Corporate Focus on ESG – Energy Crisis, Renewable Energy & Accelerating Net Zero Plans

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Corporate Focus on ESG – Energy Crisis, Renewable Energy & Accelerating Net Zero Plans

Includes

- **Global energy landscape:** Impact of the energy crisis, geopolitical developments and the accelerating transition to Net Zero.
- **Renewable energy trends:** Global and Indian developments in solar, wind, green hydrogen, battery storage and clean energy infrastructure.
- **Drivers of the energy transition:** Energy security, rising tariffs, ESG regulations, supply chain resilience and decarbonisation.
- **Policy & clean technologies:** National Green Hydrogen Mission, RPOs, EV incentives, battery storage, carbon capture and smart grids.
- **Carbon & ESG reporting:** Scope 1, 2 & 3 emissions, GHG accounting and leading reporting frameworks (BRSR, TCFD, CDP, SBTi).
- **Role of Consulting services:** ESG strategy, climate risk assessment, renewable energy transition and Net Zero implementation.

FOREWORD

Dr. Sandip Chatterjee

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Sr. Director Ministry of Electronics & IT New Delhi.

India is aspiring to achieve a trillion-dollar developed economy fuelled by digital technology, which is feasible through sustainability. As one of the fastest growing major economies, the country is at a critical juncture, transitioning towards a low-carbon and resource efficient model, while continuing to scale investments in infrastructure and energy systems. The ongoing global energy crisis has, in many ways, accelerated India's commitment to its long-term climate objectives. With a clear goal of achieving Net Zero emissions by 2070, the country is actively transforming its energy ecosystem through the rapid expansion of renewable energy, advancements in green hydrogen and a growing emphasis on energy storage and electrification. These efforts reflect a balanced approach to ensuring energy security, affordability and sustainability, while building resilience against future disruptions. From a market perspective, this transition presents significant opportunities across the energy value chain. Increased investments in renewable energy, clean mobility and industrial decarbonisation are creating new avenues for private sector participation.
A key enabler of this transition is the growing importance of critical minerals. Critical resources such as lithium, cobalt, nickel and rare earth elements are essential for clean energy technologies, electronics, storage systems, batteries, renewable power systems and electric vehicles. Recognising this strategic dependence, India has initiated measures to strengthen domestic exploration, streamline regulatory processes and secure supply chains. These efforts are crucial to reducing import dependence and

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ensuring long-term resource security. In parallel, the focus on resource efficiency and circular economy practices is gaining momentum. The E-Waste (Management) Rules, 2022 reinforce extended producer responsibility (EPR), promote organised recycling and encourage the recovery of valuable materials. This approach not only supports environmental objectives but also contributes to securing critical resources. Another important development is the increasing emphasis on sustainability reporting. Frameworks are encouraging organisations to move beyond compliance and adopt more structured and transparent disclosures. This shift enhances accountability, strengthens investor confidence and supports the integration of sustainability into core business strategies. It is at this opportune time, with the Government's continued emphasis on energy transition and sustainability and with investments and demand gaining momentum, that I am pleased to see RSM India, a well-regarded provider of consulting services, presenting this publication, "Corporate Focus on ESG – Energy Crisis, Renewable Energy & Accelerating Net Zero Plans." This publication aims to serve as a useful reference for a wide range of stakeholders, including investors, developers and corporates, by offering practical insights and supporting informed decision- making in an evolving energy landscape.

(Dr. Sandip Chatterjee)

FOREWORD

Dr. Satish Balantrapu

Principal Consultant, Infosys

India stands today at a defining point in its energy journey. What was once viewed primarily as a long-term climate aspiration has now become a strategic national imperative, central to economic growth, industrial competitiveness, energy security, and sustainable development. The transition to a cleaner energy future is no longer simply about replacing one source of power with another; it is about redesigning the very foundation of how energy is produced, delivered, managed, and governed.

In this transformation, renewable energy occupies a place of great significance. Its expanding role reflects not only the urgency of addressing climate change, but also the compelling opportunity to build a more resilient, self-reliant, and future-ready economy. India's progress in advancing clean energy capacity, strengthening policy support, and encouraging investment demonstrates both intent and momentum. Yet, the real promise of the transition lies not merely in adding renewable capacity, but in ensuring that the wider energy ecosystem evolves with equal speed, intelligence, and discipline.

The next phase of this journey will be shaped by the modernization of the grid. As renewable penetration increases and energy systems become more decentralized, dynamic, and data intensive, the need for intelligent grid infrastructure becomes paramount. Reliability, flexibility, and responsiveness will define the quality of the transition. In this context, artificial intelligence is emerging as a transformative force. From forecasting renewable generation and demand patterns to improving asset performance, outage management, and system balancing, AI has the potential to make the grid more

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predictive, adaptive, and efficient. It can help utilities move from reactive operations to anticipatory decision-making, an essential shift in a sector where precision, speed, and resilience matter enormously.

Equally important is the recognition that the energy transition is not solely a technological or infrastructural change. It is also a governance challenge and a leadership responsibility. The credibility of this transition will increasingly depend on how transparently organizations measure impact, disclose progress, and align their operations with long-term sustainability goals. Sustainability reporting, therefore, is assuming a far more important role than ever before. It is becoming a critical instrument of trust, enabling investors, regulators, customers, and communities to assess not only ambition, but accountability. The growing emphasis on materiality, credible baselines, and robust disclosures marks an important evolution in how businesses define value and stewardship in a rapidly changing world.

The themes explored in this publication are therefore both relevant and timely. The energy crisis confronting the world has also created an opportunity, to accelerate innovation, rethink legacy systems, and pursue a model of growth that is cleaner, smarter, and more inclusive. For India, this is not merely about meeting targets; it is about shaping a future in which energy becomes a driver of national strength, environmental responsibility, and shared prosperity.

The path ahead will demand bold vision, sustained collaboration, and disciplined execution. It will require governments, industry, utilities, technology providers, and financial institutions to work in concert, with a clear understanding that the transition must be commercially viable, operationally robust, and socially meaningful. If India can successfully combine renewable scale, digital intelligence, institutional capacity, and transparent governance, it will not only advance its own net zero ambitions, but also offer a powerful model for the world.

I commend RSM India for bringing together such critical perspectives at a time when both informed dialogue and decisive action are urgently required. I am confident that this publication will offer valuable insights and inspiration to all those dedicated to fostering a more resilient, transparent, and sustainable energy future.

(Dr. Satish Balantrapu)

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Executive Summary

Throughout history, societies have demonstrated a remarkable ability to adapt, innovate and emerge stronger in the face of disruption. Economic crises, natural disasters, pandemics and geopolitical conflicts have often acted as catalysts for change, reshaping priorities and reinforcing the importance of resilience. These events highlight that long-term success depends on growth, profitability, and especially the ability to anticipate risks, adapt quickly & build resilience across governments, businesses and communities.

Today, energy security has become a strategic priority for countries worldwide. Concerns over dependence on imported fossil fuels, coupled with price volatility and supply disruptions, are accelerating investments in renewable energy and energy efficiency. The European Union, with its high net energy imports, is expanding renewable energy and diversification efforts. Similarly, Japan and South Korea, both heavily dependent on energy imports, are accelerating clean energy deployment to strengthen economic resilience.

India faces a similar challenge. Net energy imports account for about 36% of the country's energy needs, compared with 24% for China, while the United States and Brazil are net energy exporters. At the same time, rapid industrialization, urbanization and infrastructure development continue to drive strong growth in energy demand. These trends underscore a critical reality: energy security and economic security are deeply interconnected. For a fast-growing economy like India, reliable, affordable and sustainable energy is essential for maintaining growth and competitiveness.

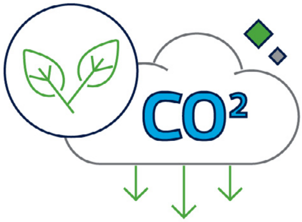
India's hard-to-abate sectors, including steel, cement, chemicals, fertilizers and heavy transport, account for more than half of the country's approximately 3 gigatons of annual CO_2 emissions. In response, renewable energy has evolved from an environmental initiative into a strategic business imperative. By reducing exposure to volatile fossil fuel markets, strengthening operational resilience and improving long-term competitiveness, clean energy is becoming central to business strategy. Many leading Indian companies are increasing their use of renewable power while also investing in renewable energy generation and infrastructure.

India is further supporting this transition through sustainable finance and policy initiatives such as Sovereign Green Bonds, the RBI Green Deposit Framework and the Carbon Credit Trading Scheme (CCTS). These measures are improving access to capital, incentivizing emissions reductions and accelerating corporate decarbonization efforts.

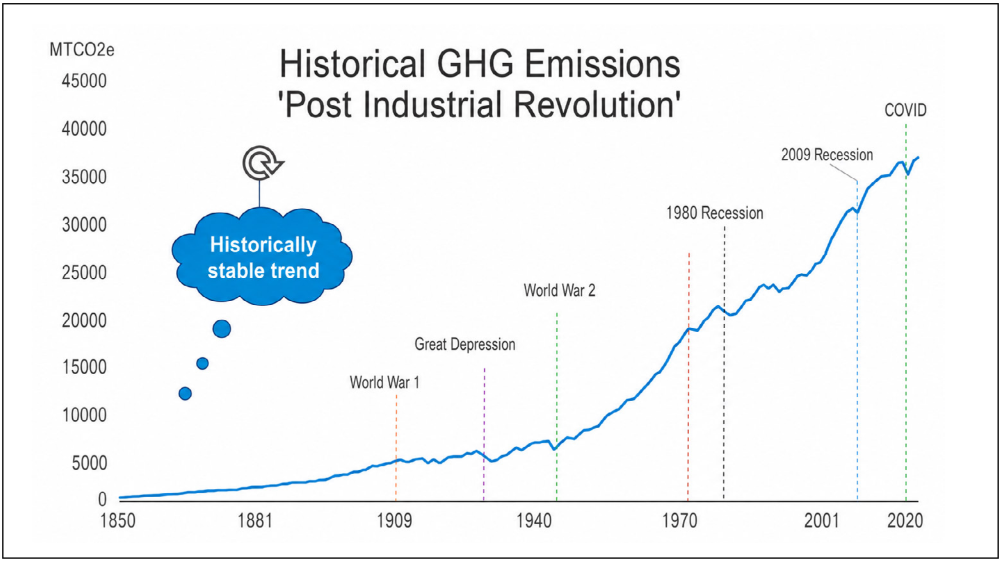
As a result, energy-intensive sectors are adopting renewable energy, electrification, energy-efficiency measures, alternative fuels, green hydrogen and other low-carbon technologies along with abatement measures such as carbon capture to meet increasingly ambitious emissions reduction and Net Zero goals. Sustainability is no longer viewed as a standalone ESG initiative; it is increasingly shaping core business decisions. For India, this transition offers an opportunity to strengthen energy security, reduce import dependence, foster innovation, create new industries and generate high-quality jobs. Companies that acknowledge past instabilities and act early will be better positioned to compete in a low-carbon economy while contributing to a more resilient and sustainable future.

