manufacturing ecosystem, technological progress, and rising income levels will contribute to increased adoption of four-wheeler EVs

While four-wheelers are significantly behind two-wheelers in the EV adoption curve, they are expected to experience accelerated adoption, increasing penetration ten-fold in the next seven years.[52]

The factors contributing to this increased adoption of 4W EVs will be falling production costs due to a maturing manufacturing ecosystem, technological progress, and rising income levels. This trend will likely be particularly pronounced in premium segments such as compact SUVs, which are gaining popularity over other segments due to their superior drivability on varied road conditions, enhanced comfort, and advanced digital connectivity. While entry-level hatchbacks are likely to lose some market share to these more premium models, the overall demand for hatchbacks is expected to remain robust, buoyed by affordability. Other key factors, including reliance on localized automotive components, advancements in road infrastructure, and increased penetration of credit facilities, will support the expected growth in the 4W segment.[78]

Reduction in emissions through smart vehicles and autonomous vehicles[79]

Enhanced efficiency of autonomous and connected vehicles directly translates to lower emissions

Smart vehicles comprise connected vehicles enhanced with Internet of Things (IoT) features enabling real-time data exchange with other vehicles, infrastructure, and systems, and autonomous or self-driving vehicles. These solutions offer a promising means to reduce emissions and foster sustainable transportation practices. In India, the connected car market is expected to reach US$ 32.5 billion by 2030, with an estimated CAGR of 22.2%.[80] Meanwhile, the autonomous vehicle market is expected to grow at a robust CAGR of 21.5% between 2023 and 2028.[81]

By harnessing smart mobility solutions such as GPS, traffic data, and vehicle-to-vehicle (V2V) communication, autonomous and connected vehicles enhance safety and streamline daily commutes by optimizing routes, significantly reducing travel time and congestion. This enhanced efficiency directly translates to lower emissions - connected vehicles constituting 20% of the vehicles on city roads can reduce greenhouse gas emissions by up to 18%.[82]

Connected vehicles constituting 20% of the vehicles on city roads can reduce greenhouse gas emissions by up to 18%

Indian firms are making significant forays in the connected vehicles space. The start-up FleetX provides fleet management systems that integrate functionalities like vehicle tracking, routing, reporting and alerts, maintenance, driver behavior analytics, and so on, towards optimizing fleet efficiency.[83] Similarly, other start-ups like CarIQ, Trak N Tell, and Flux Auto, among others, are developing novel applications in vehicle connectivity and telematics.

Legacy companies in India set the trajectory for progress in the autonomous vehicles space.[84] Mercedes-Benz Research and Development India (MBRDI) is engaged in cutting-edge work in areas related to autonomous driving. Additionally, Tata Motors' introduction of India's first Advanced Driver Assistance System (ADAS) signals a significant leap forward.

Summary of key trends in the Mobility and Transport sector

- The increasing adoption of EVs, led by two-wheeler (2W) and three-wheeler (3W) vehicles, is at the forefront of the mobility and transport sector's sustainability transition in India
- Adoption of EVs in last-mile delivery - especially two-wheelers - has been increasing
- Government-led electrification of mobility is fostering an environment for widespread adoption of EVs
- Adoption of shared mobility solutions has seen a spike, and India's shared mobility sector is expected to reach nearly 15 crore users by 2025
- The government's push on smart cities with smart mobility is making headway

Summary of future outlook for the Mobility and Transport sector

- Middle-mile and long-haul electrification can lower the logistics industry's carbon footprint
- Adoption of Mobility as a Service (MaaS) can not only curb emissions but also alleviate congestion, air pollution, social exclusion, and excess consumption of space
- Sustainable fuel alternatives are expected to replace conventional fossil fuels
- While four-wheelers are significantly behind two-wheelers in the EV adoption curve, they are expected to experience accelerated adoption, increasing penetration ten-fold in the next seven years
- Smart vehicles and autonomous vehicles offer a promising means to reduce emissions and foster sustainable transportation practices

3 Food, Agriculture, and Land Use

Climate-tech in the Indian food, agriculture, and land use sector is gaining prominence, fueled by increased government initiatives, investor confidence, technological interventions, product and business model innovation, and a heightened focus on agri-carbon practices. The sector's response to consumer awareness and its commitment to environmental sustainability contribute to its emergence as a key player in the global agricultural landscape. These multifaceted developments position the sector for continued growth, adaptation to market dynamics, and resilience in the face of evolving challenges.

Investments in the Food, Agriculture, and Land Use sector

Climate-tech investments in India's food, agriculture, and land use sector experienced consistent growth from 2019 to 2022, driven by government initiatives, infrastructural development, and a global shift towards sustainable food systems.

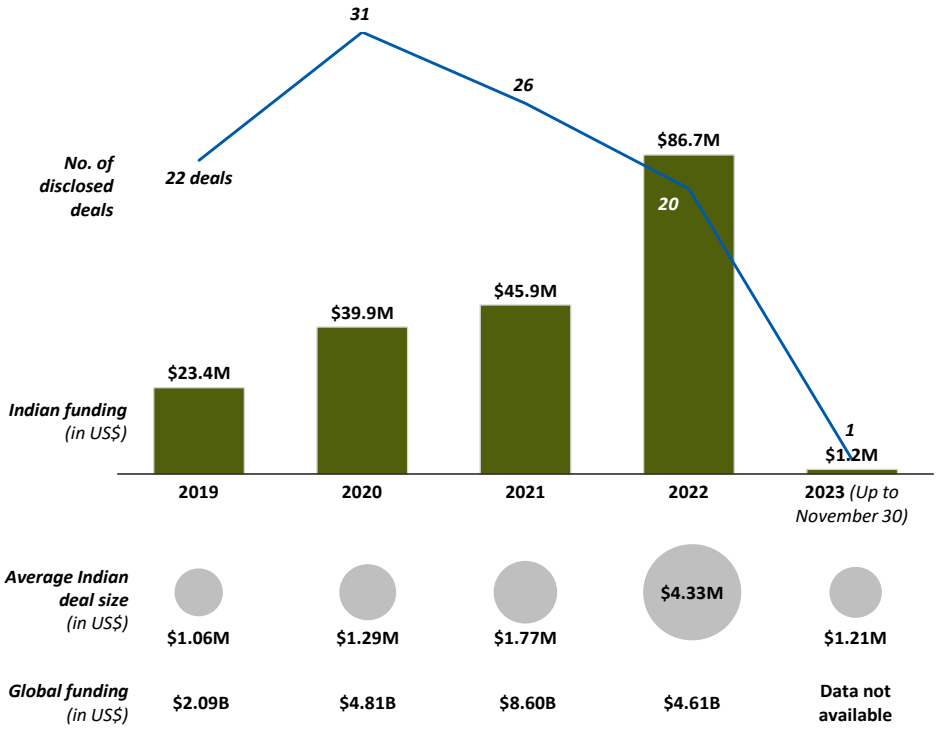
Despite a global 46% decline in climate-tech investments in the sector from 2021 to 2022, India showcased remarkable growth of 89%, marking 2022 as a record year with US$ 87 million in funding (*see Figure 7*). Noteworthy factors for the global slump included a rise in global interest rates and heightened investor caution amid prevailing uncertainty. Meanwhile, the investment surge in India was propelled by significant funding rounds for CropIn, Ecozen Solutions, and String Bio, which garnered 83% of the domestic sector's funding that year. Despite a decrease in the number of deals in the sector between 2021-22, the average deal size in 2022 surpassed those of previous years, making it a record-breaking year in terms of total investments for the sector.

However, 2023 has been a tough year for the sector, with only one disclosed deal worth US$ 1 million, raised by Satyukt, till the end of November.

Food, agriculture, and land use contribute a substantial 19% to the total GHG emissions in India. However, this sector receives a disproportionately low share of climate-tech funding, garnering a meager 1% of investments in the country's broader climate-tech sector. As India navigates the intersection of emissions reduction and climate-tech funding in the food, agriculture, and land use segment, the need for recalibrating investment strategies is apparent.

Food, agriculture, and land use contribute 19% to the total GHG emissions in India, but the sector receives a meager 1% of climate-tech investments in the country

FIGURE 7: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE FOOD, AGRICULTURE, AND LAND USE SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

Key trends in the Food, Agriculture, and Land Use sector

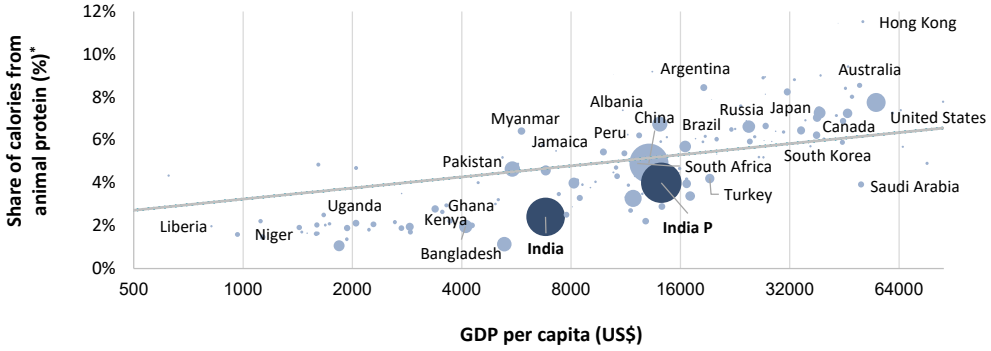
The food, agriculture, and land use sector is undergoing dynamic transformations influenced by pivotal trends stemming from farmers, consumers, and government initiatives. Trends such as the growing demand for animal protein and heightened awareness of the benefits of organic food shape the sector's landscape. Crucially, government efforts in promoting sustainable and good agricultural practices and mechanizing and digitizing farms are steering the sector towards environmental consciousness in tune with evolving consumer preferences.

The methane emissions associated with the rising demand for and consumption of animal protein is a concern

Rising demand and consumption of animal protein along with growing GDP (*see Figure 8*) poses its own set of challenges, particularly concerning the **associated methane emissions**.[85] In 2018-19, the country's milk production reached 187.7 million tonnes, showing a growth of 6.5% from the previous year. The per capita availability of milk also increased to 394 g/ day during the same period. The dairy industry is currently grappling with the dual challenges of rising demand for animal protein and declining dairy productivity, which create a significant strain on the sector.

Notably, the digestive processes of cattle account for a significant 7.85% of total GHG emissions – contributing 223 million metric tons of carbon dioxide equivalent (CO2e) of the overall emissions tally of 2.8 billion metric tons of CO2e. This highlights the environmental impact of heightened animal protein consumption and emphasizes the need for sustainable practices in the livestock sector.

FIGURE 8: SHARE OF CALORIES FROM ANIMAL PROTEIN V/S GDP PER CAPITA



Note: The data presented is as of 2018. 'India P' is the projected situation of India in 2030, calculated by taking CAGR from 2013 and 2018 data, annual GDP growth rate of 6.3% as per IMF data, and annual population growth rate of 0.8% as per World Bank data.

Source: FSG Analysis based on World Bank – WDI; UN FAO; Maddison Project Database 2020 (Bolt and van Zanden (2020); compiled by OurWorldInData.org

On a positive note, an **increasing awareness of the benefits of organic food** is driving a significant shift in consumer preferences.[86] Projections for the organic food market indicate an expected growth from US$ 1.6 billion in 2023 to US$ 9 billion by 2032, with an impressive CAGR of 21%. This robust expansion underscores consumers' changing mindset towards prioritizing healthier and environmentally conscious dietary choices. The organic food market is poised to play a pivotal role in shaping the evolving dietary landscape.

The **government is mechanizing farms to reduce agricultural emissions**. The need for increased mechanization stems from a decrease in the working-age population engaged in agriculture. The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), launched on July 1, 2015, covers the subsidy for micro-irrigation.[87] When compared to other irrigation practices, micro-irrigation in specific crops has the potential to reduce per-yield soil carbon dioxide emissions by 59%, nitrous oxide by 38%, and nitric oxide by 20%.[88]

Meanwhile, the Agriculture Ministry is offering grants up to ₹ 10 lakh (US$ 12,050) to agricultural institutes for the purchase of drones.[89] Drones play a crucial role in minimizing the overall carbon footprint of farming by optimizing input applications. They can precisely target areas that require treatment, thus minimizing excess use

The government is laying emphasis on mechanizing farms, owing to the shortage of agricultural labour and decrease in the working-age population engaged in agriculture

of fertilizers and chemicals. In plant protection operations, substituting traditional machines with drones can result in a reduction of carbon emissions by 51.45 kg CO2e (carbon dioxide equivalent) per hectare.[90]

Responding to these challenges and opportunities, the **government is facilitating digitization in agriculture** by developing Digital Public Infrastructure (DPI).[91] Key government-led initiatives are steering the country towards a digital future in agriculture marked by transparency and greater resource-efficiency – thereby contributing to emissions reduction. These include Agristack, a unified database linking farmers to their land holdings, and Geographic Information System (GIS) signature captures to demarcate farm boundaries and establish a link between land records and subsequent farm-related data. GIS plays a crucial role in precision agriculture by actively collecting and interpreting extensive field data for informed decision-making.[92] The utilization of high-tech equipment in precision agriculture practices reduces agricultural inputs through site-specific applications. This technology enables a more accurate targeting of inputs to meet the spatial and temporal needs of the fields, ultimately leading to lower greenhouse gas emissions.[93]

The government is facilitating digitization in agriculture to reduce emissions through greater resource-efficiency and transparency

Future outlook for the Food, Agriculture, and Land Use sector

As we gaze into the future, a wave of climate-conscious trends is set to transform the landscape of the food, agriculture, and land use sector in India, with implications for legacy companies, start-ups, and the government. Progressive agricultural advancements such as sustainable inputs, novel in-farm farming technologies, traceability, and agri-carbon will be instrumental in shaping the sector's trajectory. Evolving food preferences will further expand opportunities for innovation in the industry.