Introduction

The roots of today's energy crisis can be traced back to the Industrial Revolution, when economic expansion became inseparably linked to fossil fuel consumption. While this era catalysed unprecedented industrial and social progress, it also established a carbon-intensive growth model that has led to rising atmospheric CO_2 concentrations, climate change, and long-term environmental stress. Over the time, the cumulative impact of industrial emissions has transformed energy from a purely economic input into a strategic, environmental, and geopolitical variable.



In recent decades, energy security has emerged as a defining feature of global geopolitics. Conflicts, trade disruptions, and concentrated control over fossil fuel reserves have exposed the vulnerabilities of nations dependent on imported energy. These geopolitical crises have reinforced the urgency for countries to rethink energy strategies not only to ensure affordability and reliability, but also to safeguard sovereignty and economic stability in a carbon-constrained world. As a result, the global energy transition has become as much about resilience and security as it is about climate responsibility.



Against this backdrop, global leaders and policymakers play a critical role in shaping the trajectory toward net-zero emissions. Through international cooperation, regulatory frameworks, and long-term climate commitments, governments are redefining how growth is achieved and measured. However, public-sector leadership alone is insufficient.

Simultaneously, capital markets have become a powerful catalyst for change. Investors are increasingly evaluating companies through an Environmental, Social, and Governance (ESG) lens, recognising that climate risks, resource scarcity, and social inequities pose material financial risks. ESG integration reflects a broader shift in value creation-one that prioritizes long-term resilience, transparency, and sustainable returns over short-term gains. This evolving investor mindset is reinforcing accountability across industries and accelerating the transition toward cleaner energy systems.

Within this global context, the energy crisis, the pursuit of net zero, and the rise of ESG are no longer separate conversations. They represent an interconnected response to historical emissions, present-day geopolitical realities, and future economic sustainability - setting the stage for national strategies, corporate transformation, and the various frameworks discussed throughout this publication.

1.1 Background

With the advent of recent energy crises and heavy dependence on other energy-exporting countries, the world's major economies have embarked on a transition toward energy self-reliance and decarbonization. This includes renewable energy (RE) deployment, prominently in recent years, localization programs of renewable energy, grid-scale integration of solar and wind, and long-term commitments toward net-zero emissions.

Since the turn of the 21st century, responsible economic growth and corporate conduct have increasingly been shaped by global environmental and sustainability frameworks. Multilateral agreements and protocols, such as the **Montreal Protocol (1987), Kyoto Protocol (1997),** and the **Paris Agreement (2015)**, have cumulatively reinforced the global commitment to sustainable development and resource conservation.

In response, countries have enacted domestic regulatory frameworks addressing environmental protection, social welfare, and institutional accountability. This shift reflects an evolution in how economies and organizations conceptualize growth, i.e., beyond short-term financial outputs toward a model that recognizes the finite nature of natural resources, including fossil fuels, forests, water, and agricultural assets, as well as the growing importance of stable, skilled, and a socially protected human capital.

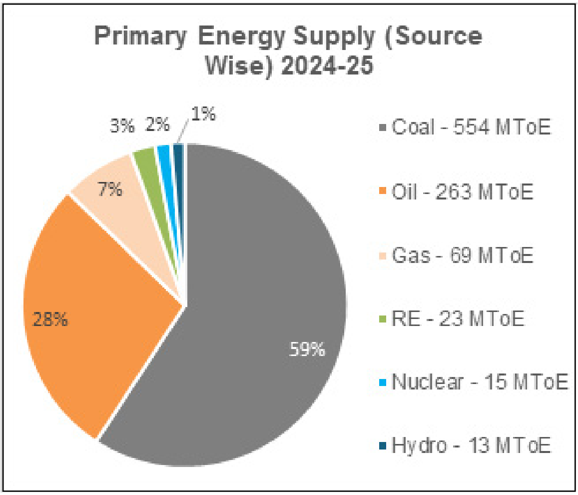
1.2 Energy Crisis, Price Volatility, Oil Dependence and Response from India

In this evolving policy and growth paradigm, global energy market dynamics, shaped by geopolitical tensions, supply disruptions, and price volatility, have become a critical external channel through which vulnerabilities in energy dependence manifest at the national level, particularly for import-reliant economies such as India. Any fluctuation in global energy markets directly transmits into the domestic economy through higher import bills, worsening current account deficits, currency depreciation, and inflationary pressures.

India's recurring exposure to global energy crises, sharp oil price volatility, and a structurally high dependence on imported crude oil has a profound impact on its economic stability and policy priorities. Out of India's current total energy supply of 42 billion GJ, India currently imports **over 85–90% of its crude oil requirement (approximately 25% of its total requirements)** and around 50% of its natural gas.

The global energy system is undergoing a profound and irreversible transformation, shaped by a convergence of structural, geopolitical, and environmental pressures. Unlike historical energy crises such as the 1970s oil crisis, which were largely cyclical and supply-driven, the current crisis is systemic in nature, however today, the countries are progressing with RE options. It reflects a global shift from a vulnerable global energy architecture for countries with excessive dependence on fossil fuels, geographic concentration of energy reserves versus future-ready low-carbon systems, including RE.

A defining trigger of the current crisis has been the ongoing conflict in West Asia, particularly the **2026 Iran war**, which has severely disrupted global energy supply chains. One of the most critical flashpoints has been the **Strait of Hormuz**, a strategic maritime chokepoint through which nearly **20% of the world's oil and a significant share of natural gas flows**. The effective blockage and militarization of this route have led to a sharp contraction in global oil supply, with exports from the Gulf region dropping significantly and millions of barrels being removed from the market.



This disruption has triggered immediate consequences across:

- Global markets' oil prices have surged sharply, with projections crossing **$100 per barrel,** intensifying inflationary pressures
- Global energy markets have witnessed what the International Energy Agency has described as the "**largest supply disruption in history**"
- Energy-importing economies, particularly in Asia, are facing **supply shortages and price volatility**

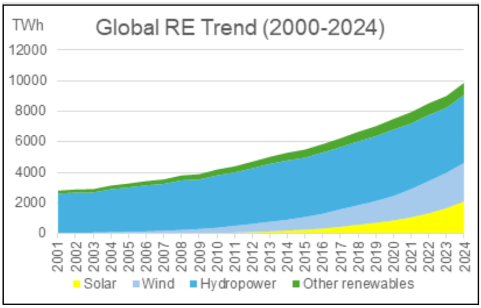
A sustained $10 per barrel rise in global crude oil prices can add roughly $13–14 billion to India's annual oil import bill, worsening the current account balance and putting pressure on the rupee. Given India's heavy reliance on imported energy, fluctuations in oil prices continue to pose material macroeconomic risks.

These vulnerabilities have gradually reshaped the country's approach to energy and climate policy. Renewable energy is no longer seen only as an environmental priority but increasingly as a tool for strengthening energy security and managing external economic shocks. Unlike fossil fuels, renewable sources such as solar and wind rely on domestic resources and have relatively stable cost structures, which helps insulate the economy from global commodity price swings. As a result, renewable expansion is now being positioned by policymakers as a way to curb import dependence, reduce external deficits, and limit exposure to geopolitical disruptions.

At the same time, the global energy system faces what is often described as a "transition paradox." While economies are moving toward cleaner energy, investment in conventional energy supply has fallen faster than renewable capacity, grids, and storage systems can scale up. This mismatch has created supply gaps, contributing to price volatility and greater uncertainty in energy markets.

Renewable energy deployment has nonetheless picked up pace in recent years, supported by falling technology costs, stronger policy frameworks, and growing investor focus on ESG considerations. While this momentum is encouraging, it has yet to deliver the scale and reliability needed to fully replace fossil fuels in the near term. This underscores the importance of managing the transition carefully – one that advances decarbonization without undermining energy security & affordability.

Consequently, India's policy response has shifted toward a multi-pronged strategy that integrates an increased mix of renewable energy in the grid, grid modernization, enabling small-scale users such as households and farmers to adapt to renewable energy, energy storage, and emerging solutions such as green hydrogen with broader energy security objectives.



Source: Our World India Data

1.3 Sustainability, ESG & Investor De-Risking

Renewable energy, which is abundantly available, is holistically considered a part of sustainable development, which is defined by the Brundtland Commission in their 1987 report, "Our Common Future," as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

ESG is often described as a practical subset of sustainability. While sustainability reflects the broader objective of long-term organizational viability (often associated with ideas such as endurance and resilience), ESG translates these objectives into measurable, non-financial indicators. The concept of ESG gained formal recognition with the 2004 United Nations—supported report Who Cares Wins: Connecting Financial Markets to a Changing World, developed under the UN Global Compact with participation from leading global financial institutions. The report highlighted that environmental, social, and governance factors are financially material, influencing long-term performance and risk-adjusted returns, and encouraged investors to integrate these considerations into core decision-making processes.

ESG metrics allow investors and stakeholders to assess, compare, and incorporate environmental, social, and governance risks into capital allocation decisions. In practice, ESG analysis helps evaluate how well an organization is positioned to manage challenges related to climate exposure, workforce stability, regulatory compliance, and governance quality over its business lifecycle.

From a conceptual standpoint, ESG aligns closely with the **Triple Bottom Line** framework introduced by John Elkington, which emphasizes value creation across **Profit, People, and Planet**. The underlying premise is that sustained financial performance cannot be separated from responsible environmental management and positive social outcomes. Enterprises that ignore ecological constraints or social externalities may generate short-term gains, but they undermine their **long-term** economic foundations.

As this thinking gained traction, sustainability gradually shifted from being viewed as a peripheral ethical concern to a core strategic and financial issue. Governments, regulators, and corporate leaders increasingly recognized that environmental degradation, social inequality, and weak governance structures pose tangible economic risks. These risks can affect asset valuations, disrupt supply chains, weaken credit quality, and ultimately undermine long term economic resilience.

Institutions such as the International Finance Corporation (IFC) played an important role in translating ESG from a conceptual framework into applied investment practice. By advising investors and project financiers, particularly in emerging markets, the IFC helped embed ESG risk management into large-scale infrastructure and development financing. Over the time, ESG evolved from a normative idea into a widely adopted investment and risk-assessment framework, used by asset managers, lenders, insurers, and regulators as a tool for capital preservation and risk mitigation.

In response to these interconnected risks, investor behaviour has shifted in a more structural way. ESG considerations are now embedded in capital allocation decisions, with ESG-linked assets exceeding $35 trillion and predicted to touch $ 40 trillion by 2040 globally. Investors increasingly assess companies based on factors such as climate risk exposure, carbon intensity, governance standards, and preparedness for the low-carbon transition, reflecting a growing recognition that sustainability and financial performance are closely intertwined.