Decarbonization of fertilizer supply chain through innovation in sustainable inputs

Nitrogen fertilizers contribute to greenhouse gas (GHG) emissions in two ways. Firstly, during the production of fertilizers, chemical reactions and fossil fuel usage lead to the production of carbon dioxide (CO_2) and nitrous oxide (N_2O). Secondly, after the fertilizer is applied on the farm, microbiological processes convert it into N2O. In 2020-21, India produced 15.3 million MT of ammonia, primarily used in urea production, and imported an additional 2.6 million MT of ammonia to produce various grades of other fertilizers. Currently, most of this production relies on fossil fuel usage to produce hydrogen, an essential raw material, which results in increased emissions from the process.[94]

The Government of India's Green Hydrogen Mission is expected to address this by supplying the raw material for green ammonia production, reducing the environmental impact of production and the dependency on fossil fuel imports.

In the field of sustainable inputs, global investments are driving innovation in genomics, gene editing, and precision breeding for enhanced seed traits. The sphere of innovation extends to biological seed treatments, including herbal or organic growth promoters, herbicides, and fungicides. This surge in research and development signifies a promising frontier for environmentally conscious solutions in agriculture.

Legacy companies can enhance their capabilities in biological treatments through corporate venturing. Multinational agrochemical firms with significant R&D budgets lead in chemical solutions and RNA-based seed modifications. For instance, in 2020, Bayer, Syngenta, Corteva, and BASF collectively invested over US$ 5 billion in new product development, overshadowing the US$ 1.6 billion raised by biotechnology start-ups.[88]

The government is actively fostering sustainable agriculture through a range of initiatives. It is promoting natural farming, utilizing local bio-inputs, with a dedicated budget allocation of US$ 55.4 million. The Prime Minister-Programme for Restoration, Awareness Generation, Nourishment and Amelioration of Mother Earth (PM-PRANAM) Yojana incentivizes states to use alternative fertilizers, aiming to reduce reliance on chemical fertilizers. Additionally, the Green Credit Program awards tradable green credits for eco-friendly actions.

In the pursuit of fertilizer self-sufficiency, the government is investing significantly in the production of nano-urea and nano-DAP

However, the focus of the government is on self-sufficiency in fertilizers, shown by its significant investments in the production of nano-urea and nano-DAP (Di-Ammonium Phosphate), developed by the Indian Farmers and Fertilizer Cooperative (IFFCO). The goal is to gradually reduce dependence on imported urea, replacing it with domestically produced nano-urea fertilizers by 2025. This involves a major transition from 8.5 million tonnes of conventional urea to 170 million bottles of nano urea. This strategic pivot can help boost domestic production and potentially reduce the subsidy bill of nearly ₹ 2.25 lakh crore (US$ 27 Bn) for conventional fertilizers in 2022-23.

Innovations and inclination towards in-farm and novel farming solutions (including precision agriculture solutions)

The agricultural landscape is witnessing a surge in innovations and a growing preference for in-farm and novel farming solutions. On a global scale, technological advancements in the in-farm category are centered around farm automation, precision agriculture, remote sensing, advisory services, and farm management. These innovations harness the power of robotics, artificial intelligence (AI), the Internet of Things (IoT), and data analytics to enhance efficiency and productivity in modern farming practices.

The greenhouse gas emissions from the biological conversion of fertilizers to nitrous oxide (N_2O) account for almost 50-80% of the emissions from fertilizers. Practices like precision agriculture, which uses inputs from various constituent technologies like geographic

Practices like precision agriculture can reduce the environmental impact of fertilizers by helping farmers use the right amount of fertilizers at the right time

information systems, satellite positioning, remote sensing, and yield monitoring to optimize yields, can reduce the environmental impact of fertilizers by helping farmers use the right amount of fertilizers at the right time. This reduces wastage and decreases the emissions from the microbiological process. Precision agriculture also results in higher yields with greater efficiency, reducing the land required and stopping deforestation. It also leads to greater food security for the populace.[95]

Companies like Absolute, an agriculture hardware and software provider; Pixxel, a hyperspectral imaging solution provider; BharatAgri, a farm advisory solutions provider; and Fasal, a precision irrigation advisory firm, have already raised more than US$ 185 million in 2021-22 and are doubling down on the opportunities in the precision agriculture space.[96]

Each of the four leading agrochemical companies has undertaken development of in-house digital farming solutions

Both start-ups and multinational corporations have the opportunity to cultivate in-house capabilities and strategically invest in this dynamic space. Recognizing the vast potential, each of the four leading agrochemical companies has undertaken development of in-house digital farming solutions. Examples include BASF's xarvio software, Bayer's Climate FieldView, along with its partnership with Microsoft, Syngenta's AgriEdge/FarmShots, and Corteva's Granular. This dual approach of internal development and strategic investments reflects a collective industry recognition of the transformative power and possibilities within the digital farming landscape.

Growing demand for traceability is spurring agri-carbon innovation

The significance of traceability and its demand in the food industry is on the rise. Projections indicate that the global food traceability market, valued at US$ 16.8 billion in 2020, is poised to reach US$ 26.1 billion by 2025.[97] This growth is attributed to the expanding consumer base in the Asia Pacific region and a heightened demand for traceable, high-quality fresh produce. As consumers increasingly prioritize transparency and quality assurance, the importance of traceability in the food supply chain is becoming a pivotal factor driving industry dynamics. Traceability in agriculture promotes agri-carbon innovations by fostering transparency and enabling strategic measures to minimize the carbon footprint of the entire agricultural supply chain.

In terms of traceability, companies like BASF and Corteva offer a restricted range of 'farm-to-retail' solutions primarily focused on specific crops like cotton and oilseeds. There is room for traditional companies to enhance their innovation and investment efforts to further improve traceability in the agricultural supply chain. Start-ups across the world are taking the lead in innovating comprehensive 'seed-to-fork' traceability solutions. French start-up Connecting Food, for example, offers a third-party food transparency platform. This platform seamlessly connects farmers, food producers, manufacturers, and distributors, utilizing blockchain technology to establish an unalterable record across all production stages.[88]

Notably, major agrochemical multinational corporations have initiated pilot carbon farming projects, such as the Bayer Carbon Initiative, Corteva Carbon Initiative, BASF's Global Carbon Farming Program, and Syngenta's Good Growth Plan. Meanwhile, start-ups have the opportunity to innovate in agri-carbon by developing robust verification mechanisms, ensuring transparency, and offering educational and operational support to farmers. For reliable verification, solutions developed by Agreena, Hummingbird Technologies, and Nori use multi-source remote sensing, ground data validation software, and satellite imagery. Indigo provides educational and operational support to farmers through digital tools, personalized agronomic assistance, and direct market access.

Start-ups have the opportunity to innovate in agri-carbon by developing robust verification mechanisms, ensuring transparency, and offering educational and operational support to farmers

Modified animal feed to reduce emissions from cattle[98]

Modifying animal feed with additives like linseeds and seaweed offers a dual advantage: it significantly reduces emissions from cattle (12-64% decrease in methane emissions) and enhances yields, with up to an 8% increase in milk production.

Government support for research and development (R&D) related to modified animal feed will be critical to emissions reduction goals. While the government has taken steps in this direction, further intervention is crucial to foster advancements in this field. Currently, the National Livestock Mission provides comprehensive training on animal husbandry practices, including feed production, and a 50% capital subsidy to support the establishment of feed/fodder value addition units. Additionally, the Food Safety and Standards Authority of India (FSSAI) plays a pivotal role by mandating compliance with BIS specifications for all commercial feeds intended for meat and milk-producing animals.[99,100]

Modifying animal feed with additives like linseed and seaweed reduces emissions from cattle and enhances yields

The animal feed space represents a lucrative opportunity for start-ups. To maximize this potential, they should invest in R&D for innovative feed formulations, collaborate with research institutes, employ data analytics for impact optimization, and conduct awareness campaigns. Krimanshi Technologies in Jodhpur demonstrates this approach by creating a new value chain using food waste to produce highly nutritious feeds.[101]

Traditional companies in the animal agriculture sector should explore partnerships or acquisitions with start-ups specializing in innovative feed technologies. Another avenue is adapting existing product lines to incorporate sustainable features. For example, Cargill collaborated with TREES Consulting, resulting in a Gold Standard-approved methodology for measuring methane emissions reduction in the beef industry. This involved incorporating the feed supplement SilvAir into beef cattle diets.[102]

Alternative protein and meat substitutes offer consumers a responsible choice to mitigate emissions

Consumers are increasingly embracing plant-based options, not only for ethical reasons but also to actively contribute to emissions reduction. The environmental benefits are significant, as the production of plant proteins emits 30-90% less greenhouse gases compared to conventional meat.[103]

As part of the shift towards a more sustainable and eco-conscious global food industry, the vegan food market is poised for substantial growth, projected to surge at a CAGR of 11.32% from 2023 to 2027.[98] Within this segment, the plant-based meat and dairy markets are set to experience even more impressive expansion, with expected CAGRs of 25% and 20.7%, respectively, during the same period.[105]

Entrepreneurs can tap into the rising demand for plant-based and cell-based options by creating innovative products and technologies. Indian start-ups are already making headway – Phyx44 is developing cow milk using microbe-created proteins and fats, ProMeat offers high-protein plant-based meats from indigenous crops, and Naya M!lk focuses on plant-based paneer with properties akin to dairy-based versions.[106]

Established companies can strategically expand their product portfolios to embrace the growing market for alternative proteins and meat substitutes, a move that some FMCG giants are undertaking

Established companies can strategically expand their product portfolios to embrace the growing market for alternative proteins and meat substitutes, a move that some FMCG giants are undertaking. Tata Consumer Product Ltd (TCPL) has entered the plant-based meat products category with the introduction of four variants under the new brand 'Tata Simply Better'.[107] Additionally, ITC has launched plant-based protein products under its `ITC Master Chef Incredible' brand.

Summary of key trends in the Food, Agriculture, and Land Use sector

- Rising demand and consumption of animal protein poses its own set of challenges, particularly concerning the associated methane emissions
- An increasing awareness of the benefits of organic food is driving a significant shift in consumer preferences
- The government is mechanizing farms to reduce agricultural emissions
- The government is facilitating digitization in agriculture by developing digital public infrastructure

Summary of future outlook for the Food, Agriculture, and Land Use sector

- Innovation in sustainable inputs has the potential to decarbonize the fertilizer supply chain
- The agricultural landscape is witnessing a surge in innovations and a growing preference for in-farm and novel farming solutions (including precision agriculture solutions)
- The growing demand for traceability is spurring agri-carbon innovation
- Modifying animal feed with additives can reduce emissions from cattle
- Alternative protein and meat substitutes offer consumers a responsible choice to mitigate emissions

4 Industry, Manufacturing, and Resource Management

The industry, manufacturing, and resource management sector is experiencing robust growth propelled by technological advancements and rapid industrial development. However, this expansion raises concerns about increased emissions and environmental impact. Recognizing these challenges, various stakeholders, including government bodies, established companies, start-ups, and investors, are actively taking measures to render the sector more environmentally sustainable. Technological progress is not only driving the sector's growth but is also being harnessed to ensure its alignment with climate-friendly practices.

Investments in the Industry, Manufacturing, and Resource Management sector

Rapid industrial development and growth of the manufacturing sector raises concerns about increased emissions and environmental impact

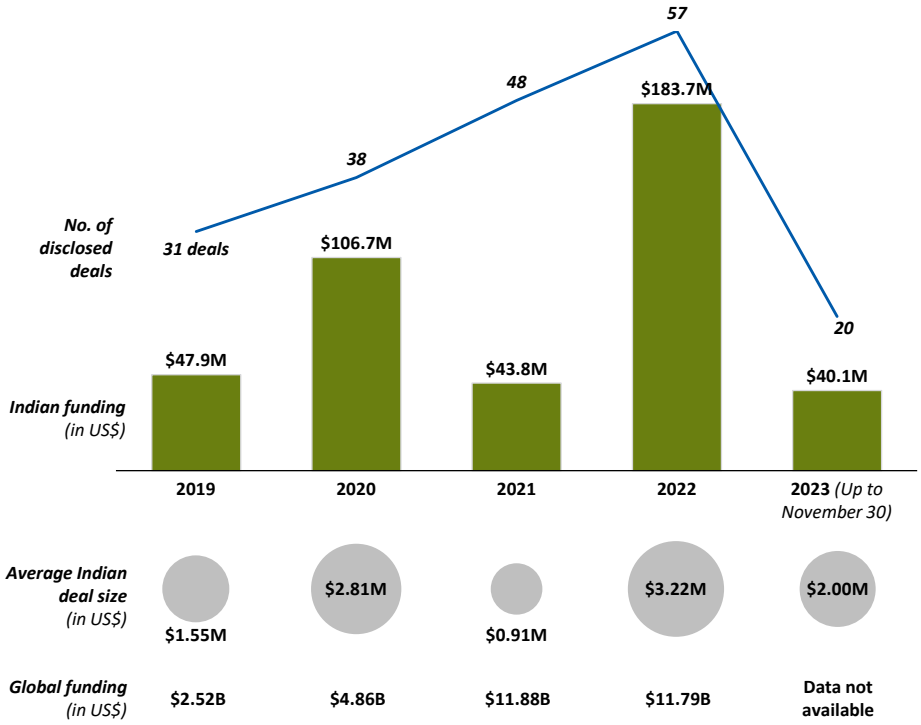
The sector experienced an impressive 122% growth in investments from 2019 to 2020, driven largely by the contributions of four key companies – Nepra, Wabag, Antony Waste Handling, and Lohum. These companies collectively accounted for 71% of the total funding in 2020.

Globally, the sector demonstrated a remarkable 140% growth from 2020 to 2021, contrasting sharply with India's contraction of 59% during the same period. The global upswing can be attributed to factors such as industries adapting resiliently to the challenges posed by the COVID-19 pandemic, ongoing technological advancements, and rapid digital transformations across various sectors. In contrast, in India, despite an increase in the overall number of deals, the investment per deal remained comparatively low compared to 2020.

While global investments remained stagnant between 2021 and 2022, the domestic sector experienced a spectacular 318% growth in investments with US$ 184 million in funding (*see Figure 9*). This notable funding surge was largely propelled by major contributions from key players, with Shriram EPC securing US$ 43 million, Detect Technologies obtaining US$ 29.6 million, and Recykal receiving US$ 29.3 million. Together, these three companies collectively represent a substantial 55% share of the total funding in the sector for the year.

However, 2023 saw the sector struggling with only US$ 40 million raised by the end of November, a 78% decrease from the peak in 2022.

FIGURE 9: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE INDUSTRY, MANUFACTURING, AND RESOURCE MANAGEMENT SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

Despite contributing 29% of India's total GHG emissions, the industry, manufacturing, and resource management sector receives a disproportionately low share of climate-tech sector funding; i.e. 2%

Despite contributing 29% of India's total greenhouse gas emissions, the industry, manufacturing, and resource management sector receives a disproportionately low share of climate-tech sector funding, i.e. 2%. Addressing this misalignment will be critical for achieving comprehensive and effective solutions to combat climate change.

Key trends in the Industry, Manufacturing, and Resource Management sector

The industry, manufacturing, and resource management sector is witnessing dual trends. On the one hand, there are positive shifts like the government's promotion of green steel, FMCG brands adopting sustainability, and increased consumer preference for eco-friendly products. On the other, challenges arise from rising emissions in sectors like iron, steel, cement, ammonia, and chemicals. The government, start-ups, investors, and legacy companies must address these emissions for sustainable industry growth.

The government is actively promoting decarbonization of `hard-to-abate' sectors such as steel and cement through policy support

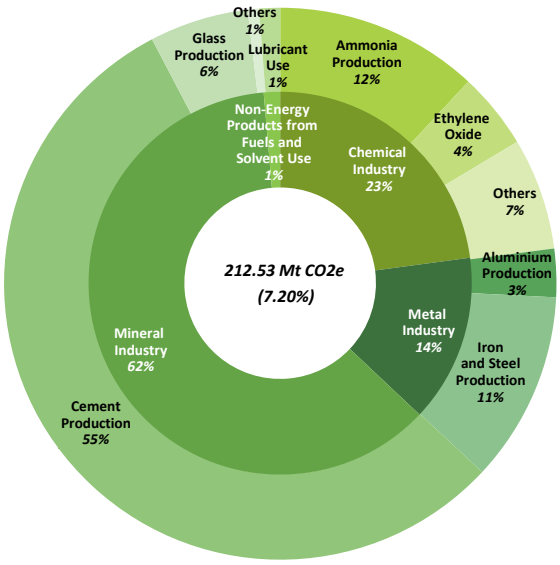
To curb emissions in the sector, the **government is actively promoting decarbonization of `hard-to-abate' sectors such as steel and cement** through a series of policies. In alignment with environmental goals, the Ministry of Steel has committed to achieving net-zero status by 2070. The Steel Scrap Recycling Policy of

2019 and the Motor Vehicles Rules from September 2021 work together to enhance scrap availability in the steel sector, reducing coal consumption.[108] Moreover, India is a part of the new Industrial Deep Decarbonization Initiative (IDDI), which pledged to buy low-carbon steel and concrete from heavy industries that manufacture them.[109] Given the impact of the Carbon Border Adjustment Mechanism (CBAM) on the steel industry, green steel adoption is expected to pick up in the near future, with the government coming up with policy instruments to help domestic steel producers adopt green standards.[110]

With the rise of conscious consumerism in India, FMCG brands are actively pursuing sustainable practices that are in line with the global shift towards environmentally responsible operations

Meanwhile, **with the rise of conscious consumerism in India, FMCG brands are actively pursuing sustainable practices** that are in line with the global shift towards environmentally responsible operations. Indian consumers are exhibiting a growing preference for sustainability in their purchasing decisions. Over the past two years in India, 48% of consumers have embraced sustainable product choices, with 20% prioritizing environmental and social benefits and 49% emphasizing health benefits.[111] Keeping pace with this change in customer preferences, FMCG brands are pursuing sustainable practices. For example, ITC aims for 100% reusable, recyclable, and optimized plastic packaging. Similarly, P&G has committed to using 100% renewable or recycled materials, striving for zero waste to landfills.[112]

FIGURE 10: EMISSIONS FROM IPPU (INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR) IN INDIA, 2018[113]



However, the expected **growth in India's manufacturing sector sparks concern about a surge in emissions**. Cement and steel, responsible for 15-20% of India's emissions, heavily rely on fossil fuels[114]. From 2005 to 2018, GHG emissions almost

doubled, reaching 212 Mt CO2e in 2018 from 100 Mt CO2e in 2005. Manufacturing of iron, steel, and cement contributed to 65% of the emissions from the industrial processes and product use (IPPU) sector in 2018. The cement industry alone contributed 54% of the sector's emissions that year (*see Figure 10*). Addressing emissions from these sectors is imperative as the manufacturing industry expands.

Addressing emissions from the manufacturing of iron, steel, and cement is imperative as the manufacturing industry expands

Future outlook for the Industry, Manufacturing, and Resource Management sector

As India charts a course towards a more sustainable and climate-resilient economic landscape, a confluence of green technologies, sustainable material innovations, and digital transformations is emerging as a catalyst for a sustainability pivot in the industry, manufacturing, and resource management sector.

Transition from conventional Ordinary Portland Cement (OPC) to greener alternatives

Green cement, manufactured through techniques minimizing carbon emissions, stands out against Ordinary Portland Cement (OPC). It consumes 60% less thermal energy, resulting in a 60% reduction in carbon emissions intensity. The primary contributors to emissions in cement production are the energy-intensive kiln heating and chemical processes converting limestone into calcium oxide. To reduce emissions from production, companies are adopting innovative technologies such as Waste Heat Recovery (WHR) systems, reduction or cessation of fossil fuel use, incorporation of solar energy, and the transformation of existing fossil-fuel-based facilities into renewable biomass fuel-based units.

Apart from green cement, other alternatives, such as pozzolanic cement, hempcrete, ashcrete, fiber cement, ferrock, etc., are also emerging as sustainable alternatives to OPC. These materials have properties similar to conventional cement but are sustainable, with carbon footprints as low as 99% compared to OPC.[15,116]

Companies must prioritize green steel manufacturing, emphasizing the recycling and reuse of by-products to produce green cement

Corporates must prioritize green steel manufacturing, emphasizing the recycling and reuse of by-products to produce green cement and its alternatives like ferrock. For example, companies like JSW Cement utilize blast-furnace slag, a by-product generated during the iron-making process in integrated steel plants, to produce environmentally friendly, low-carbon green cement.[117]

The government should actively promote OPC alternatives by implementing policies and initiatives and fostering collaboration with other nations to enhance global adoption. A collective effort is crucial, and governments worldwide should unite against environmental challenges. Under the Industrial Deep Decarbonization Initiative (IDDI), the governments

of the United Kingdom (UK), India, Germany, the United Arab Emirates, and Canada announced a pledge in November 2021. This commitment involves the intention to purchase low-carbon steel and concrete from heavy industries, encouraging the production of eco-friendly materials on a global scale.[118]

Potential to replace conventional plastic packaging with bio-based plastics or compostable packaging[119,120,121]

Bio-based plastics, derived from renewable sources like vegetable fats, oils, starch, wood, and food waste, offer a sustainable alternative to conventional plastics

Bio-based plastics, derived from renewable sources like vegetable fats, oils, starch, wood, and food waste, offer a sustainable alternative to conventional plastics. In India, the bio-plastics market, valued at US$ 447.25 million in 2023, is projected to reach US$ 1809.51 million by 2030, with an impressive CAGR of 22.1%.

The government can play a pivotal role in fostering such innovation, with a notable example being the approval of a start-up loan of ₹ 1.15 crore (US$ 0.14 million) given to TGP Bioplastics for advancing the commercialization of "compostable" plastic.

Start-ups play a crucial role in driving innovation, particularly in the development of eco-friendly products. Some start-ups are focusing on creating bioplastics from organic waste. International examples include Bioelektra Group (Poland), Bio-On (Italy), and TerraCycle (US), while in India, EviGreen is actively contributing to the bioplastic sector. These start-ups exemplify the diverse and impactful initiatives that emerging companies can undertake on a global scale, highlighting the significance of their contributions to sustainable practices.

Adoption of new sustainable fibers[122,123,124]

The adoption of innovative sustainable fibers is reshaping the future of fashion and textiles. Among these advancements, Lyocell Fiber stands out as a synthetic yet eco-friendly alternative, derived from pulped wood in sustainably managed forests. Another example is Mylo Unleather, a vegan leather alternative crafted from mycelium, the underground root-like system of mushrooms. There are many other fibers, like Circulose, Agraloop Biofibre, and AirCarbon, that are leading the way in terms of innovation in sustainable materials and reducing pollution from textiles.

The opportunity to embrace sustainability is prompting both established legacy firms and agile start-ups to diversify their product offerings, with a notable focus on introducing innovative and ecofriendly fibers

The opportunity to embrace sustainability is prompting both established legacy firms and agile start-ups to diversify their product offerings, with a notable focus on introducing innovative and eco-friendly fibers. For example, Aditya Birla Group's Birla Cellulose, a prominent player in man-made cellulosic fibers, has achieved a milestone by successfully piloting Lyocell Fiber containing 20% microbial cellulose from Nanollose Limited. Meanwhile, with increasing interest in cruelty-free and sustainable fashion, start-ups are also playing a pivotal role in driving transformative change within the industry. For example, biotechnology

company BoltThreads has caught the attention of major fashion brands like Stella McCartney, Lululemon, and Adidas with its vegan leather alternative Mylo. As both legacy and emerging entities seize the opportunity, the textile landscape is witnessing a noteworthy shift towards sustainability-driven innovation.

Digitization of manufacturing industries using Industry 4.0[125]

The Indian manufacturing sector is undergoing substantial digital transformation with investments ranging from US$ 5.5-6.5 billion in cutting-edge technologies like IoT platforms, cloud computing, data analytics, artificial intelligence, machine learning, augmented reality, and virtual reality. These technologies have a great potential in reducing the wastage and carbon emissions from various industries. For example, automation of cutting process in textile industry through design technology reduces the wastage of material from factories. IoT devices and data analytics can optimize the energy usage in factories thereby reducing the emissions associated with power generation through fossil fuels. Fueled by both government policies and private sector investments, this concerted effort aims to position digital technologies as a cornerstone for the sector. This strategic push signifies a pivotal moment for Indian manufacturing, embracing technological advancements to enhance efficiency, productivity, and consequently reduce environmental impact.

The Indian manufacturing sector is undergoing a digital transformation with investments in a range of cutting-edge technologies like IoT platforms, AI, machine learning, augmented reality and virtual reality

Summary of key trends in the Industry, Manufacturing, and Resource Management sector

- The government is actively promoting decarbonization of 'hard-to-abate' sectors such as steel and cement through a series of policies
- With the rise of conscious consumerism in India, FMCG brands are actively pursuing sustainable practices
- The expected growth in India's manufacturing sector sparks concern about a surge in emissions

Summary of future outlook for the Industry, Manufacturing, and Resource Management sector

- Transitioning from conventional Ordinary Portland Cement (OPC) to greener alternatives can reduce carbon emissions intensity significantly
- Bio-based plastics or compostable packaging offer a sustainable alternative to conventional plastic packaging
- The adoption of innovative sustainable fibers is reshaping the future of fashion and textiles
- The Indian manufacturing sector is undergoing a digital transformation with investments in cutting-edge technologies like IoT platforms, cloud computing, data analytics, artificial intelligence, machine learning, augmented reality, and virtual reality

5 Built Environment

As India undergoes rapid urbanization and demographic expansion, the domestic built environment sector is experiencing substantial growth, driven by a blend of environmental, economic, and technological factors. This growth is underpinned by an emphasis on sustainable and energy-efficient practices in building and urban planning, crucial for tackling India's urban environmental challenges and guiding investment and policy towards a sustainable urban landscape. Reflecting this evolving trend, there has been a significant shift in investment patterns – more capital is being directed towards green buildings, smart city projects, and sustainable infrastructure, signaling growing investor confidence in the sector's potential for unlocking economic value.