Chapter 2 Global Energy Trends & RE in India

The reorientation of capital toward sustainability and transition readiness is unfolding alongside meaningful shifts in global energy markets. As investors and policymakers increasingly prioritize resilience, efficiency, and decarbonization, energy demand growth itself has begun to moderate, reflecting both structural changes in economic growth patterns and deliberate efficiency-led interventions. These evolving dynamics form the backdrop against which global energy trends are reshaping India's expanding and increasingly strategic role within the global energy landscape.

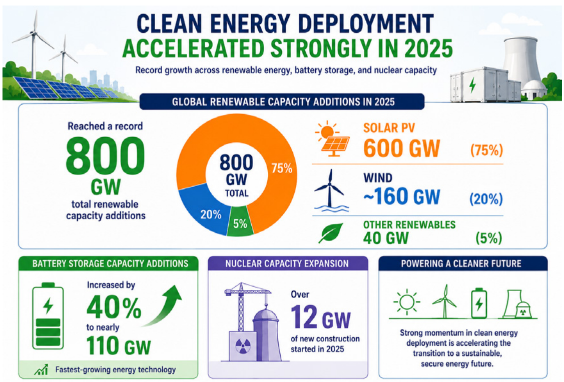
In the year 2025, global energy demand growth slowed to around 1.3%, down from approximately 2.0% the previous year and broadly in line with the average observed over the past decade. This slowdown was influenced by slightly weaker global economic growth, continued gains in energy efficiency, and lower weather-related demand, particularly for cooling. While emerging and developing economies continued to account for the bulk of demand growth, momentum softened across several major markets. China remained the single largest contributor, though its growth rate moderated to 1.7%, while India's energy demand expansion fell to one of its lowest levels in recent years.

Electricity consumption remained the main driver of energy demand growth, increasing by roughly 3% in 2025, more than twice the pace of overall energy demand. Although weaker than the surge seen in 2024, this trend reinforces the structural shift toward electrification across economies. Growth was spread across buildings, industry, and transport, with emerging economies responsible for most of the incremental demand. China alone accounted for more than half of global electricity demand growth, while electricity use from electric vehicles and data centres continued to rise rapidly, albeit from a relatively low base.

On the supply side, low-emissions sources met nearly 60% of the growth in global energy demand. Solar power emerged as the single largest contributor, followed by natural gas and oil. Within the power sector, additional generation from renewables and nuclear energy exceeded total growth in electricity demand, underscoring the ongoing transformation of the global electricity mix. Solar photovoltaic generation recorded a particularly strong increase, lifting its share of global electricity output to over 8%. Renewables accounted for roughly one-third of global electricity generation, while low-emissions sources reached their highest share in decades. Nonetheless, fossil fuels continued to play a dominant role, with coal remaining the largest single source of power generation worldwide.

Fossil fuel demand growth slowed across all major fuels. Oil demand increased by only ~0.7%, significantly below historical averages. Gas demand growth weakened sharply relative to the previous year, and coal demand expanded only grew marginally by ~0.4%. In the power sector, coal-fired generation declined slightly, marking a rare non-crisis-related contraction and highlighting the changing economics and policy environment facing thermal generation.

At the same time, clean energy deployment accelerated further. Global additions of renewable capacity reached record levels, driven overwhelmingly by solar power (~75%) and supported by continued growth in wind energy. Battery storage emerged as the fastest-growing segment of the energy system, reflecting its growing role in supporting grid stability and renewable integration. Nuclear capacity expansion also progressed, with over 12 GW of new construction started.



Growth in energy-related carbon dioxide emissions slowed further in 2025, rising by only around 0.4%. Despite this moderation, total global emissions still climbed to a new high of more than 38 billion tonnes. Short-term weather effects played a significant role, contributing an estimated 90 million tonnes to emissions for the year. Emissions trends varied sharply across regions: China recorded a modest decline, advanced economies saw a slight increase, and India's emissions were broadly unchanged. India's flat emissions profile (its first such outcome since the 1970s oil shocks) can be seen as a combination of expanding renewable capacity and unusually favourable monsoon conditions.

India's overall energy demand growth slowed markedly to about 1.1%, a sharp departure from the stronger pace observed in recent years. The early and intense monsoon reduced cooling needs, leading to particularly subdued electricity demand growth of roughly 1.3%, well below the levels typically recorded in recent summers. In several peak months, cooling demand fell by double-digit percentages, highlighting the sensitivity of short-term energy trends to climatic conditions.

Coal-fired electricity generation declined by around 3%, making 2025 only the third year in the past five decades to record such a fall. This decline was driven primarily by rapid renewable expansion and higher hydropower output. Overall coal demand also edged lower, although this was partially offset by strong growth in steel production, which continued to rely heavily on coal inputs.

Oil demand growth slowed to around 0.6%, influenced by a sharp increase in biofuel blending and softer transport activity. At the same time, natural gas demand fell by approximately 3.5%, with gas-based power generation declining by about 10% as renewables displaced marginal thermal output and milder weather reduced system stress.

On the clean energy front, India continued to play an important role in global renewable deployment, with large-scale additions of solar and wind capacity. However, rising shares of variable renewables are placing increasing pressure on the power system, underscoring the need for accelerated investment in grid infrastructure, energy storage, and broader system flexibility.

Viewed in aggregate, 2025 represents a transitional year for the global energy system. Demand growth slowed, efficiency gains strengthened, and clean energy sources accounted for most of the incremental supply. Electricity continued to shape overall energy trends, while growth across fossil fuels weakened further, reflecting underlying structural shifts rather than short-term volatility.

Although India's energy demand temporarily softened due to climatic factors, its long-term trajectory remains intact. The country continues to sit at the centre of global energy demand growth and clean energy expansion, with an increasingly important role in shaping the pace and direction of the global energy transition.

2.1 Energy Transition Drivers, Risks and Strategic Shifts

Recent energy trends suggest that the global system is undergoing a structural realignment rather than experiencing a temporary slowdown. Improvements in efficiency and the growing role of clean energy are reshaping demand patterns, even as persistent concerns around energy security and system resilience remain unresolved. For countries such as India, this interplay between moderating demand growth and long-term transition pressures underscores the importance of addressing the strategic forces and vulnerabilities shaping the global energy landscape.

The pace and direction of the energy transition are being influenced by several overlapping structural challenges. Geopolitical tensions have increasingly disrupted trade flows and supply chains, while sharp swings in fossil fuel prices have contributed to inflationary pressures and macroeconomic instability. At the same time, climate-driven extreme weather events are placing a growing strain on energy infrastructure, exposing weaknesses across power, fuel, and transport systems. Compounding these pressures is the concentration of critical energy resources-such as oil, gas,

and transition minerals in a small number of countries, leaving import-dependent economies particularly exposed to supply disruptions and strategic risk.

Against this backdrop, India occupies a relatively strong position due to its substantial renewable energy potential. Abundant solar and wind resources offer a pathway to expand domestic energy supply, reduce reliance on imports, and support long-term industrial development. This trajectory aligns with India's broader development ambitions, including its long-term economic growth objectives and its commitment to achieving net-zero emissions by 2070.

Reducing import dependence has emerged as a central driver of the energy transition. Fossil fuel markets are highly concentrated geographically, exposing economies to price shocks and geopolitical leverage. In response, governments are increasingly prioritizing energy strategies that lower import bills and reduce vulnerability to external disruptions. Rising geopolitical fragmentation has reinforced this shift, effectively transforming energy from a purely economic input into a strategic asset.

At the same time, tightening carbon constraints are accelerating the move toward low-carbon energy systems. With the remaining global carbon budget narrowing rapidly under current emission trends, the window for gradual adjustment is closing, increasing the urgency of decisive decarbonization efforts.

Renewable energy technologies sit at the centre of this transition because of their structural advantages. Resources such as solar, wind, and biomass are domestically available in many regions, have low operating costs once deployed, and support more decentralized energy systems. As electrification expands and technologies such as energy storage and green hydrogen mature, energy systems are gradually shifting toward power-centric models that reduce dependence on imported fuels.

Viewed together, the transition resembles a chain reaction. Global shocks-whether driven by price volatility, supply disruptions, or climate impacts-heighten concerns around energy security. These concerns, in turn, prompt policy responses that accelerate clean energy deployment: oil price spikes strengthen the case for renewables, supply risks drive investment in storage and hydrogen, and climate pressures push electrification across end-use sectors.

Within this evolving landscape, India is well positioned to leverage its renewable resource base, strengthen energy security, and play a more influential role in shaping a secure, sustainable, and low-carbon global energy system.

2.2 India's Energy Demand and System Evolution with RE

India's energy transition cannot be understood without considering the scale and direction of its underlying energy demand. While clean energy deployment is advancing rapidly, long-term forces such as population growth, rising incomes, urban expansion, and widespread electrification continue to reshape the country's energy system. This creates a dual challenge: demand growth strains energy security in the near term, yet it also drives the expansion of infrastructure and accelerates system-wide transformation over the long run.

India's final energy demand is projected to increase from 688 Mtoe in 2025 to 1381–1617 Mtoe by 2050 and 1465–1811 Mtoe by 2070, representing a 2.1–2.6-fold rise. Economic growth and urbanisation are steadily increasing energy use across households, industry, and transport, while electrification is shifting demand toward the power sector. As a result, electricity consumption is projected to grow significantly, accompanied by a substantial rise in per-capita usage as living standards improve. Importantly, this demand expansion is occurring alongside meaningful progress on the supply side; India has already achieved nearly 50% of its installed power capacity from non-fossil sources. Under long- term decarbonisation pathways, non-fossil generation is expected to dominate the electricity mix by 2070, supported by sustained investment in grid infrastructure and clean generation assets.

This evolution marks a clear departure from India's earlier energy strategy. Historically, planning focused on meeting basic needs quickly and affordably, with coal playing a central role in ensuring grid stability and supporting rapid electrification. Renewable energy was added gradually to meet incremental demand rather than to reshape the system itself. Over time, however, a combination of falling renewable costs, rising dependence on imported fuels, exposure to fossil-fuel price volatility, and growing climate risks prompted a strategic reassessment.

Today, India's energy approach is increasingly shaped by long-term commitments rather than short-term necessity alone. Renewables have moved from the margins to the centre of system design, influencing planning decisions across generation, transmission, and end-use electrification. India's Nationally Determined Contributions and the net-zero target have transformed energy planning into a forward-looking exercise, one that seeks to balance energy security, economic development, and decarbonisation, rather than treating them as competing objectives.

2.3 India's Climate Commitments and RE Integration

This evolution of India's power sector from a demand-driven, coal-anchored framework to a renewables-led, net-zero-aligned trajectory has been institutionalised through its climate commitments and policy architecture. The scale of non-fossil capacity deployment and long-term transition planning reflects not only technological and market shifts but also India's deeper engagement with global climate governance frameworks, which have progressively shaped domestic policy priorities and investment decisions.