Investments in the Built Environment sector

An analysis of climate-tech investments in the built environment sector reveals a stark contrast between the global and Indian funding landscapes – while the domestic sector exhibits a top-heavy funding structure, where a few large deals determine the funding levels for the year, the funding is distributed more evenly in a global context. Consequently, this leads to a lot of volatility with respect to year-on-year changes in funding levels in India as compared to the linear growth exhibited by the global landscape.

While the domestic sector exhibits a top-heavy funding structure, where a few large deals determine the funding levels for the year, the funding is distributed more evenly in a global context

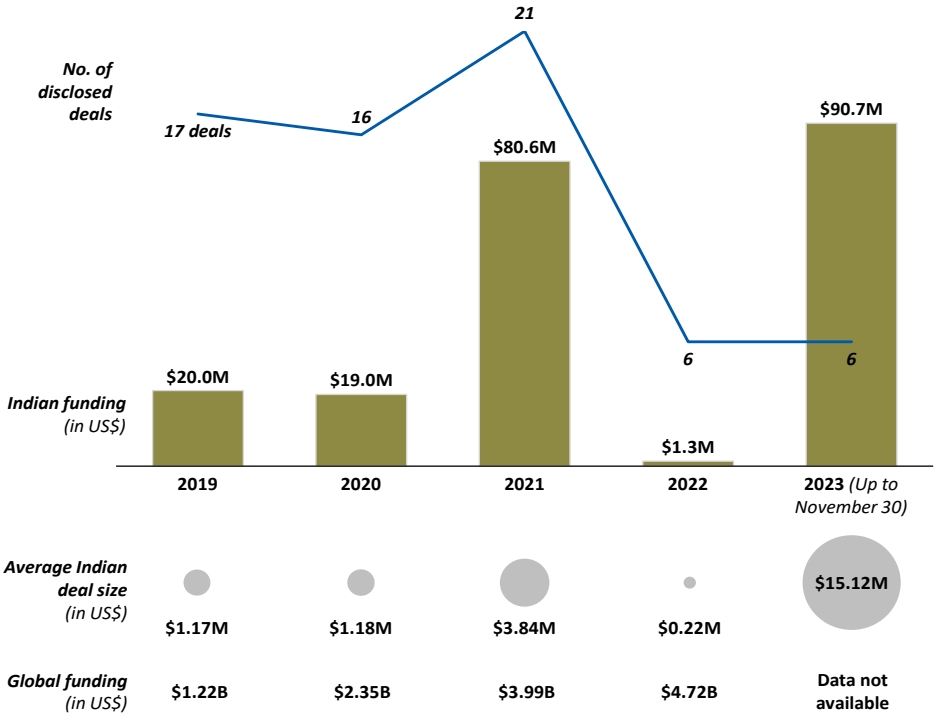
Volatility notwithstanding, the sector in India has witnessed a remarkable trajectory of funding growth over recent years, starting from a modest base of approximately US$ 20 million in 2019. While there was no significant change in 2020, the sector saw a dramatic hike in investment in 2021, reaching a peak of around US$ 81 million. This impressive growth was primarily driven by two large deals – with Transcon and Atomberg's series B and C funding rounds, respectively, accounting for about 76% of the funding in 2021.

However, following this period of exponential growth, there was a steep reduction, with the overall funding plummeting to US$ 1.3 million in 2022 (*see Figure 11*). This decline was driven by broader economic turmoil affecting markets globally, including a downturn in climate-tech funding across various geographies.

In 2023, the sector experienced a remarkable resurgence, achieving its highest funding levels since 2019. By the end of November, it had amassed approximately US$ 91 million in funding. This surge can largely be credited to Atomberg's notable marquee Series C deal,

which alone represented about 95% of the sector's total funding for the year till the end of November. It also drove the average deal size that year to a record high, as the total number of deals was comparatively low.

FIGURE 11: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE BUILT ENVIRONMENT SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

More capital is being directed towards green buildings, smart city projects, and sustainable infrastructure, signaling growing investor confidence in the sector's potential for unlocking economic value

The pronounced fluctuations in the funding raised by the sector over these five years are primarily due to the two whopping deals secured by Transcon and Atomberg in 2021 and 2023, respectively.

The built environment sector in India was responsible for approximately 4% of the national GHG emissions from 2019 to 2022 but received only 0.82% of climate-tech investments in the same period

In the context of climate action, it is important to assess these funding dynamics against the sector's environmental implications. The built environment sector in India was responsible for approximately 4% of the national greenhouse gas emissions from 2019 to 2022 but received only 0.82% of the climate-tech investments during the same period. However, there has been a notable change of late, as evidenced by the sector's increased share of climate-tech investments, rising to 3.18% by the end of November 2023. This underscores a significant opportunity to implement more impactful emissions reduction strategies. By better aligning investments with the sector's environmental impact, India can pursue its

environmental objectives more effectively. The shift in funding dynamics observed in 2023 indicates a promising step towards this alignment.

Key trends in the Built Environment sector

The built environment in India is witnessing a significant shift towards sustainable practices, driven by several key factors such as conscious consumerism, policy measures rolled out by the government, technological innovation by start-ups, and a growing commitment to sustainability among larger and more established players in the market.

While the Indian green building market was sized at $20 billion in 2021 and has historically grown at a CAGR of ~7% between 2017 to 2021, it is expected to compound as we move forward.[126]

While the Indian green building market has historically grown at a CAGR of around 7% between 2017 and 2021, it is expected to compound as we move forward

Government is driving the uptake of green solutions through building standards and incentives such as tax benefits, fast-track approvals, and low-interest loans. The Eco Niwas Samhita (ENS) and the Energy Conservation Building Code (ECBC) are at the forefront of this push. The ENS, a residential energy conservation building code, and the ECBC, which sets minimum energy standards for new commercial buildings, represent a significant step towards reducing the environmental impact of new constructions and promoting energy efficiency.[127]

Along with these building codes, the government has implemented a range of national incentives to encourage green construction. Developers of LEED-certified buildings enjoy tax benefits under the Income Tax Act, allowing them to claim up to 100% depreciation on the cost of green building assets. Additionally, low-interest loans are available through the Indian Renewable Energy Development Agency (IREDA) for projects with green certifications. To set an example, the government mandates that all new government buildings meet green building standards. Moreover, certified green buildings benefit from fast-track approvals, expedited inspections, and reduced building fees, further incentivizing sustainable development.[128]

Accelerating the green transition in the sector, India is witnessing considerable **start-up-led innovation towards developing affordable solutions that are scalable** in the prevailing socio-economic context. For example, Agrocrete, made from agricultural residues, and Geopolymer Concrete Blocks, an eco-friendly alternative to traditional walling, are redefining building materials. Technologies such as the Textile Reinforced Concrete Prototyping Technology (TRCPT) are enabling new construction methods. Additionally, the AVATAR Small Wind Turbine is expanding the accessibility of wind energy.[129]

Accelerating the green transition in the sector, India is witnessing considerable start-up-led innovation towards developing affordable, scalable solutions

Indian start-ups are also developing recycling processes – Carbon Tile, produced from upcycled carbon waste, and RecycleX's building materials, made from 100% recycled content, including paver blocks and tiles, focus on minimizing waste.

Consumers are increasingly favoring sustainable building solutions, prompting large developers to lead the way with LEED-certified and net-zero buildings

Driven by the long-term economic advantages of sustainable building practices and a growing social awareness of climate change, **consumers are increasingly favoring sustainable building solutions, propelling large developers to lead the way with LEED-certified and net zero buildings**. People are choosing sustainable options, recognizing that while these might entail a higher initial investment — typically around a 2% increase in construction costs — they offer substantial savings in the long term — reduction in operational expenses by 14%-19% over the lifespan of a building.[130] The significant impact of traditional construction practices on emissions is also behind this shift in consumer behavior. Almost half of all mineral resources extracted globally are used in housing and infrastructure development. Moreover, due to minimal end-of-life repurposing, building materials account for half of the solid waste generated worldwide.[131]

Godrej Properties, a pioneer in green building practices, has developed over 100 LEED-certified projects.[132] Similarly, Mahindra Lifespaces has made significant strides and developed India's first net-zero energy residential building. Over 80% of Tata Housing Development Corporation's portfolio meets the certification requirements of the IGBC/USGBC, and more than half is IFC-EDGE Zero Carbon certified.[133] L&T Realty, in its commercial ventures, ensures that all developments are LEED Certified Gold Rated buildings. These projects emphasize sustainability through various means, including solar energy harnessing, energy-efficient water pumps, and rainwater harvesting.[134]

Smaller developers and retail consumers lag in the adoption of green practices in construction

However, **smaller developers and retail consumers lag in the adoption of green practices in construction**. While large builders have access to significant capital and the economies of scale required to make long-term investments, mid-scale, small, and retail developers are facing considerable challenges. Retail consumers encounter several demand-side challenges in this fragmented market. These include the lack of integrated shopping solutions, uncertainty around the availability of products, a predominant presence of unbranded products due to the unorganized market, and inconsistent product pricing.

On the supply side, resellers and retailers are grappling with their own set of challenges. They often need multiple sources to procure a variety of green products, highlighting a lack of aggregators or cross-value chain producers. Large Minimum Order Quantities (MoQs) imposed on contractors and resellers create additional hurdles. Further, they also face inconsistent delivery schedules and a poor penetration of digital solutions, which hampers the efficiency of unassisted buying processes for such green products.[135]

Future outlook for the Built Environment sector

As India strides forward in its sustainable development journey, innovations in sustainable building materials, smart infrastructure, and circular construction practices can help create green, resilient, and healthy living spaces. As the sector evolves, the government and businesses will have compelling opportunities to drive sustainability in construction.

Increased adoption of building management and IoT solutions among advanced industry 4.0 applications

Building management systems are expected to be an integral component of the built environment, helping India achieve its emissions reduction goals. The sector is set to embrace advanced industry 4.0 applications, wherein automation and inter-device connectivity, driven by IoT (Internet of Things) solutions, are integrated into buildings, marking a significant shift toward enhanced efficiency. Technologies such as low-energy HVAC systems, hybrid ventilation, dedicated outdoor air systems, hydronic cooling systems, demand-controlled ventilation, and fault detection and diagnostics with predictive maintenance are poised to play central roles in this evolution.[136]

The built environment is set to embrace advanced industry 4.0 applications, wherein automation and inter-device connectivity are integrated into buildings, marking a significant shift towards enhanced efficiency

This presents a major investment opportunity for businesses in this space. While legacy manufacturers like Voltas, Blue Star and Daikin have already started the transition towards high-tech HVAC systems, they are being complemented by a surge of new entrants in the form of service providers dealing with end-to-end design, customization, and outfitting, and software platform management. This includes companies such as TheSmartHVAC, which specializes in design engineering for custom HVAC solutions; Falcon Labs, known for their IoT-based digitization solutions aimed at enhancing energy and operational efficiency; Clairco, which offers tailored fittings for indoor air purification; among several others. In addition to residential and commercial applications, companies such as Messung are leading the way in providing solutions in industrial use cases, ranging from development of integrated hardware for manufacturing processes to management platforms that enable remote monitoring and control.

Potential for start-ups to bring new and emerging technologies to India

Technologies such as cool roofs, storm water management, and geothermal heating, among others, are starting to make their way from countries like the US and the UK to India. Some Indian start-ups are already leveraging these technologies to develop innovative business models *(see Figure 12)*.

Technologies such as cool roofs, storm water management, and geothermal heating, among others, are starting to make their way from countries like the US and the UK to India

FIGURE 12: ILLUSTRATIVE LIST OF EMERGING TECHNOLOGIES AND START-UPS OPERATING IN THE BUILT ENVIRONMENT SECTOR IN INDIA AND GLOBALLY

	Emerging technologies in built environment	Indian start-ups in the sector	Global Start-ups
	**Cool Roofs** – includes technology designed to offer increased solar reflectance to reduce the heat transfer to the rooms	ReMaterials	TAMKO BUILDING PRODUCTS
	**Storm Water Management** – includes systems such as grass paving, rainwater reservoirs, etc., to manage surface runoff and conserve water	ira water first.	FLOOD-CON
	**Geothermal Heating** – includes technology that utilizes geothermal energy for energy generation and heat storage	GIBSS	FERVO ENERGY; GreenFire Energy
	**Electrochromic Smart Glass** – includes switchable glass technology that helps reduce energy costs by varying the access to sunlight	AIS	view; ChromoGenics
	**Low-energy HVAC Systems** – includes various energy-efficient cooling and ventilation appliances used at homes and offices	atomberg; ottomate	DANDELION; tado°
	**Hybrid Ventilation Systems** – includes systems that use both natural and mechanical solutions to increase efficiency and comfort	AMBIATOR	Breathing Buildings
	**Dedicated Outdoor Air Systems** – includes systems that use conditioned outdoor air for HVAC applications	NA	OXYGEN 8; MOJAVE
	**Green Insulation**– includes insulation material made from sustainable sources such as cellulose, glass wool, aerogel, hemp, etc.	NA	THERMULON; ACTIV HOME

Offsite manufacturing and modular construction's potential to curb emissions

Offsite manufacturing and modular construction promises faster project delivery, reduced costs, and a smaller ecological footprint through waste minimization and standardized processes

In parallel, offsite manufacturing and modular construction is expected to transform construction methodologies. By shifting construction to controlled factory environments, this technology promises faster project delivery, reduced costs, and a smaller ecological footprint through waste minimization and standardized processes. This approach is anticipated to reduce overall costs by over 20%, shorten construction periods by 60%, and require 75% fewer operatives on-site.[137]

While significant growth within prefabricated construction is expected, it will be confined to specific niches and consumer segments, serving areas that align closely with the inherent strengths of prefabricated construction, such as standardization and at-scale production of constituent parts and building, rather than achieving universal application in all construction domains as modular construction limits customizability.

Emergence of sustainable, energy-efficient, passive design and structural alternatives like timber, hempcrete, etc.

Passive design is a methodology that uses natural resources to reduce a building's energy consumption and create a comfortable indoor environment. This approach is grounded in

the principle of leveraging natural environmental forces to provide ventilation, cooling, and optimized heating, in contrast to active design which uses technologies such as solar panels, heat recovery systems or wind turbines. Examples of passive design strategies include planned orientation of buildings and use of sunscreens to provide maximum exposure to sunlight, inclusion of spill-out areas to facilitate fresh air circulation, and hollow brick masonry and insulated panels to regulate the heat. The implications of passive design are far-reaching, as evidenced by its potential to reduce active energy requirements associated with key building functionalities such as space cooling, lighting, and appliances by up to 40%, according to some projections.

Structural alternatives like timber, hempcrete, and other innovative materials are also becoming increasingly important in reducing the built environment's carbon footprint. These materials are environmentally friendly and contribute to energy savings and optimized resource utilization.[138]

Though limited in scope, the current market for pollution-reducing construction materials is anticipated to witness growth, particularly in urban centers with pronounced air pollution issues

Though limited in scope, the current market for pollution-reducing construction materials is anticipated to witness growth, particularly in urban centers with pronounced air pollution issues. This expected growth is underscored by government action, including temporary bans on construction practices that contribute significantly to pollution.[139]

This scenario presents a unique opportunity, particularly for large-scale developers, to integrate sustainable design and structural alternatives into their offerings. While niche developers have been pioneers in using sustainable materials, their limited scale constrains widespread impact. In contrast, larger developers, with more substantial resources, have the potential to drive significant change across the industry.

Retrofitting old buildings to reduce climate impact

Retrofitting is emerging as another area for impactful climate-tech innovation in the built environment, driven by the prevalence of mid-lifecycle buildings constructed without green practices

Retrofitting is emerging as another area for impactful climate-tech innovation in the sector, driven by the prevalence of mid-lifecycle buildings constructed without green practices. Retrofitting these structures is essential for reducing their carbon footprint and enhancing operational efficiency. Depending on the building, retrofitting can lead to a 33% reduction in operational emissions on account of reduced energy consumption. This has given rise to a substantial global market for energy-based retrofitting, valued at $161 billion in 2023. It is further projected to grow at a CAGR of 6.8%, growing to US$ 272 billion by 2032.[140]

The current market fragmentation and limited consumer awareness present a significant opportunity for companies to establish a strong foothold. By developing expertise in this under-served sector, businesses can capitalize on the potential to shape and lead the market, especially given the current landscape of medium and small businesses with modest expertise.[141]

Summary of key trends in the Built Environment sector

- The Government is driving the uptake of green solutions through building standards and incentives such as tax benefits, fast-track approvals, and low-interest loans
- Accelerating the green transition in the sector, India is witnessing considerable start-up-led innovation towards developing affordable, scalable solutions
- Consumers are increasingly favoring sustainable building solutions, prompting large developers to lead the way with LEED-certified and net-zero buildings
- Smaller developers and retail consumers lag in the adoption of green practices in construction

Summary of future outlook for the Built Environment sector

- The sector is set to embrace advanced industry 4.0 applications, wherein automation and inter-device connectivity are integrated into buildings, resulting in enhanced efficiency
- New technologies such as cool roofs, storm water management, and geothermal heating, among others, are starting to make their way from countries like the US and the UK to India
- Offsite manufacturing and modular construction promises faster project delivery, reduced costs, and a smaller carbon footprint through waste minimization and standardized processes
- The emergence of sustainable, energy-efficient, passive design and structural alternatives like timber, hempcrete, etc. are reducing the built environment's environmental footprint
- Retrofitting is emerging as another area for impactful climate-tech innovation in the sector, driven by the prevalence of mid-lifecycle buildings constructed without green practices

6 Financial Services

The journey towards a net-zero future entails high capital investments in the climate-tech sector. In this context, financial services, encompassing funding, investment management, and financial consultancy, are becoming increasingly tailored to support the unique needs of innovative climate technologies. This trend is underpinned by the increasing involvement of specialized financial services that recognize both the potential for significant returns and the imperative for environmental stewardship.

Consequently, specialized financial service providers and instruments have become a fundamental aspect of a robust climate tech ecosystem. It is crucial to acknowledge that these service providers, in turn, need substantial funding to initiate and continue operations. This financial backing enables them to mobilize and allocate resources effectively across the entire climate-tech ecosystem.

Financial services encompassing funding, investment management, and financial consultancy are becoming increasingly tailored to support the unique needs of innovative climate technologies

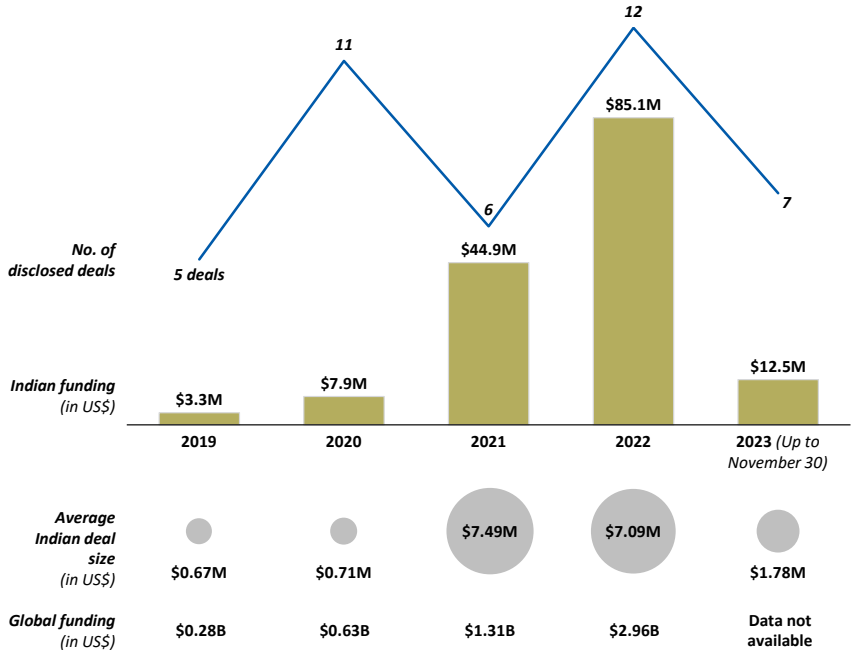
Investments in the Financial Services sector

Raking in a modest US$ 3.3 million in 2019, financial services for climate-tech has conventionally been a niche space in India. However, with the broader funding ecosystem expanding, the need for targeted financial instruments and corollary service providers has risen proportionally, leading to an increase in funding across the board for such service providers.

This has led to exponential year-on-year funding growth since 2019, increasing over 2400% (a 24-fold rise) in a three-year span to US$ 85 million in 2022. While this is a result of an increase in funding across the ecosystem, it must be noted that a single company – Jai Kisan, a financial service provider catering to the underserved rural farmer population – was responsible for raising the highest quantum of funding every single year. It was responsible for about 59% of the overall funding raised in the entire ecosystem in 2022. In 2023, only US$ 12.5 million had been raised by the end of November; most of it by Aerem (52%) and Unnati (28%), which accounted for 80% of the funding.

While not as pronounced as the staggering growth rate experienced by the Indian ecosystem, global climate-tech funding in financial services has also experienced impressive growth – investments have risen by 960%, from US$ 280 million in 2019 to US$ 2.96 billion in 2022 (*see Figure 13*).

FIGURE 13: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE FINANCIAL SERVICES SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

Compared to the broader global context, India lags considerably in the proportion of climate-tech funding directed at financial services

However, compared to the broader global context, India lags considerably in the proportion of climate-tech funding directed at financial services. Between 2019 and 2022, 2.7% of the overall global funding in climate-tech went into financial services, as opposed to just 0.72% in India.

Key Trends in the Financial Services sector

As climate-tech gains prominence on the financial stage, the financial services sector in India is being shaped by an interplay of several discernable trends – a strategic focus on aligning venture capital investments with sustainability, the advent of green financing mechanisms and sustainable funding avenues, and a collaborative effort at mobilizing capital for green initiatives.

Agriculture companies, collaborating with insurance and financial players, are pioneering innovative agri-financing solutions

Agriculture companies, collaborating with insurance and financial players, are pioneering innovative agri-financing solutions. These include parametric insurance, protecting farmers and seed breeders against losses in seed costs, and seed germination insurance that protects farmers in case of seed failure. For instance, Upaj by Absolute collaborated with Digisafe to launch the 'Seed Germination Protection Cover', which entitles farmers to receive a predetermined payment if the germination rate of the seed is below a certain threshold. Along with its farm advisory services, it

includes insurance advice to protect farmers against losses. Platforms like WRMS and Gramcover are empowering farmers with information, advice, and a quick and easy means to obtain insurance coverage for any losses incurred from crop failure.

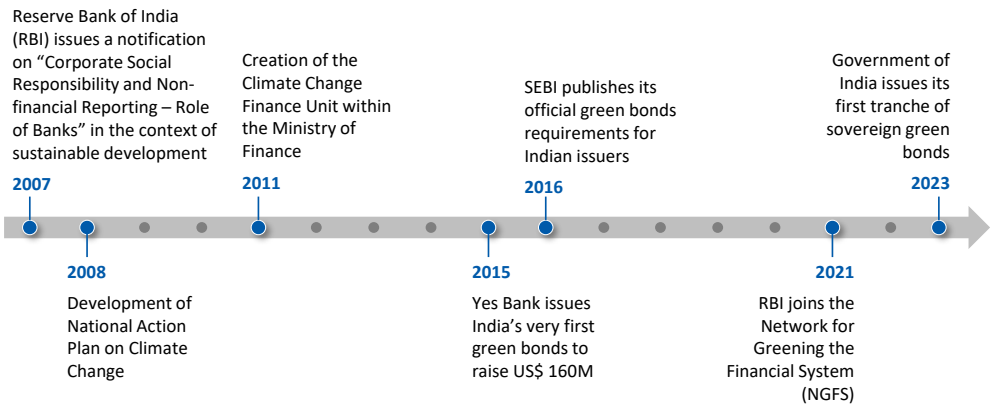
While venture capital focuses on early- to mid-stage entities, **larger organizations are relying on green bonds**, as they become a significant financial instrument in India's climate tech funding landscape, with over US$ 21 billion raised as of mid-2023.[142] In early 2023, in a significant development for the sector, the Indian government issued sovereign green bonds worth US$ 1.95 billion.[142] Additionally, local governments like Ghaziabad Nagar Nigam and Indore Municipal Corporation have raised US$ 20 million and US$ 87 million, respectively through green bonds.[142] Corporates are also embracing this trend, with ReNew Energy, AzurePower, and Tata Power collectively raising over US$1 billion, underscoring green bonds' increasing role in India's climate-tech funding.[143, 144, 145]

While venture capital focuses on early- to mid-stage entities, larger organizations are relying on green bonds that are becoming a significant financial instrument in India's climate-tech funding landscape

Besides these investment and debt-based financing mechanisms being used across the ecosystem, the government has forayed into **instituting carbon trading as a way to mobilize funds**. Not only does this play a role in offsetting emissions from vital but polluting industries, it also makes capital available for green interventions. The Carbon Credit Trading Scheme is set to be finalized soon. It will set up standards and policies for a voluntary carbon trading market in India[146], which, while currently valued at US$ 150 million[147], is poised to grow at a CAGR of 16% till 2027.[148]

Carbon trading plays a role in offsetting emissions from vital but polluting industries, and also makes capital available for green interventions

FIGURE 14: GREEN FINANCE MILESTONES IN INDIA



India has undergone a significant journey in the realm of green finance over the years. Green finance first took root in the country in 2007 when the RBI emphasized the role of banks in sustainable development. Moving forward to 2023, the government took a substantial leap by issuing its inaugural tranche of sovereign green bonds (*see Figure 14*).