India's involvement in defining its climate transition plan and ambitious targets came post the major watershed moment at COP21 in Paris in 2015, where the

Paris Agreement pivoted climate governance from binding targets for a few developing countries to universal participation through Nationally Determined Contributions (NDCs). The Agreement established the long-term objective of limiting global temperature increase to well below 2°C and pursuing efforts toward 1.5°C, fundamentally shifting carbon accounting toward economy-wide, forward-looking assessments rather than retrospective compliance alone. Unlike the Kyoto Protocol, the Paris Agreement did not mandate a uniform 50% reduction by 2030; instead, it required progressively ambitious, country-specific targets within a transparent accounting framework.

India's **original Nationally Determined Contributions** based on the Paris Agreement signoff outlined three key targets:

- Reduce emissions intensity of GDP by 33—35% from 2005 levels
- Achieve 40% cumulative installed electric power capacity from non fossil sources
- Create 2.5—3.0 billion tonnes CO_2e carbon sink through forests

Building on these commitments, Prime Minister Narendra Modi announced an enhanced five-point climate agenda at COP26 in Glasgow in 2021, known as the **Panchamrit goals:**

1. Achieving 500 GW of non-fossil fuel energy capacity by 2030

2. Meeting 50% of energy requirements from renewable energy by 2030

3. Reducing total projected carbon emissions by one billion tonnes by 2030

4. Reducing the carbon intensity of GDP by 45% by 2030, from 2005 levels

5. Achieving net-zero emissions by 2070

These commitments are closely aligned with the objectives of United Nations SDG 7 and SDG 13, which emphasize the transition to sustainable energy systems and urgent action to combat climate change.

Due to already achieving one of its targets of ~50% of installed electricity capacity from non-fossil sources achieved way ahead of its target timeline of 2030, in March 2026, India approved its NDC for the period 2031–2035, further enhancing ambition:

- Emissions-intensity reduction increased to 47% by 2035 from 2005 level
- Non-fossil electricity capacity target raised to 60% by 2035
- Carbon sink target expanded to 3.5–4.0 billion tonnes CO_2e

2.4 Long-Term Net Zero Pathway

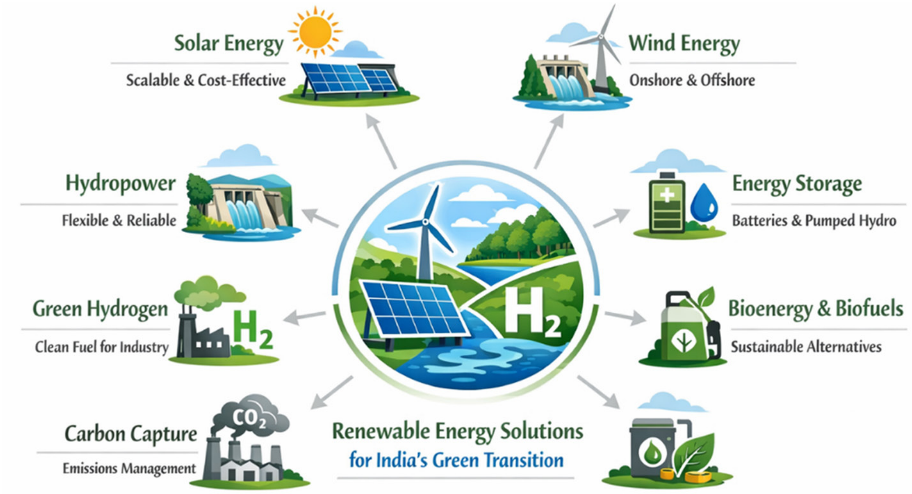
Renewable energy technologies sit at the core of India's shift away from a coal-centric power system toward a low-carbon future, but their roles are differentiated rather than interchangeable. Solar power has emerged as the main engine of this transformation, largely because it can be deployed at scale, remains cost-competitive across regions, and adapts well to both grid-connected and decentralized applications. Innovations such as floating solar and hybrid renewable projects further expand its usability in a land-and resource-constrained environment.

Wind power complements solar by helping smooth variability across seasons and time of day. The combination of onshore and offshore wind capacity adds geographic and temporal diversity to the power mix, strengthening overall system stability. Hydropower plays a different but equally important role by providing operational flexibility. Its ability to deliver peaking power and storage services makes it particularly valuable as renewable penetration rises and system balancing requirements increase.

Energy storage has become an essential enabler of this evolving system. Battery technologies address short-term balancing needs and grid stability, while long-duration options such as pumped hydro allow renewable generation to be shifted across days or seasons. Together, these technologies help move the system beyond incremental integration toward much higher shares of variable renewables.

For sectors where electrification alone is insufficient, alternative solutions are becoming increasingly relevant. Green hydrogen is gaining traction as a decarbonization pathway for emissions-intensive industries such as steelmaking, fertilisers, and heavy transport, as well as through derivatives like green ammonia. Bioenergy and biofuels provide additional flexibility, particularly in segments where direct electrification remains technically or economically challenging. The emphasis is gradually shifting toward advanced biofuels to address sustainability and land-use concerns. Carbon capture, utilisation, and storage is expected to play a limited but targeted role, helping manage residual emissions from fossil-based industrial processes as the broader transition unfolds.

Looking ahead, India has set a long-term goal of achieving net-zero emissions by 2070. Electrification is a key pillar, with electricity's share in total energy consumption expected to increase from 21% to around 60% by 2070. Renewable energy capacity is planned to scale significantly, exceeding 3000 GW of solar and wind power. Additional pillars include the adoption of green hydrogen for hard-to-abate sectors, circular economy practices such as recycling and efficiency and the deployment of carbon capture, utilisation, and storage (CCUS) for residual emissions.



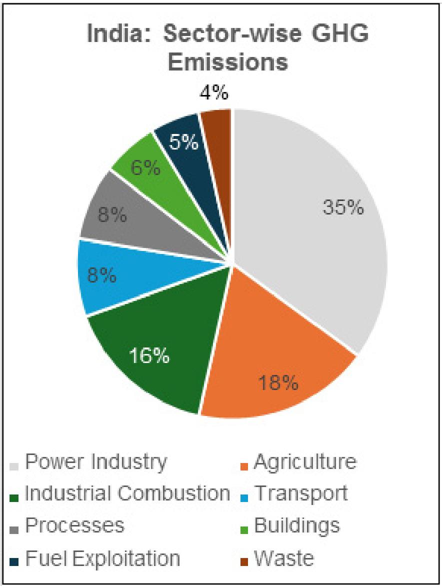
The transition pathway indicates a gradual shift from a coal dominated system in 2025 to a mixed system by 2050 and ultimately a renewable dominated system by 2070. During this period, electricity's share is expected to rise from 21% to about 40% and eventually to 60%, while oil consumption declines and approaches near elimination in the transport sector.

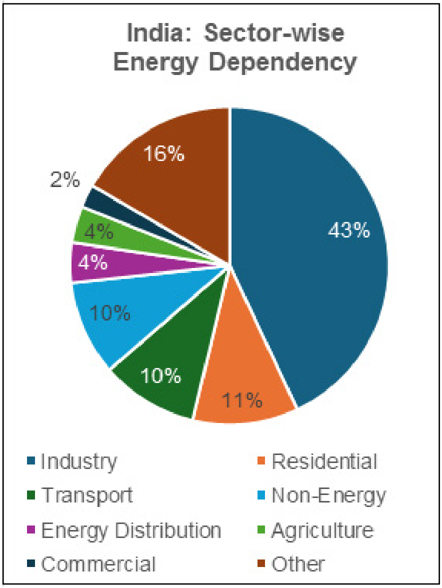
Chapter 3 Policy, Budget, and Investor Support

Turning India's long-term net-zero pathway into reality will depend on how effectively policy design translates ambition into action. This requires a coordinated policy framework that links emissions-reduction targets with sector-specific measures and clearly defined investment priorities. The scale of electrification, renewable expansion, and decarbonization envisioned in India's transition cannot be achieved through market forces alone; it calls for targeted government programmes, regulatory reforms, and fiscal support to address entrenched emissions sources and energy-use patterns across the economy.

India's greenhouse-gas emissions profile and its patterns of energy consumption provide a clear guide to where policy attention should be focused. Power generation and industrial processes account for the largest share of emissions, followed by agriculture and transport. At the same time, industry is by far the most energy-intensive sector, ahead of residential use and transport. This overlap suggests that the greatest near-term gains can be achieved by prioritizing the decarbonization of electricity generation and industrial energy use. Clean power and industrial electrification not only deliver large emissions reductions but also reduce dependence on imported fossil fuels.

Alongside this, accelerating transport electrification and efficiency, particularly in freight movement and public transport, remains essential, given the sector's rising energy demand and emissions footprint. Agriculture presents a different challenge. While it is less energy-intensive, it is a significant source of emissions, pointing to the importance of non-energy mitigation measures such as methane reduction, improved fertiliser practices, and climate-smart farming techniques.

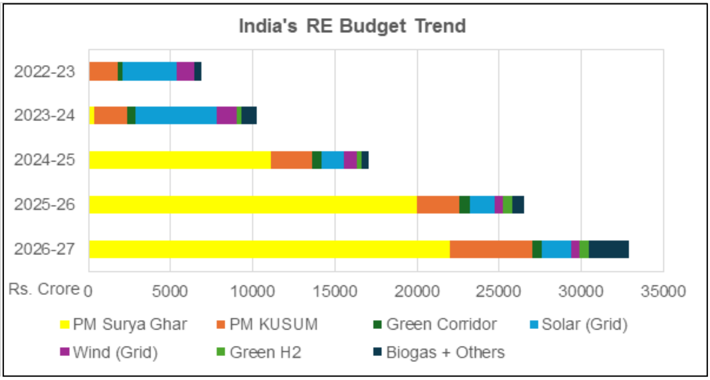




In response to these priorities, the Ministry of New and Renewable Energy, together with the Government of India, has rolled out a broad set of schemes, subsidies, and policy initiatives aimed at scaling up renewable energy and supporting the wider clean-energy transition across households, farms, and industry. A defining feature of the current approach is its emphasis on decentralised implementation-ranging from rooftop systems and agricultural applications to large, grid-connected renewable projects-combined with regulatory mechanisms designed to simplify deployment while maintaining oversight and system reliability.

3.1 Fiscal Support and Investment Momentum in RE & Clean Energy

India's policy direction continues to prioritise sustainability, with a strong push toward decarbonisation reflected in recent fiscal allocations. In the FY 2026–27 budget, approximately Rs.33,000 crore has been earmarked to advance the country's renewable energy strategy under flagship initiatives such as *Make in India and Atmanirbhar Bharat*. Solar and wind energy remain central to this transition, supported by nearly Rs.22,000 crore through schemes like PM Surya Ghar and KUSUM. At the same time, emerging solutions such as bioenergy and green hydrogen are gaining traction as complementary pathways, supported by grid infrastructure capable of handling over 260 GW of renewable capacity through the Green Energy Corridor.