The government took a significant leap by issuing its inaugural tranche of sovereign green bonds in 2023

Since green investments often require large-scale financing, **partnerships and collaborations toward targeted large-scale liquidity injections are taking center stage**. For example, the Macquarie Group's blended finance platform aims to mobilize US$ 1.5 billion for electric vehicle adoption. Tata Motors, targeting a US$ 2.4-3 billion market by 2030, collaborates with banks for electric vehicle financing. Tata Group and Larsen & Toubro are developing Public-Private Partnership structures that could unlock US$ 2 billion by 2030 at the municipal level, which would aid in waste management and infrastructural development. Additionally, Kotak Mahindra Bank is leading a pooled funding initiative to raise US$ 100 million for green infrastructure. These steps represent a significant move towards sustainable investments and environmental commitment.[149]

Future outlook for the Financial Services sector

Green-asset backed securities and strategic adoption of blended finance structures are emerging as cornerstones of the future evolution of the financial services sector

The rise of green asset-backed securities and the strategic adoption of blended finance structures are emerging as cornerstones of the future evolution of the financial services sector. As policies align with global sustainability goals, India is poised to unlock significant credit availability for private entities, navigate the complexities of emerging financial instruments, and usher in a new paradigm that marries economic growth with environmental responsibility.

Green asset-backed securities (ABSs) are emerging as a key financial tool

Green asset-backed securities (ABS) are financial instruments that are backed by a pool of loans or leases related to environmentally sustainable assets. These can include loans for renewable energy projects, energy-efficient buildings, or low-emission transportation.

These instruments are being adopted globally. For instance, the Dutch lender Obvion issued the Green Storm RMBS in 2021, a Residential Mortgage-Backed Security underpinned by energy-efficient Dutch properties, all rated A for energy efficiency. Similarly, the UK's Kensington Mortgages launched the Green Finsbury Square RMBS, focusing on financing properties with low emissions.[150]

For investors, asset-backed securities offer a structured opportunity to contribute to sustainable projects, diversifying their portfolios with assets aligned with environmental goals

While the securitization market in India is relatively underdeveloped,[151] it is highly beneficial for a variety of stakeholders and is expected to expand rapidly. The government has already issued its first tranche of Sovereign Green Bonds (SGB) in 2023 and has developed a framework for future issues. For investors, ABS offers a structured opportunity to contribute to sustainable projects, diversifying their portfolios with assets that align with environmental goals. However, it necessitates thorough due diligence to assess the environmental impact accurately, adding complexity to investment decisions.

Simultaneously, the regulatory bodies overseeing these securities must balance encouraging green finance growth with stringent oversight to prevent 'greenwashing', ensuring that the environmental benefits of these assets are real and measurable. Currently, India has no fixed definitions for what constitutes a "green" security. Further, the Business Responsibility and Sustainability Report (BRSR) has been made mandatory by SEBI, but it only applies to the top 1000 listed entities on the basis of market capitalization. This leaves the ecosystem at the risk of being manipulated by misreported data by individual companies that can exploit the reporting process to avail the benefits of green securities.[152]

Emergence of blended financing structures to manage risks

To encourage private investment, blended finance models are used to manage or offset various risks – economic, regulatory, or market-related – that private investors might face. This risk management shifts the burden from private investors to donors like governments or philanthropic organizations, making it more feasible for private capital to flow into development projects or sectors in emerging markets.[153]

India has witnessed a surge of blended finance projects. For example, the Fourth Partner project, which is aimed at decarbonizing industrial power generation, utilized a senior loan of US$ 52 million from the IFC with concessional funding from international programs. Similarly, UK's Market Accelerator for Green Construction ("MAGC") Program provided a financing package to Home First and IIFL Home Finance Limited to assist their retail clients in overcoming additional costs to obtain EDGE green-building certification and for green design features that support GHG reduction. Performance-linked incentives were a part of the financing package. The government is exploring further options to leverage these financing structures for green projects.[153]

The government is exploring options to leverage blended financing structures for green projects, but the absence of a standardized blended finance framework would hold back large-scale adoption

However, the government faces a number of challenges before these structures witness large-scale adoption. These include regulatory constraints across the process, the lack of a standardized blended finance framework and associated knowledge gaps, and the lack of sector analytics and measurement mechanisms.[153] Development finance institutions will also play a key role going forward, disseminating best global practices and assisting the government in curating them to the local context.

Summary of key trends in the Financial Services sector

- Agriculture companies, collaborating with insurance and financial players, are pioneering innovative agri-financing solutions
- While venture capital focuses on early- to mid-stage entities, larger organizations are relying on green bonds
- The government has forayed into instituting carbon trading as a way to mobilize funds
- Partnerships and collaborations toward targeted large-scale liquidity injections are taking center stage

Summary of future outlook for the Financial Services sector

- Green asset-backed securities are emerging as a key financial tool
- Emergence of blended financing structures to manage risks can encourage private investment in green projects

7 GHG Capture, Removal, and Storage

Greenhouse gas capture, removal, and storage utilizes critical technologies aimed at mitigating climate change by intercepting GHGs before they enter the atmosphere, extracting them directly from the air, and safely sequestering them. Greenhouse gases present in the atmosphere are responsible for raising the planet's surface temperature by absorbing the heat radiated by the earth, and include water vapor, carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons. As the impacts of climate change intensify, the importance of these technologies is growing, especially given that certain critical industrial processes in hard-to-abate sectors cannot be decarbonized in the near future.

While widely acknowledged as a critical component of net-zero emissions plans set out by various countries, the carbon capture, removal, and storage sector is nascent, with several barriers to adoption

While widely acknowledged as a critical component of net-zero emissions plans set out by various countries, the segment is nascent, with several key barriers to adoption. These include high costs associated with capture and storage technologies that are still being developed, substantial investments required for infrastructure development, the lack of adequate regulatory frameworks and incentives, the lack of a viable market for captured carbon, and challenges in ensuring long-term storage safety and reliability.

Investments in the GHG Capture, Removal, and Storage sector

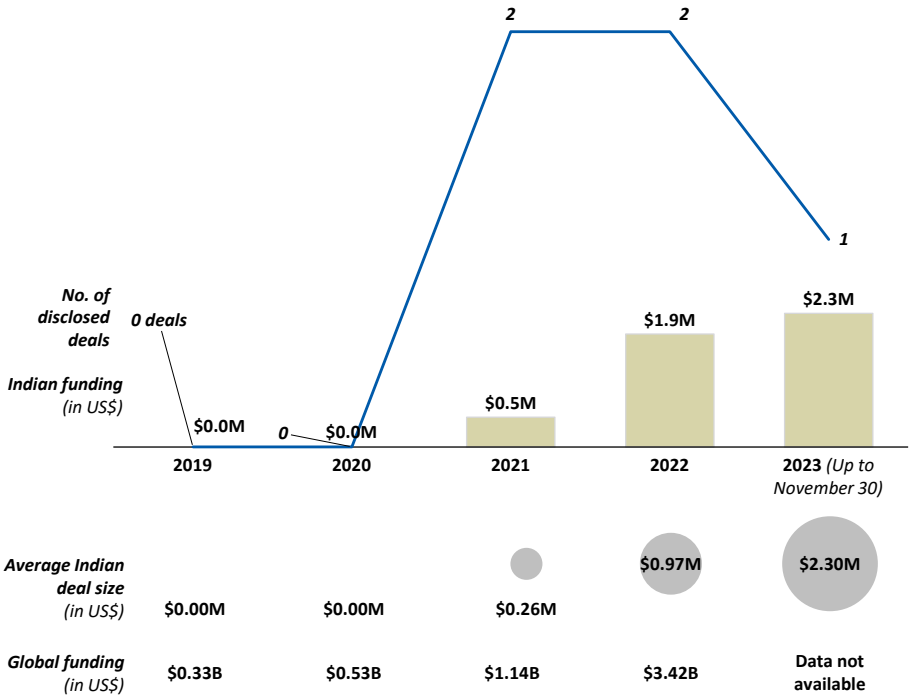
Despite the stiff challenges, the criticality of the need for GHG capture, removal, and storage has led to a significant amount of global attention in the sector, wherein the funding has followed a linear growth trajectory, registering over a 10-fold increase from US$ 0.33 billion in 2019 to US$ 3.42 billion in 2022.

The limited funding raised in the domestic sector has been concentrated across just three firms

India, however, has lagged – registering only ~US$ 4.75 million worth of investments over the same period. The limited funding raised in the domestic sector has been concentrated across just three firms – Maithri Aquatech and Vayujal, which manufacture atmospheric water generators that generate clean water from water vapor, and Uravu Labs, which sells water extracted from vapor in the air.

While Vayujal raised an undisclosed amount in 2018, there was no funding for the sector in 2019 and 2020 *(see Figure 15)*. Between 2021 and November 2023, Uravu Labs and Maithri Aquatech raised US$ 4.2 million and US$ 0.53 million, respectively.

FIGURE 15: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE GHG CAPTURE, REMOVAL, AND STORAGE SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

The lag in the segment stems mainly from the significant upfront costs involved in carrying out research and development for the technology and setting up the infrastructure for adoption

Globally, start-ups like See O2 Energy, Capture6 and Qaptis have developed revolutionary technologies to enable GHG capture from various sources. See O2 Energy converts the carbon dioxide and water vapor in air to hydrogen and carbon monoxide using reversible fuel cells to produce syngas, which can be used as a fuel. Capture6 employs direct air capture (DAC) to remove GHG from the air and create purified water and other derivatives. Qaptis has developed a mobile carbon capture system that can capture emissions from freight trucks and convert them into a liquid with minimal energy.

Notably, Carbon Clean, an Indian start-up set up in 2009 and now headquartered in London, has developed a technology to extract carbon dioxide from flux gases to make valuable chemicals. It has two CCU plants in India, but is not included in the analysis presented in *Figure 15* as it is registered in the UK and raised money overseas.

The lag in the segment stems mainly from the significant upfront costs involved in carrying out research and development for the technology and setting up the infrastructure for adoption.

The larger trend in India currently points towards a nascent system being driven by lone,

disaggregated deals. However, given the sector's importance in the context of achieving net zero goals, investments are expected to pick up in the near to mid-term future.

Key trends in the GHG Capture, Removal, and Storage sector

While uptake in GHG capture, removal, and storage has been relatively slow so far, there are a number of promising trends driving the domestic ecosystem.

Public sector undertakings (PSUs) and private players are adopting Carbon Capture and Storage (CCS) and Carbon Capture Utilization and Storage (CCUS) technologies, recognizing the need to stay carbon-neutral for sustainability and competitiveness. ONGC is collaborating with Equinor and IOCL and implementing a carbon capture project at Koyali refinery for CO2 storage at Gandhar oil field. IOCL aims to cut emissions by over 40% through CCUS and tree planting. GAIL's pilot project in Uttar Pradesh employs microalgae for CO2 conversion, showcasing innovative carbon fixation methods.[154] Private players are complementing these efforts by PSUs. For instance, Dalmia Cement, is targeting an ambitious 30 kgCO2/ton of cementitious material by 2040. Simultaneously, Tata Steel is planning to deploy the 'HISARNA' technology with CCS, potentially rolling it out across the company upon successful implementation.[155]

PSUs and private players are adopting CCS and CCUS technologies, recognizing the need to stay carbon-neutral for sustainability and competitiveness

To realize its net zero goal, the **Indian government has actively supported the sector through academic collaborations and market-based solutions**. Though the current efforts fall shy of global best practices –reflected in the investment figures - the government is nonetheless implementing strategic interventions across the entire value chain and advancing related technologies.

To this end, the government has launched two National Centres of Excellence for Carbon Capture Utilization and Storage (CCUS) technologies at IIT Bombay and JNCASR, Bengaluru, enhancing research and innovation in the field.[156] Alongside this, the Mission Innovation Challenge on CCUS supports 20 projects in CO2 capture and storage, focusing on the power and industrial sectors[156]. To generate demand for these initiatives, the government has also notified the process for the creation of an Indian Credit Market, which will be instrumental in facilitating market-based solutions for carbon capture.[157]

While research and development remain one of the key challenges, **foreign firms are paving the way for R&D through local partnerships**. Meanwhile, **domestic R&D efforts remain limited to academic institutions**. Fugro, a geotechnical services provider from the Netherlands, has signed a Memorandum of Understanding with IIT Bombay, committing to serve as a technical advisor.[158] Similarly, AspenTech,

a U.S.-based company specializing in asset optimization software for capital-intensive industries, has identified carbon capture as a key focus area for its operations in India.[149] IIT Roorkee has signed a MoU with the Bokaro Steel Plant (BSL) to further new solutions and develop practical applications.[160] Meanwhile, IISC is developing construction materials that can be used for carbon sequestration.[161]

Future outlook for the GHG Capture, Removal, and Storage sector

As India moves to finalize its Carbon Capture Utilization and Storage (CCUS) 2030 roadmap, a number of changes are expected going forward in the domestic landscape, ranging from transfer and development of better technologies, new business and operational models suited to the local context, to increased governmental support, among others.