Decarbonisation efforts are also reshaping India's transport ecosystem. Ongoing programs like PM E-DRIVE, expansion of rail and metro electrification, and the development of high-speed rail corridors are accelerating this shift. The Ministry of Power has further allocated Rs. 1,176 crore toward energy efficiency initiatives and viability gap funding for battery energy storage systems (BESS), which are critical for integrating intermittent renewable sources into the grid.

Additionally, the introduction of carbon capture, utilisation, and storage (CCUS) with an outlay of Rs. 20,000 crore over five years, alongside increased emphasis on nuclear energy through the Sustainable Harnessing and Advancement of Nuclear Energy for Transforming India (SHANTI) Act, highlights a broader and more diversified pathway toward achieving net-zero goals. Policy support has been reinforced through import duty exemptions on key components for BESS, solar, and nuclear infrastructure, offering relief to industry stakeholders. Budgetary trends across strategic sectors indicate a sustained commitment to long-term growth and resilience. Total allocations have risen steadily in recent years, with significant investments directed toward rail and metro infrastructure, nuclear energy, and energy transition initiatives. These spending patterns underline India's intent to strengthen its position as a competitive and self-reliant global economy, aligned with its aspiration of becoming the world's third-largest economy.

Strategic Sustainability Initiatives: Budget Provisions (INR Crore)					
Budget (Y-O-Y)	**2022-23**	**2023-24**	**2024-25**	**2025-26**	**2026-27**
Green Mission	188	220	160	220	213
Rail & Metro	29757	33815	39691	46239	43740
Sus. Agriculture	0	0	91	91	97
Nuclear Energy	7436	6963	5767	6126	7122
Transport (E-Drive)	2908	5172	4429	4000	1586
Efficiency / BESS	60	135	118	356	1176
Grand Total	**40349**	**46305**	**50256**	**57032**	**53933**

Beyond public spending, private sector participation is playing an increasingly important role. Large Indian conglomerates are channeling capital into future-focused industries, including green hydrogen, renewable energy, semiconductors, and electric mobility. Planned investments of approximately Rs.67.4 trillion (around US$800 billion) by 2034 signal a decisive shift toward low-carbon technologies and advanced manufacturing, reinforcing confidence in the country's long-term transition outlook.

According to data from the Department for Promotion of Industry and Internal Trade (DPIIT), cumulative Foreign Direct Investment (FDI) in non-conventional energy reached approximately Rs. 2.04 trillion (US$23 billion) between April 2000 and mid-2025, indicating strong long-term capital inflows.

The policy framework allows 100% FDI under the automatic route across renewable energy segments, including solar, wind, energy storage, and green hydrogen, enabling direct participation from global investors.

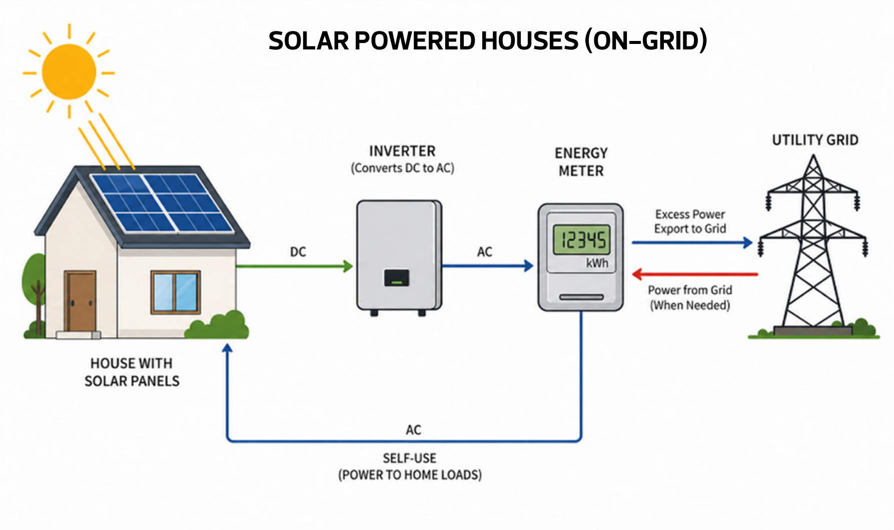
Investment activity has accelerated in the post-pandemic period, supported by policy stability, large-scale project pipelines, and increasing global capital allocation toward clean energy.

3.2 Household Sector Initiatives: Rural & Urban

India's rural energy landscape is shaped by its scale and diversity. Large distances between settlements, difficult terrain, and gaps in last-mile connectivity continue to make electricity distribution challenging. Although nearly 70% of the population lives in rural areas, the quality and consistency of power supply still lag urban standards. Over the years, government-led electrification drives have significantly expanded grid access, but reliability, affordability, and the high cost of extending infrastructure to remote regions remain ongoing concerns.

At the same time, decentralized energy solutions have yet to reach their full potential. Only a small share of rural households-estimated at around 2.4%-currently use solar-based systems. This points to a significant opportunity to expand access through localized technologies. Rooftop solar installations and standalone solar home systems can offer practical and scalable alternatives where grid connectivity is weak or inconsistent, while also contributing to broader sustainability goals.

Several national schemes are working to address these gaps at the household level. The PM Surya Ghar Muft Bijli Yojana, for instance, aims to bring rooftop solar to one crore homes by offering subsidies of up to 40% for smaller systems. By enabling access to up to 300 units of free electricity per month, the scheme directly reduces household energy expenses. Other initiatives complement this effort: the UJALA programme has driven widespread adoption of LED lighting, improving energy efficiency, while the Pradhan Mantri Ujjwala Yojana has expanded access to cleaner cooking fuels. Meanwhile, the Saubhagya scheme has played a key role in achieving near-universal electrification, and Mission LiFE promotes more sustainable consumption habits at the individual level.



On the broader renewable energy front, the Grid Connected Rooftop Solar Programme (Phase II) focuses on scaling adoption, particularly in urban and semi-urban areas. With an outlay of approximately Rs.11,814 crore, the programme targets 40 GW of rooftop capacity. Financial support is structured to make adoption more accessible, with subsidies ranging from 20% to 40% for residential users depending on system size. While households receive direct support, commercial and institutional segments are largely driven by regulatory incentives and market dynamics rather than subsidies.

3.3 Sustainable Agriculture – A Game Changer

India's agriculture sector, which supports a large share of the population, is increasingly under pressure to become more sustainable. A major challenge lies in how efficiently resources are used across the value chain, particularly after harvest. Despite being one of the largest producers of agricultural commodities globally, the country loses an estimated 78–80 million tonnes of food each year-worth ~ Rs.1.5 lakh crore. Much of this loss can be traced to gaps in storage infrastructure, limited cold chain networks, and low levels of food processing.

The problem is especially severe for perishable crops. Nearly 30–40% of fruits and vegetables are lost before reaching consumers, while only about 8–10% of total agricultural output is processed. This not only limits income opportunities for farmers but also results in significant waste of water, energy, and land. Addressing these inefficiencies requires a shift toward more sustainable and decentralized solutions. Solar-powered technologies-such as irrigation systems, drip irrigation, cold storage, and small-scale processing units-are emerging as practical tools to reduce losses and improve farm-level economics. In this space, initiatives like PM-KUSUM are helping connect clean energy with agriculture, creating a pathway toward a more resilient agri-food system.

The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) is one of the key schemes driving this transition. With an overall allocation of around Rs.34,422 crore, the programme aims to add close to 34.8 GW of decentralized solar capacity in the agricultural sector by 2026. It is structured in three parts: Component A focuses on setting up 10 GW of small, ground-mounted solar plants (up to 2 MW each), Component B supports the installation of 2 million standalone solar pumps, and Component C targets the solarisation of 1.5 million existing grid-connected pumps.

The scheme is designed to reduce the financial burden on farmers. Up to 60% of the project cost is covered through subsidies, while another 30% can be financed through low-interest loans, leaving farmers to contribute roughly 10% upfront. Evidence suggests that solar-powered irrigation under PM-KUSUM can produce electricity at Rs.3—4 per kWh, significantly lower than the Rs.6—7 per kWh cost of conventional supply. This difference can translate into substantial savings for state governments that currently bear high agricultural power subsidies. For example, even limited solarisation-covering just 10% of agricultural feeders-could generate long-term savings of over Rs.6,000 crore in states like Madhya Pradesh over a 25-year period.

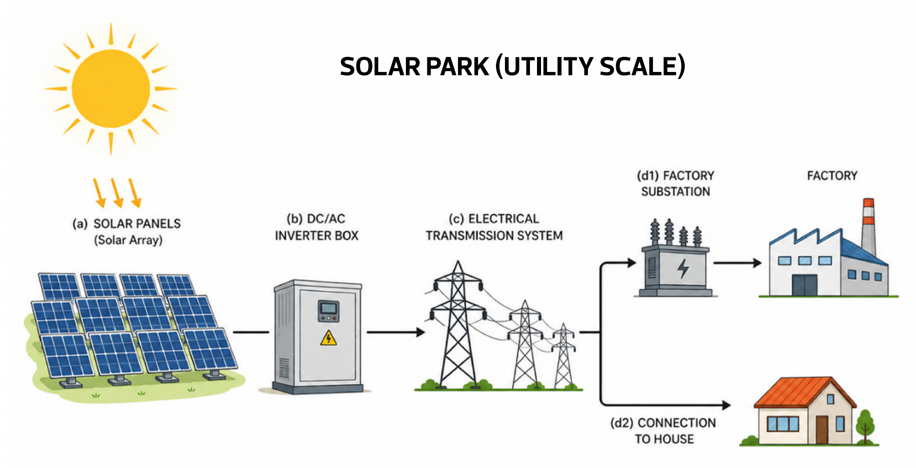
There are also direct income opportunities for farmers. Solar installations can generate returns in the range of 11—16% annually, and in some cases, farmers can earn lease income of around Rs.30,000 per acre. However, progress on the ground has been uneven. Deployment remains relatively low in certain components-around 8.4% under Component A and 38.2% for feeder-level solarisation. Key challenges include land constraints, grid integration issues, access to financing, and limited awareness among stakeholders.

3.4 Utility-Scale Renewable Programs

At the utility scale, the Solar Park Scheme plays a key role in expanding India's solar capacity by enabling large, ready-to-develop project sites. The programme targets the development of around 50 solar parks with a combined capacity of 40 GW. By offering pre-developed land and shared infrastructure, it reduces project risks and speeds up deployment timelines for developers. Financial support under the scheme includes assistance of up to Rs. 25 lakh per park for preparing Detailed Project Reports, along with additional funding of up to Rs. 20 lakh per MW or 30% of the infrastructure cost, whichever is lower.

Alongside solar expansion, the National Bioenergy Programme is focused on diversifying the renewable energy mix. With a Phase-I budget allocation of Rs.