New CCUS technologies for capturing and utilizing atmospheric or industrial carbon will slowly move to India as they mature and can catalyze the momentum in the GHG capture sector

Maturing CCUS technologies in the global landscape to make their way into India

Many technologies, such as direct air capture, aqueous amine-based capture, membrane gas separation, bioenergy with carbon capture and storage, chemical looping, cryogenic capture, etc., can theoretically capture and convert carbon into useful products or store it.[162]

Globally, many start-ups use these technologies to capture and utilize atmospheric or industrial carbon. Start-ups such as Greenlyte Carbon Technologies, Airhive, Airbuild, and Carbonaide employ low-energy direct air capture, fluidization-based capture, algae-based filters, biological fixation, conversion to concrete, etc., to capture and utilize carbon. These technologies will slowly move to India as they mature and can catalyze the momentum in the GHG capture sector.[163]

Adoption of these new technologies would be a critical enabler for tangible progress in driving down costs in the sector. Currently, it takes ~US$ 40-120 to sequester one ton of carbon dioxide directly from the atmosphere, and ~US$ 15-25 to capture the same from industrial sources,[164] which is not economically viable.

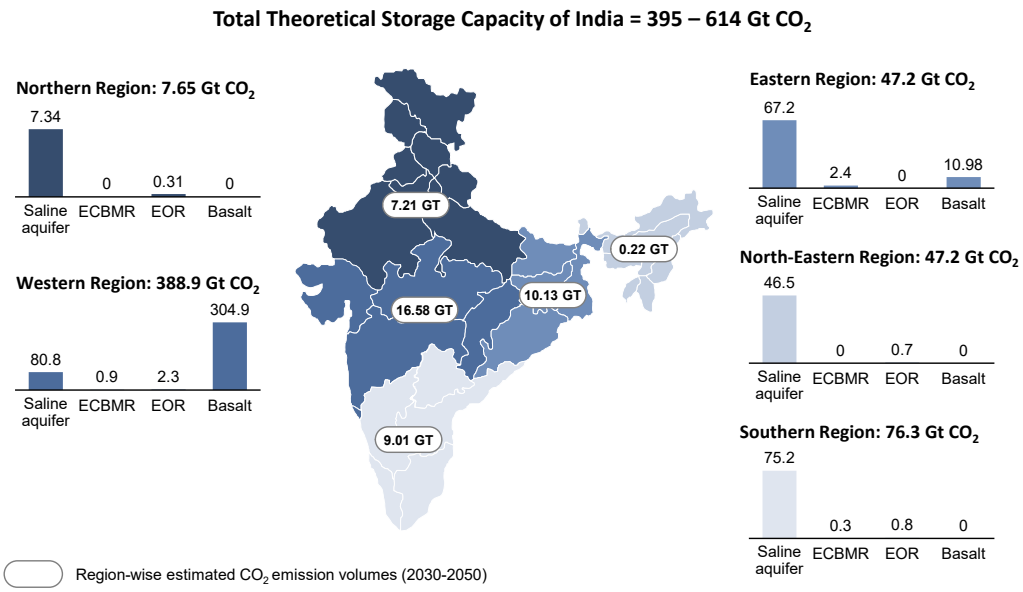
The Hub Model as a way forward

The Niti Aayog has proposed a hub model for Carbon Capture, Utilization, and Storage (CCUS) near high-emission areas, which has the potential to streamline efforts from multiple sources for greater efficiency and cost reduction. Theoretically, establishing five such hubs near storage sites could address about 70% of India's point source emissions within a 500-kilometer radius, underscoring their efficacy and strategic importance in the nation's climate action plan.

India boasts a theoretical carbon storage capacity ranging from approximately 395 - 614 Gt of CO2, with the western region promising the highest capacity at 388.9 Gt of CO2 and the

northern region the lowest at 7.65 Gt of CO2 (*see Figure 16*). This immense potential can be strategically harnessed through the hub model.

FIGURE 16: REGION-WISE CARBON STORAGE CLUSTERS IN INDIA



Gt = Gigatonne
Source: Carbon Capture, Utilization and Storage (CCUS) Policy Framework and its Deployment Mechanism in India, NITI Aayog

The hub model can be used to strategically harness India's theoretical carbon storage capacity of approximately 395 - 614 Gt of CO2

However, with the lack of a market-based model for incentivizing investments into these models, the government will have to initiate the push towards their development, facilitating the mobilization of private capital.

Transport and storage operators are capitalizing on the demand for specialized CO2 handling, including transportation and injection into subsurface geologies. The business case in the segment requires a mature market, lacking which the government has to act as a contractor for safe disposal, providing revenue for the transporter. This model is used in the Norway's Longship/Northern Lights, where the government is funding 80% of the investment costs and up to 95% of the operational costs for the initial transport and storage infrastructure.

Transport and storage operators are capitalizing on the demand for specialized CO2 handling, including transportation and injection into subsurface geologies

This evolving sector is particularly evident in regions like northern Europe, where dedicated carbon transport operators are emerging, suggesting potential growth and business expansion opportunities in similar markets, including India. A number of private industry companies, such as Antwerp@c, and public-private partnership initiatives, such as the aforementioned Norway's Longship/ Northern Lights have already started operating in the space in international markets.[165]

As the model matures, India will have a tall task ahead of it to modify and curate the model to the local context and ensure the appropriate stakeholders are involved in their corresponding capacities.

Increased governmental support globally for carbon capture technology adoption

While the Government of India has begun to undertake measures towards assisting the ecosystem, there are several other avenues that are being adopted by governments worldwide and are expected to be explored by their Indian counterparts as well.

This further support is likely through tax credits or subsidies, mirroring initiatives like the Inflation Reduction Act in the US, which provides substantial credits for sequestered emissions. On the demand side, measures such as public procurement of low-CO2 building materials, transport fuels, and power, including those produced with CCUS, are expected to be operationalized. This approach is akin to policies in Canada and the Netherlands, where rules favor low-CO2 material inputs for construction projects.[166]

Further government support through tax credits or subsidies, regulatory standards, and risk mitigation instruments would significantly accelerate India's carbon capture industry

Regulatory standards will also play a crucial role in the medium to long term, providing market advantages to firms implementing carbon capture technologies and regulating carbon-intensive processes. This could involve mandating the use of commodities, such as green steel or green cement, in construction projects, similar to the European Union's upcoming carbon border tax[167] and the UK's plan to phase out unabated gas power by 2035.[168]

Lastly, to mitigate the risks associated with the high upfront investment of carbon capture technologies, the government could also consider risk mitigation instruments. These might include loan guarantees for project developers, pain-gain risk-sharing mechanisms, and CO2 liability ownership post-project closure, as seen in Australia.[168]

These comprehensive government support measures, if implemented, would significantly accelerate India's carbon capture industry, seamlessly integrating it with the global shift towards a more sustainable future.

Summary of key trends in the GHG Capture, Removal, and Storage sector

- Public sector undertakings (PSUs) and private players are adopting Carbon Capture and Storage (CCS) and Carbon Capture Utilization and Storage (CCUS) technologies
- The Indian government has actively supported the sector through academic collaborations and market-based solutions
- While foreign firms are paving the way for R&D through local partnerships, domestic R&D efforts remain limited to academic institutions

Summary of future outlook for the GHG Capture, Removal, and Storage sector

- Maturing CCUS technologies in the global landscape are expected to make their way into India, and their adoption can drive down costs in the sector
- The hub model presents a centralized approach to Carbon Capture, Utilization, and Storage near high-emission areas, streamlining efforts from multiple sources for greater efficiency and cost reduction
- In line with the increased governmental support globally for carbon capture technology adoption, further measures from the Government would significantly accelerate India's carbon capture industry

8 Climate Change Management and Reporting

The climate change management and reporting sector is at a nascent stage both in India and globally. The landscape predominantly involves start-ups and companies specializing in emissions data monitoring, management, and reporting. Additionally, there's a focus on climate risk and resilience management, along with the generation of climate/earth data.

Investments in the Climate Change Management and Reporting sector

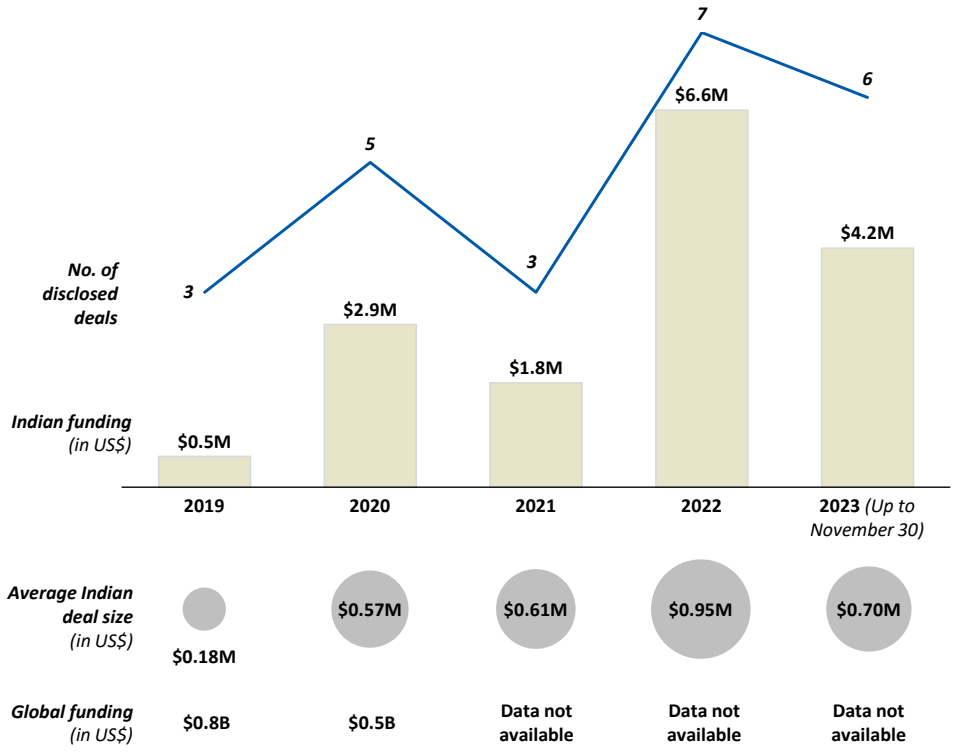
The climate change management and reporting sector is at a nascent stage both in India and globally

Investments in India's climate change management and reporting sector surged by a remarkable 474% from 2019 to 2020, rising from US$ 0.5 million to US$ 2.87 million. Notably, only four companies secured funding in 2020, with Blue Sky Analytics and Ambee collectively capturing 92% of the total funding. However, in 2021, investments dwindled to 64% of the previous year's funding, a trend attributed to investor caution amid the uncertainties brought about by the COVID-19 pandemic. Encouragingly, investments rebounded from 2021 to 2022, reaching a new high of US$ 6.64 million *(see Figure 17)*. In 2022, seven companies secured funding, with the start-up Varaha securing 60% and Climes accounting for 18% of the total investment in the sector. In 2023, the sector witnessed a 36% fall in funding from its peak. However, it was still a decent year compared to 2020 and 2021, with a total funding of US$ 4.21 million until the end of November. Two key players, sentra.world and Mynzo Carbon, together secured approximately 83% of the total funding in 2023.

Key trends in the Climate Change, Management, and Reporting sector

Key trends propelling climate change management and reporting forward include technological innovations such as GPS and sensor-based tracking systems and the escalating prominence of Software as a Service (SaaS) platforms. Further, there is a projected growth in the market for emissions monitoring systems, underscoring the increasing demand for and significance of these solutions.

FIGURE 17: INDIAN AND GLOBAL FUNDING LANDSCAPE FOR THE CLIMATE CHANGE MANAGEMENT AND REPORTING SECTOR, FOR CALENDAR YEARS 2019-23



Source: FSG Analysis based on Tracxn (FY19-23), Dealroom data

Technological developments like **GPS and sensor-based tracking systems are revolutionizing emissions monitoring**. GPS-based tracking systems can estimate the emissions produced during transportation by tracking the location and movement of vehicles. The benefits of GPS-based tracking systems include improved accuracy, increased efficiency, and reduced costs. GPS-based tracking systems can increase delivery efficiency by up to 30% and reduce fuel consumption by up to 20%. Sensor technologies are used for precise greenhouse gas (GHG) emissions measurements. These sensors can detect pollutants like carbon dioxide and nitrogen oxides in real time. Examples include onboard sensors in vehicles and stationary sensors at warehouses and distribution centers.[169]

GPS and sensor-based tracking systems, and the emergence of SaaS platforms, are revolutionizing emissions monitoring

In tandem, the **emergence of Software as a Service (SaaS) platforms for monitoring GHG emissions** is contributing to the advancement of the sector. Several key players have embraced this trend. SaaS platforms can play an important role in monitoring Scope 3 emissions, which are tough to estimate through traditional methods. For example, Accacia has a software suite that helps track Scope 1, Scope 2,

and scope 3 emissions, calculate financed emissions, and set net-zero targets for real estate companies. Varaha provides a SaaS-based Digital Monitoring, Reporting, and Verification (dMRV) platform to quantify GHG emissions and use this data to create carbon credits. FigBytes and StepChange have pioneered integrated SaaS platforms, encompassing modules for Environmental, Social, and Governance (ESG) strategy management, data handling, analytics, reporting, and stakeholder engagement. IBM's Environmental Intelligence Suite is tailored to minimize business disruptions triggered by severe weather and climate change. IFS expanded its Cloud platform with the IFS Cloud Sustainability Hub, a Microsoft Teams application focused on tracking GHG emissions and managing carbon footprints. Salesforce launched the Sustainability Cloud in 2019 to streamline sustainability reporting processes through its SaaS product.[170]

Deteriorating air quality is driving significant expansion in the emissions monitoring systems market

Besides the impact created by these technological innovations, **deteriorating air quality is driving significant expansion in the emissions monitoring systems market.**[171,172] Since 2019, the global emissions monitoring system market has been growing at a CAGR of 6%. The escalating demand for these systems, driven by deteriorating air quality, is evident in the projected growth of the global market size from US$ 3.2 billion in 2023 to US$ 5 billion in 2028. This reflects a substantial CAGR of 9.3% over 2023-28.