858 crore for the period 2021–2026, the programme supports projects based on biogas, biomass, and waste-to-energy technologies. It provides capital subsidies to help offset initial costs, making such projects more financially viable, particularly in decentralized and rural settings where these solutions can be most effective.



3.5 Industrial and Market-Based Mechanisms

On the industrial and manufacturing front, policy efforts are increasingly focused on strengthening domestic capabilities while lowering carbon intensity. The Production Linked Incentive (PLI) Scheme for High Efficiency Solar PV Modules, with a total allocation of Rs.24,000 crore, is designed to scale up local manufacturing of advanced solar technologies. By encouraging domestic production, the scheme also aims to reduce reliance on imports and build a more resilient supply chain.

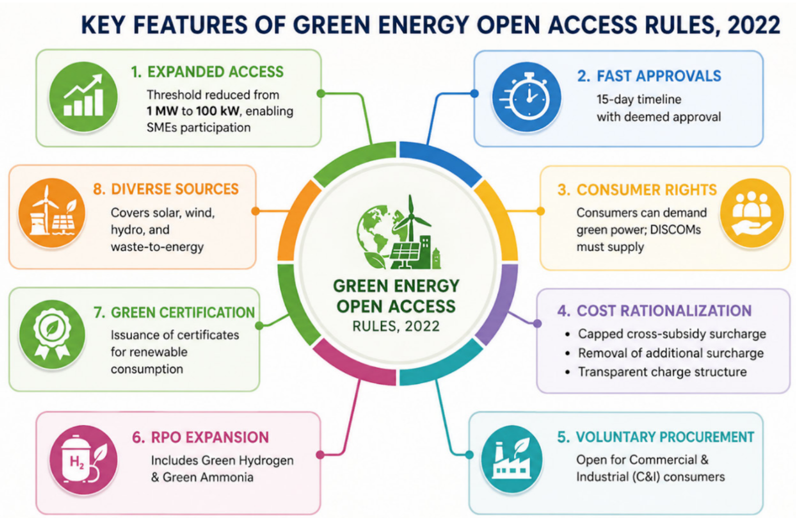
At the same time, energy efficiency remains a key priority for industry. The Perform, Achieve and Trade (PAT) scheme takes a market-driven approach by setting specific energy reduction targets for energy-intensive sectors. Companies that exceed their targets can trade energy saving certificates, creating a financial incentive for improved performance.

Expanding on these efforts, the Carbon Credit Trading Scheme (CCTS), introduced in 2023, lays the foundation for a domestic carbon market. Under this framework, emission reductions can be converted into tradable carbon credits, encouraging industries to actively lower their greenhouse gas footprint.

In addition to these measures, green public procurement is emerging as an important demand-side lever. By prioritizing the purchase of energy-efficient and low-carbon products, government agencies can help create stable market demand and accelerate the broader shift toward cleaner industrial practices.

3.6 Green Energy Open Access

India's target of reducing emissions intensity by 45% by 2030, as outlined in its updated Nationally Determined Contributions (NDCs), places significant pressure on the power sector to evolve. One of the key steps in this direction has been the introduction of the Green Energy Open Access (GEOA) Rules, 2022, under the Electricity Act, 2003. These rules are designed to make it easier for a wider set of consumers to procure renewable energy, while also helping lower power costs and improve overall system efficiency.



By expanding eligibility to smaller consumers and simplifying access procedures, the GEOA framework opens renewable energy markets beyond large industrial users. It also creates space for integrating newer technologies and business models in green power procurement. Taken together, these changes improve transparency, encourage competition, and support a gradual shift toward cleaner energy use–aligning the power sector more closely with India's 2030 climate goals.

Chapter 4 Accelerating India's Green Growth & RE Transition

India's pathway to net zero will depend on more targeted and sector-specific strategies rather than a one-size-fits-all approach. Policies already in place-such as building efficiency codes, EV and biofuel programs, renewable energy targets, and circular economy initiatives-provide a strong foundation across key sectors. At a broader level, "Green Growth" has emerged as a central national priority, linking climate action with economic development. This includes expanding solar use in agriculture, enabling MSMEs to adopt cleaner technologies, and generating employment in sectors like construction, mobility, and waste management.

4.1 Individual and Industrial Decarbonisation Pathways

At the individual level, achieving net zero follows a structured pathway beginning with baseline emissions assessment, followed by demand reduction, electrification, renewable energy adoption, offsetting of residual emissions and continuous monitoring. Demand-side behavioural changes alone can reduce emissions by 40–70% by 2050, supported by digital tools such as smart meters that improve energy efficiency by 5–15%. Individuals contribute through rooftop solar adoption, use of energy-efficient appliances, electrified mobility, reduced consumption, and circular practices such as recycling and composting.

A structured approach must be taken for industrial decarbonization to optimize efforts in implementation and financing, through the following process:

- **Baseline Assessment & Tracking:** Establish current emissions through carbon accounting and adopt digital tools.
- **Process Efficiency & Optimization:** Improve energy and material efficiency across operations to reduce waste and lower overall emissions intensity.
- **Electrification of Operations:** Shift from fossil fuel-based processes to electric systems where feasible. Impact: Can reduce industrial emissions by

~15–25%.

- **Renewable Energy Integration:** Increase the share of clean energy through on-site generation or open access procurement to further decarbonize energy consumption.
- **Circular Economy Practices:** Adopt recycling, reuse, and resource efficiency measures, especially in material-intensive industries. This measure can potentially contribute to ~20–25% emissions reduction.
- **Adoption of Green Hydrogen:** Use green hydrogen as an alternative fuel/ feedstock in hard-to-abate sectors such as steel, cement, and chemicals.
- **Carbon Capture, Utilisation and Storage (CCUS):** Deploy carbon capture technologies for residual emissions where direct reduction is difficult. In the long-term role, Hydrogen + CCUS together may contribute **30–35% of industrial decarbonisation by 2050.**
- **Enabling Systems & Digital Infrastructure:** Use carbon management platforms and data systems such as Monitoring, Reporting, and Verification (MRV) systems to track performance, ensure compliance, and optimize emissions reduction strategies.

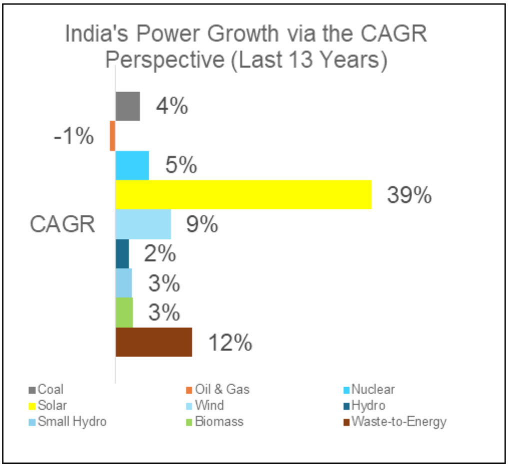
Achieving this transition at scale requires strong enabling conditions, including an estimated investment of approximately $22–23 trillion for India to reach net zero by 2070. Advancements in energy storage, green hydrogen, and carbon capture technologies, supported by policy instruments such as carbon markets and financial incentives, are critical.

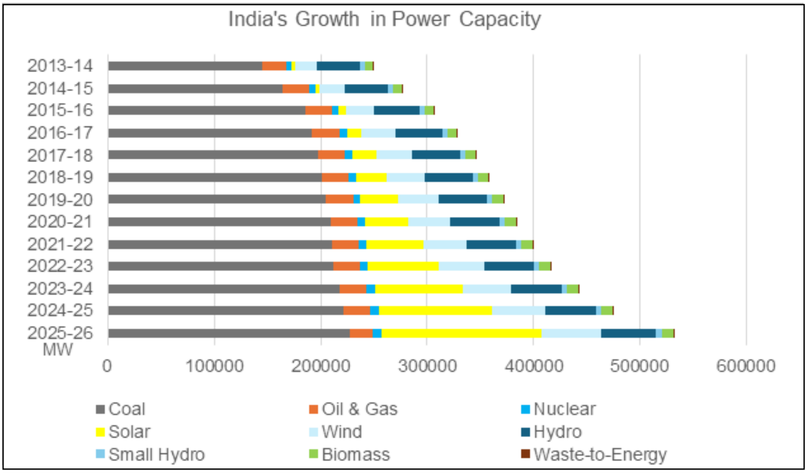
4.2 India's Renewable Energy Milestones

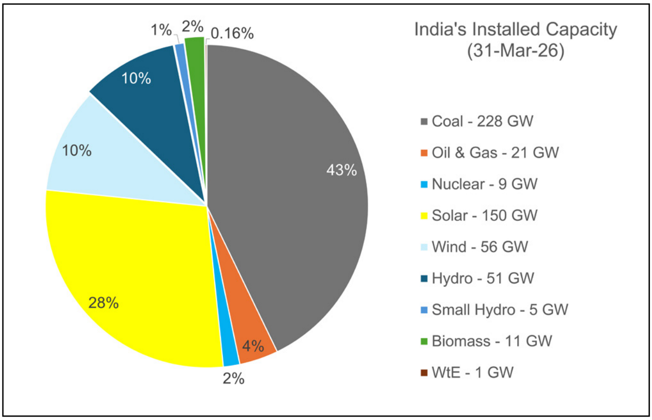
In March 2026, a total of 8,000.24 MW was added, led by solar power (6,656.35 MW), followed by wind (962.34 MW) and smaller contributions from biomass, waste-to-energy, and large hydro (250 MW).

For the full FY 2025–26, total additions reached 54,591.78 MW, again dominated by solar (44,614.25 MW) and wind (6,057.02 MW), with modest growth in other segments, including small hydro and waste-to-energy.

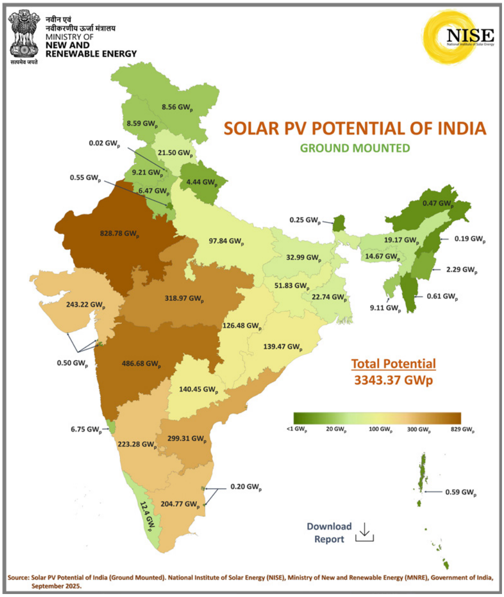
Cumulatively, India's renewable energy capacity stood at 274,688.10 MW as of 31 March 2026. Solar remains the largest contributor (150,260.70 MW), followed by wind (56,094.84 MW) and large hydro (51,414.67 MW), while biomass, waste-to-energy, and small hydro contribute smaller shares. The country surpasses Japan to become the world's third-largest solar power producer. Renewable energy attracts rising global investor interest, with the share of FDI increasing significantly and billions of dollars flowing into the sector.