Meanwhile, as the need for climate change mitigation takes center stage across sectors, **regulators and investors are increasingly calling for emissions tracking at both direct and indirect levels**. Notable instances include the Sustainable Finance Disclosure Regulation (SFDR)[173], which compels European fund managers to report Scope 3 emissions in their portfolios from 2023.[174] The Science Based Targets initiative (SBTi)[175] sets criteria for companies pursuing validation of Scope 3 targets, particularly emphasizing near-term goals. Companies contributing 40% or more to the combined total of Scopes 1, 2, and 3 must proactively establish and report Scope 3 emissions targets to align with these evolving regulatory and investor expectations.

Though regulators and investors are increasingly calling for emissions tracking at both direct and indirect levels, very few companies effectively measure their emissions

India's Ministry of Power introduced amendments to the **carbon credits trading scheme** (CCTS) in December 2023, which **paves the way for a carbon offset market**, with the Bureau of Energy Efficiency (BEE) developing the standards and registering the project under offset mechanisms. The BEE is also responsible for validating the carbon credits generated in the country. Experts believe that developing new standards would save a lot of costs for the domestic companies that get their credits validated through global agencies under existing standards.[176]

However, currently, **very few companies effectively measure their GHG emissions**, with merely 10% comprehensively assessing both direct and indirect emissions in 2022, a marginal increase from 9% in 2021. Notably, an average error rate of 25-30% persists in emissions measurement practices. Surprisingly, only 12% of organizations prioritize the assessment of indirect emissions as their top concern, signaling a gap in addressing this crucial aspect of environmental impact within corporate sustainability practices.[177]

Future outlook for the Climate Change Management and Reporting sector

While the climate change management and reporting sector is currently nascent, some pivotal trends are moulding its future in India. Emerging global market dynamics that necessitate emissions monitoring, the use of innovative technologies, and a heightened focus on transparency, accountability, and sustainability are defining this evolution.

EU's Carbon Border Adjustment Mechanism (CBAM) will drive investment in robust data collection systems for accurate emissions tracking

Enforceable from 2026 as part of the EU Green Deal, the Carbon Border Adjustment Mechanism (CBAM) aims to impose carbon tariffs on energy-intensive products exported to the EU. India, with exports valued at US$ 7.4 billion to the EU in 2023, anticipates over 50% of these exports falling under CBAM. The US, the UK, Canada, and Japan are also contemplating similar proposals.[178, 179]

Since CBAM requires quarterly reporting of data, Indian companies will have to invest in setting up robust data collection systems to accurately track emissions throughout their production processes. They will have to collaborate with technology providers to develop software tools that can help streamline data capture and management for reporting.

To adapt to the challenge, the government should invest in green energy to reduce India's emissions. In response to the CBAM, India plans to introduce its own carbon tax and will invest in green energy through this tax.

Potential of IoT, blockchain and remote sensing technologies to revolutionize GHG emissions tracking and carbon credit trading[180, 181]

Unlocking the potential of IoT, blockchain, and remote sensing technologies holds the key to transforming GHG emissions tracking and carbon credit trading. Digital Monitoring, Reporting, and Verification (dMRV) leverages remote sensing, satellite imagery, and machine learning to automate the measurement and verification of carbon-reduction projects. When integrated with blockchain, dMRV ensures transparent, secure, and auditable records, providing a crucial boost to Voluntary Carbon Markets, which are projected to grow to US$ 10-40 billion by 2030.

Unlocking the potential of IoT, blockchain, and remote sensing technologies holds the key to transforming GHG emissions tracking and carbon credit trading

As India develops new standards for its carbon offset market, the reliability of these credits will be in focus as the value of carbon credits depends a lot on who certifies them and what standards are applied. Transparent and secure records on technologies like blockchain can help credits generated in India be accepted in the international markets.[176]

Legacy companies such as nurture.farm by UPL tried to create a platform for carbon credit generation through sustainable agriculture but saw limited uptake. Start-ups can craft innovative business models around these technologies to revolutionize GHG emissions management. For example, Agerpoint utilizes spatial intelligence for sustainable food systems, disease detection, carbon sequestration estimation, biodiversity assessment, and more through advanced technologies.

Increased adoption of Continuous Emission Monitoring Systems (CEMS) and Predictive Emission Monitoring Systems (PEMS)

As monitoring costs rise, Predictive Emission Monitoring Systems emerge as an attractive alternative, utilizing advanced computation models to predict emissions based on variables like pressure and temperature

The Continuous Emission Monitoring Systems (CEMS) market, currently valued at US$ 2.72 billion in 2023, is expected to grow to US$ 4.22 billion by 2033 at a CAGR of 4.5%.[182] This growth is propelled by factors like governments' stringent emissions reduction policies, rapid industrialization, heightened public health concerns, and the demand for energy efficiency. As monitoring costs rise, Predictive Emission Monitoring Systems (PEMS) emerge as an attractive alternative, utilizing advanced computational models to predict emissions based on variables like pressure and temperature. PEMS can cut operational costs by 50% over five years, eliminating the need for measurement-related hardware found in CEMS.[183]

Enhancing national emissions reporting accuracy and pinpointing emissions hotspots, satellites like GHGSat and MethaneSAT measure atmospheric concentrations of carbon dioxide and methane

Legacy companies are encouraged to implement CEMS to ensure effective monitoring of air pollution from their operations. Noteworthy examples include Honeywell and Siemens AG, which have successfully adopted CEMS for continuous measurement of air pollution concentration or mass. Additionally, Predictive Emission Monitoring Systems (PEMS) offer a valuable tool for legacy companies to predict emission concentrations based on process data. While adoption of PEMS is less common, companies like Unisearch Associates Inc. and Trace Environmental Systems Inc. have successfully utilized PEMS to enhance their emissions prediction capabilities.[184, 185]

Start-ups can capitalize on this trend by establishing ventures in this domain. For instance, Yokogawa America provides design and fabrication services for CEMS. This highlights an opportunity for start-ups to enter the market, offering specialized solutions and services in the design and implementation of CEMS, catering to regulatory requirements and contributing to the broader landscape of emissions monitoring and management.[186]

Advancement in satellite technology for GHG reporting

Enhancing national emissions reporting accuracy and pinpointing emissions hotspots, satellites like GHGSat and MethaneSAT measure atmospheric concentrations of carbon dioxide and methane. Scientists have innovated by comparing greenhouse gas inventories with space-based measurements, as exemplified by the Regional Carbon Assessment and Processes (RECCAP-2) project. High-resolution greenhouse gas measures are delivered by sentinel satellites of NASA, the European Space Agency, and the Chinese and Japanese space exploration agencies.[187, 188, 189]

Legacy companies stand to gain operational insights, thereby enhancing their sustainability efforts and bolstering their reputation. Notable examples include Chevron and Royal Dutch Shell, both clients of GHGSat.[190]

Satellite technology advancements for GHG reporting offer start-ups cost-effective monitoring and spur innovation. A prime illustration is Blue Sky Analytics, which is developing a geospatial intelligence platform utilizing satellite data for environmental monitoring and climate risk assessment.[191]

Increased emphasis on transparency in GHG reporting

A heightened focus on transparency in GHG reporting is evident through the initiatives of the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC has implemented robust transparency arrangements, ensuring the regular availability of data encompassing countries' GHG emissions, policies, progress towards targets, climate change impacts, adaptation measures, support levels, and capacity-building needs. To uphold transparency standards, the UNFCCC has established clear and standardized requirements for reporting national inventories.[192, 193]

Transparent reporting empowers legacy companies to pinpoint inefficiencies and high carbon intensity in their operations, offering a detailed understanding of their carbon footprint and uncovering opportunities for cost savings and operational enhancements. Walmart conducted a comprehensive assessment of its trucking fleet, supersize stores, and product offerings as part of a sustainability initiative. This effort resulted in a significant reduction of emissions equivalent to 22 million tons of carbon dioxide by 2015.[194] Likewise, Amazon sets a goal of achieving a 50% net-zero carbon footprint in its deliveries by 2030.[195]

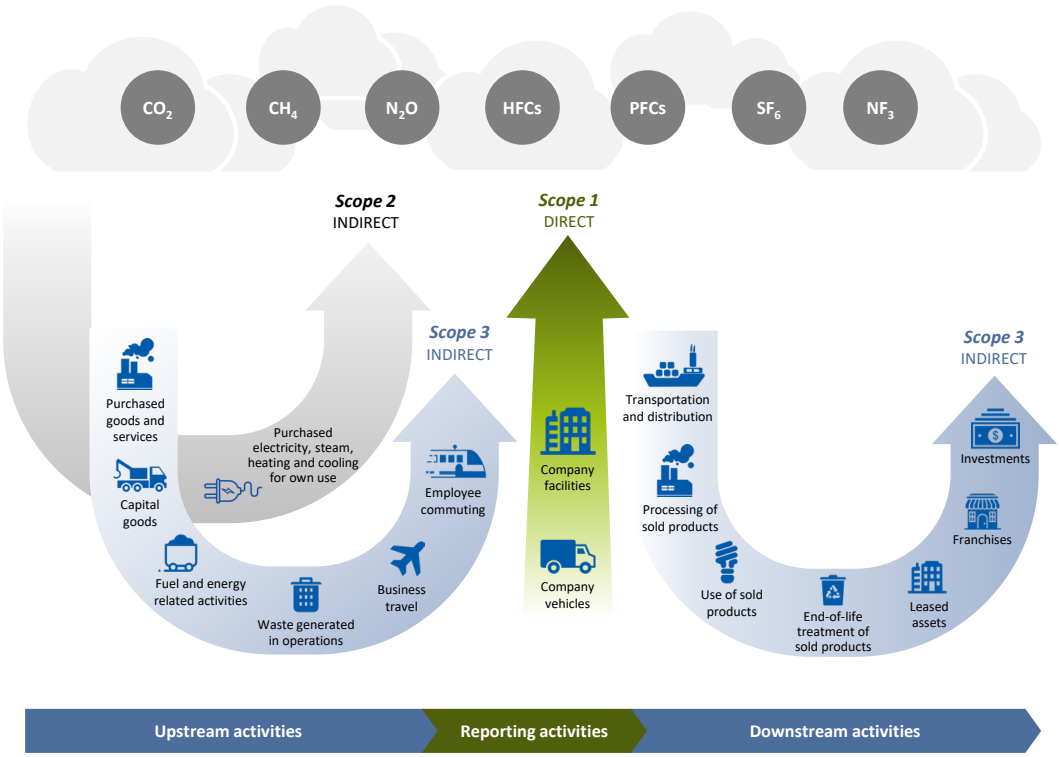
The government can actively implement policies promoting transparent and standardized disclosures on ESG parameters, as well as sustainability-related risks and opportunities for listed companies in India. India has already taken steps in this direction by mandating new ESG reporting requirements for the top 1,000 listed companies by market capitalization,

Transparent reporting empowers legacy companies to pinpoint inefficiencies and high carbon intensity in their operations, offering a detailed understanding of their carbon footprint

The government can actively implement policies promoting transparent and standardized disclosures on ESG parameters, as well as sustainability-related risks and opportunities for listed companies

effective from FY 2022-23. These requirements encompass detailed disclosure obligations, including GHG emissions reporting for Scope 1, Scope 2, and Scope 3 emissions (*see Figure 18*).[196]

FIGURE 18: GHG PROTOCOL SCOPES AND EMISSIONS ACROSS VALUE CHAIN[197]



Source: Adapted from Technical Guidance for Calculating Scope 3 Emissions, Greenhouse Gas Protocol

Summary of key trends in the Climate Change Management and Reporting sector

- GPS and sensor-based tracking systems are revolutionizing emissions monitoring
- The emergence of Software as a Service (SaaS) platforms for monitoring GHG emissions is contributing to the advancement of the sector
- Deteriorating air quality is driving significant expansion in the emissions monitoring systems market
- Regulators and investors are increasingly calling for emissions tracking at both direct and indirect levels
- The carbon credits trading scheme paves the way for a carbon offset market
- Currently, very few companies effectively measure their GHG emissions

Summary of future outlook for the Climate Change Management and Reporting sector

- EU's Carbon Border Adjustment Mechanism (CBAM) will drive investment in robust data collection systems for accurate emissions tracking
- IoT, blockchain and remote sensing technologies have the potential to revolutionize GHG emissions tracking and carbon credit trading
- Adoption of Continuous Emission Monitoring Systems (CEMS) and Predictive Emission Monitoring Systems (PEMS) is expected to increase
- Advancements in satellite technology are enhancing national emissions reporting accuracy and enabling the pinpointing of emissions hotspots
- A heightened focus on transparency in GHG reporting is becoming evident

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