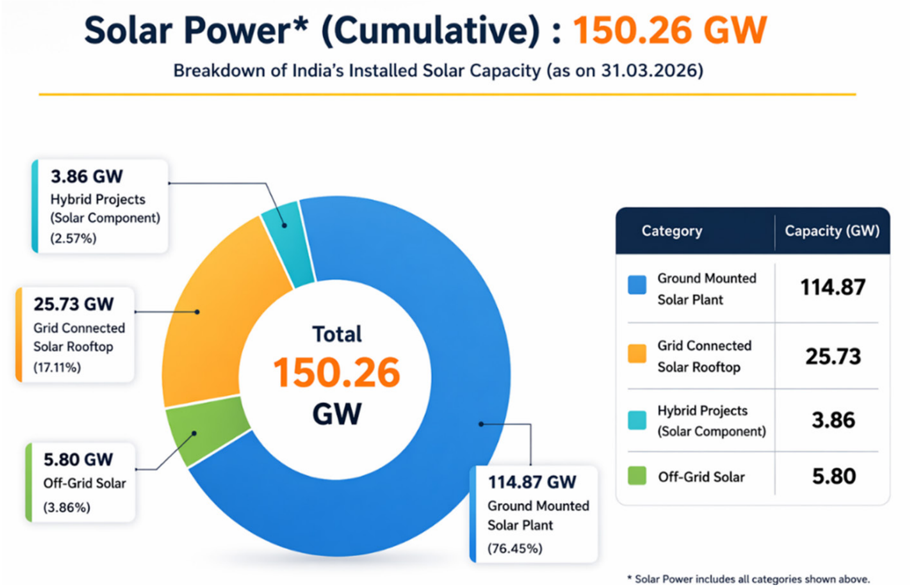




The growth profile of India's power sector across fuels and technologies highlights a clear structural shift toward renewables. Solar energy has emerged as the dominant growth driver, expanding from about 2.8 GW to over 150 GW over the period shown, translating into a 39% CAGR. Wind power has continued steady expansion, increasing from roughly 21 GW to 56 GW at a 9% CAGR, while waste-to-energy, though small in absolute terms, shows strong momentum with a 12% CAGR. On the fossil and legacy side, coal capacity has grown slowly (~4%), while oil and gas have contracted (-1%), reducing dependence on fossil fuel and oil imports.



To reduce dependence on grid integration of variable solar energy input, the Government of India is focusing on more decentralization of solar projects such as off-grid solar rooftops, with focus on PM KUSUM and PM Surya Ghar Muft Bijli Yojana.



Source: MNRE, GoI

India's renewable energy leadership in solar and wind is shaped by resource availability and proactive policies. Rajasthan, Gujarat, and Maharashtra dominate solar power due to abundant land and high solar irradiance, enabling large-scale projects such as Bhadla Solar Park in Rajasthan and hybrid solar-wind parks in Gujarat.

For wind energy, Gujarat leads with its extensive coastline and strong wind corridors, supported by robust infrastructure and state incentives. Tamil Nadu and Karnataka have also leveraged policy support to establish wind power sites in their regions. These states exemplify how geographic advantages combined with strategic planning have driven India's progress toward renewable energy expansion and Net Zero goals.

Additionally, India strengthens its infrastructure through ambitious transmission plans, expanded grid capacity, and growing integration of storage and emerging technologies such as green hydrogen. The sector witnesses record capacity additions, rising investments and strong government backing, positioning India to achieve its target of 500 GW renewable energy capacity by 2030 while supporting sustainable growth, energy security, and employment generation.

4.3 Grid Infrastructure and Digitalisation

Grid infrastructure and digital systems play a central role in supporting India's growing renewable energy capacity. Expanding transmission networks, along with the adoption of smart grids and energy storage, is helping the power system handle higher shares of renewable energy more reliably.

Alongside physical infrastructure, digital tools are becoming increasingly important. Technologies such as smart meters, real-time monitoring, and improved forecasting help operators better manage fluctuations in solar and wind generation. This allows for quicker responses to supply changes and improves overall grid performance.

Initiatives like Regional Energy Management Centres (REMCs) further strengthen this ecosystem by enabling more accurate forecasting and continuous monitoring of renewable energy flows.

4.4 Renewable Transition Pathways for Global Capability Centres (GCC) in India

India's Global Capability Centre (GCC) ecosystem has become an important part of global business operations, driven by ongoing digitalisation and the growing use of data-heavy technologies. As a key contributor to India's services exports, GCCs are expanding rapidly in India, especially across major and emerging cities. This growth is also increasing electricity demand, as digital infrastructure, cloud systems, and round-the-clock operations require significant energy.

The sector has grown to an estimated US$**98.4** billion, with a steady CAGR of about 9.9% between FY2021 and FY2026. India currently hosts over 2,100 GCCs, employing around 2.36 million people and accounting for more than half of the global GCC presence. This expansion is expected to continue, with projections indicating up to 2,500 centres and a market size of around US$110 billion by 2030.

Much of this growth is tied to rising adoption of technologies like AI, cloud computing, and real-time analytics. These trends are increasing the need for data processing, particularly in energy-intensive environments such as data centres. As a result, electricity use (Scope 2 emissions) has become a major concern for companies aiming to meet their climate targets.

In this context, renewable energy is becoming a practical solution rather than just a compliance step. Sourcing power from solar or wind, whether through on-site systems or power purchase agreements, can significantly reduce emissions linked to electricity use.

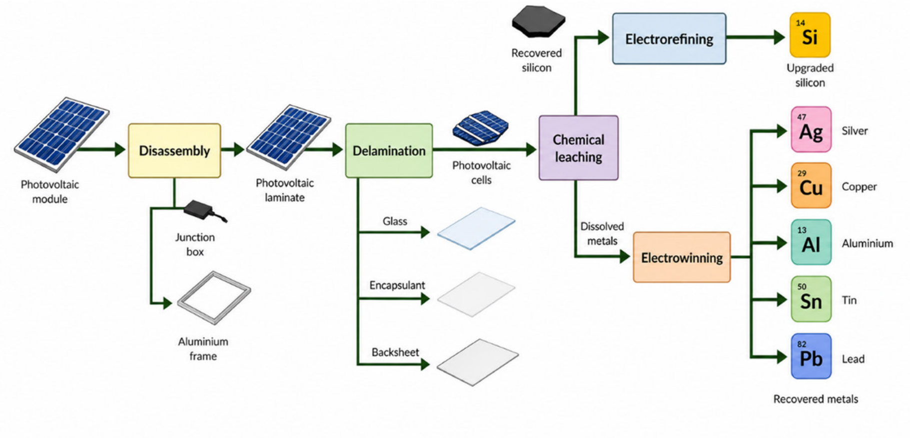
This shift is especially relevant for data centres, which account for a large share of energy consumption within GCCs. Moving toward "green data centres," which combine renewable energy with better cooling and efficiency practices, can lower environmental impact while also improving performance and reliability.

4.5 Recycling of Solar Components and Circular Economy

India is stepping up efforts to build domestic recycling capacity and move toward a more circular economy, particularly as solar installations continue to grow. According to **Ministry of New and Renewable Energy (MNRE)** estimates, solar panel waste could reach nearly 600 kilo-tonnes by 2030, making waste management an emerging priority.

To address this, the E-Waste (Management) Rules, 2022 mandate proper handling and recycling of electronic waste, including solar modules. Supporting this, the Central Pollution Control Board has introduced an Extended Producer Responsibility (EPR) portal to streamline the collection and processing of solar panel waste.

Alongside regulation, there is also a push toward innovation. The Department of Science and Technology is encouraging joint research between industry and academia to develop more efficient and scalable recycling solutions. In addition, the Ministry of Mines has launched a Rs.1,500 crore incentive program under the National Critical Mineral Mission to promote the recovery of valuable materials from solar and other electronic waste.



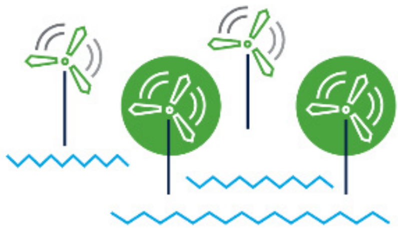
4.6 The Role of Critical Minerals as a New Currency of Progress

Critical minerals are natural resources that are essential for modern industries, clean energy systems, and national security. What makes them "critical" is not just their importance, but the fact that their supply is limited, geographically concentrated, and difficult to substitute, making them vulnerable to disruptions.

Their relevance has increased significantly with the global shift toward clean energy. Unlike fossil fuel-based systems, renewable technologies require far higher material inputs. For instance, an electric vehicle typically needs nearly six times more minerals than a conventional vehicle, while an onshore wind plant requires about nine times more mineral resources than a gas-based power plant. This indicates that the energy transition is not only fuel-driven but also resource-intensive.

Key minerals such as lithium, cobalt, nickel, copper, and rare earth elements are central to technologies like solar panels, wind turbines, battery storage, and electric mobility. As decarbonization efforts accelerate, demand for these materials is expected to rise sharply, potentially increasing four to six times by 2040 under net-zero scenarios. At the same time, supply chains remain concentrated in a few countries, creating geopolitical and economic risks.

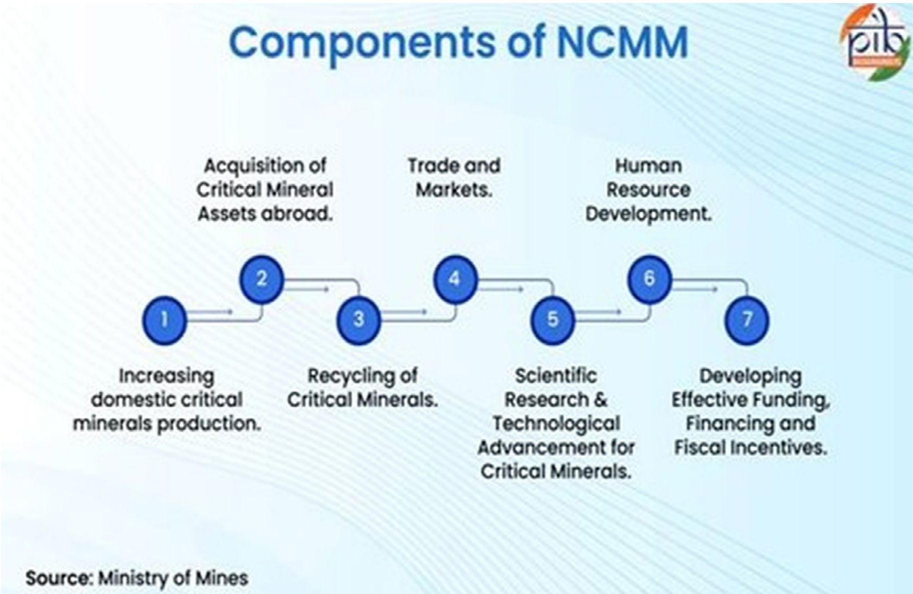
For India, critical minerals are directly linked to its clean energy ambitions. Their importance is evident across sectors:



- Solar panels depend on minerals like silicon, tellurium, indium, and gallium. India's solar capacity is about 64 GW, and its growth depends on the availability of these materials.
- Wind turbines require rare earth elements such as neodymium and dysprosium. India plans to increase wind capacity from 42 GW to 140 GW by 2030, which will significantly increase demand.
- EV batteries rely on lithium, nickel, and cobalt. With a target of 30% EV penetration by 2030, the demand for these minerals will rise sharply. Lithium-ion batteries, which depend on lithium, cobalt, and nickel, are important for storing renewable energy and ensuring power availability during peak demand.

With targets such as 500 GW of non-fossil capacity and 30% EV penetration by 2030, demand for these minerals is expected to grow substantially.

Recognizing this, India launched the **National Critical Mineral Mission (NCMM)** in 2025 for a seven-year period (2024–25 to 2030–31). With a government outlay of Rs.16,300 crore and expected additional investments of Rs.18,000 crore, the mission aims to secure mineral supply chains and reduce import dependence. It focuses on the entire value chain–from exploration and mining to processing, recycling, and research–making it a strategic initiative rather than just a resource program.



In parallel, the Ministry of Mines has identified **30 critical minerals**, including lithium, cobalt, nickel, copper, rare earth elements, and others essential for energy, electronics, and defence applications. Policy support has also been strengthened through amendments to the MMDR Act, enabling the central government to auction key mineral blocks.

Beyond mining, there is a growing emphasis on resource efficiency and recycling. The government has allocated Rs.100 crore for pilot projects to recover minerals from unconventional sources such as mine tailings, fly ash, and industrial waste. Additionally, a Rs.1,500 crore incentive scheme has been approved to promote recycling from secondary sources like e-waste and used batteries. These initiatives aim to build a circular ecosystem, reduce dependence on imports, and create domestic capacity for critical mineral recovery.

The Mission was introduced in the Union Budget 2025–26 as a key initiative to strengthen India's long-term energy security and support its transition to clean energy. This mission places nuclear energy as a major pillar of India's future energy mix, with a clear target of achieving 100 GW of nuclear power capacity by 2047. This expansion is intended to ensure reliable electricity supply, reduce dependence on fossil fuels and support India's broader development goals under the Viksit Bharat.

4.7 Nuclear Energy Mission for Viksit Bharat

A key pillar of the Viksit Bharat mission is the development and deployment of advanced nuclear technologies, with a strong emphasis on Small Modular Reactors (SMRs). The government has earmarked Rs.20,000 crore for research and development in this space, with the objective of designing and operationalizing at least five indigenous SMRs by 2033. These reactors are inherently flexible and scalable, typically ranging from below 30 MWe to over 300 MWe in capacity. This makes them suitable not only for integration into the central grid but also for decentralized applications, including deployment in remote or underserved regions where conventional large-scale plants may not be viable.

Alongside SMRs, the mission introduces Bharat Small Reactors (BSRs), based on 220 MW Pressurised Heavy Water Reactor (PHWR) technology. Unlike newer designs, these are derived from well-established and proven reactor systems but are being re-engineered to reduce land requirements and improve deployment flexibility. This enables their use in proximity to energy-intensive industries such as steel and aluminium, where they can provide reliable captive power. The implementation model reflects a public-private partnership approach: private players contribute land, water, and capital investment, while the Nuclear Power Corporation of India Limited (NPCIL) retains responsibility for reactor design, operations, and safety regulation.

To support faster execution and attract broader participation, the mission also proposes amendments to key legislations, including the Atomic Energy Act, 1962 and the Civil Liability for Nuclear Damage Act. These proposed changes are aimed at easing entry barriers for private investment while ensuring that regulatory oversight and nuclear safety standards remain uncompromised. The policy direction clearly signals a shift toward collaborative development, with private sector involvement envisaged across reactor deployment, SMR development, and next-generation nuclear technologies.

In terms of current capacity, India's nuclear power stands at approximately 8,780 MW (8.78 GW) as of March 2026. The government has outlined a phased expansion plan to scale this up significantly. Installed capacity is projected to reach 22,480 MW by 2031–32, supported by the construction of 10 new reactors with a combined capacity of around 8,000 MW, along with preparatory activities for an additional 10 reactors. Further, there is in-principle approval for six large reactors of 1,208 MW each at Kovvada in Andhra Pradesh, being developed in collaboration with the United States.

The mission follows a dual-track strategy to meet its long-term objectives. On one hand, it prioritizes the expansion of large-scale nuclear capacity through indigenous 700 MW PHWRs and imported high-capacity reactors. On the other hand, it actively promotes smaller and more advanced systems, including Bharat SMRs (around 200 MWe), smaller 55 MWe SMRs, and even micro-reactors of up to 5 MWth. These advanced designs, being developed by the Bhabha Atomic Research Centre (BARC), are intended for a range of applications-from repurposing retiring coal plants and supporting industrial energy needs to enabling off-grid power supply and hydrogen production.

Overall, the Nuclear Energy Mission for Viksit Bharat outlines a structured and forward-looking pathway for scaling nuclear energy in India. With a long-term target of 100 GW of nuclear capacity by 2047, supported by Rs. 20,000 crore in R&D investment, the development of indigenous SMRs by 2033, and a near-term expansion to over 22 GW by the early 2030s, the mission positions nuclear power as a dependable and low-carbon component of India's future energy mix. At the same time, it aligns energy security, industrial growth, and climate commitments within a single strategic framework.

4.8 AI and Energy

The rapid growth of artificial intelligence is significantly increasing global energy consumption, particularly through its reliance on data centres. As AI applications expand, so does the need for large-scale computing power, leading to a sharp rise in electricity demand. Data centres alone consumed an estimated 448 TWh of electricity in 2025, and this is projected to more than double to 945 TWh by 2030 (about a 111% increase: ~3% of future electricity consumption). This trend highlights the growing energy footprint of AI and the need for more sustainable and efficient energy solutions to support its expansion.

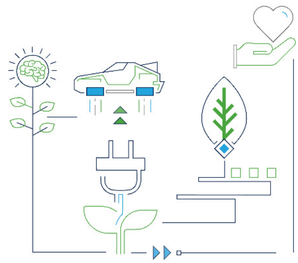
At the same time, AI is emerging as a powerful tool to improve energy efficiency and optimize infrastructure. Advanced AI systems can enhance grid reliability by detecting faults early, reducing outage durations by 30% to 50%. Additionally, AI-enabled monitoring and smart management systems can significantly improve the use of existing transmission networks. By leveraging remote sensors and intelligent optimization, it is possible to unlock up to 175 GW of additional transmission capacity without building new infrastructure thus showing how AI can play a critical role in making energy systems smarter, more efficient, and more resilient.

Chapter 5 Emerging Technologies & Clean Energy

5.1 Electric Mobility: Global Momentum and India's Transition

The rapid adoption of electric vehicles (EVs) has become a central element of global climate action. Many countries now include transport electrification in their Nationally Determined Contributions (NDCs) as a practical way to reduce emissions. This shift is already visible in market trends. Global EV sales crossed 20 million units in 2025, accounting for roughly 25% of all new vehicle sales, compared to less than 1% in 2015 when the Paris Agreement was signed.

For India, this transition presents a dual opportunity. Expanding EV adoption not only supports its emissions intensity reduction targets but also opens access to global capital, technology partnerships, and domestic manufacturing growth. In this sense, EVs are not just a climate solution but also an economic and strategic lever for reducing dependence on fossil fuel imports.



India's EV ecosystem has been expanding rapidly, supported by policy interventions, growing environmental awareness, and improvements in technology. Government initiatives, most notably the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, have played a key role in building early momentum. Looking ahead, India has set ambitious adoption targets for 2030: 30% penetration in private cars, 70% in commercial vehicles, 40% in buses, and 80% in two- and three-wheelers. Together, these targets could translate into nearly 80 million EVs on the road, alongside a strong push for domestic manufacturing under the ***Make in India*** initiative.

This growth is underpinned by an evolving policy framework. The FAME-II scheme (2019–2024) has supported demand across vehicle segments (two-wheelers, three-wheelers, passenger vehicles, and buses) while also funding charging infrastructure. As a result, more than 1.6 million EVs have been deployed under the scheme. Building on this, the PM E-DRIVE programme (2024–2028), with an allocation of around Rs.10,900 crore, aims to accelerate adoption further, particularly in public transport segments such as electric buses, trucks, and ambulances, while continuing to expand the charging network.

On the supply side, the government is focusing on strengthening domestic manufacturing capabilities. The Production Linked Incentive (PLI) scheme for automobiles and auto components encourages the development of advanced vehicle technologies, including electric and hydrogen-based mobility, by linking incentives to local value addition. In parallel, the PLI scheme for Advanced Chemistry Cell (ACC) batteries, with an outlay of Rs.18,100 crore, supports large-scale battery manufacturing. This is particularly important as batteries represent a significant portion of EV costs and are currently import-dependent. Additional measures, such as reduced GST on EVs, rationalized import duties, and state-level incentives like road tax & registration fee exemptions are further improving affordability and adoption.

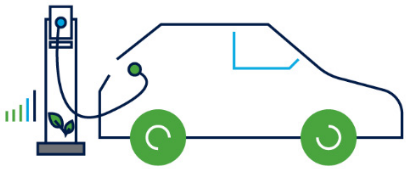
From a market perspective, both global and domestic EV sectors are on a strong growth trajectory.

The global electric vehicle (EV) market is projected to grow from approximately **US$917.3 billion in 2025 to US$4,886.2 billion by 2034, at a CAGR of ~20%**. India's EV market is also projected to increase from **US$3.71 billion in 2025 to US$191.04 billion by 2034, at a CAGR of ~55%.**

The **EV battery segment in India is also witnessing strong momentum,** expanding from about **US$5.27 billion in 2024 to nearly US$19.47 billion by 2030**, at a **CAGR of ~24%,** supported by localisation initiatives, PLI schemes, and increasing demand for lithium-ion batteries; India already accounted for approximately **8.6% of the**

global EV battery market in 2024.

Adoption trends within India reflect this upward momentum. By Q3 FY26, EV sales had reached nearly 6.9 lakh units, accounting for nearly 7.3% of total vehicle sales. Two- and three-wheelers continue to dominate the market, contributing close to 90% of total EV volumes. Certain segments, such as electric goods carriers, are witnessing particularly rapid expansion, with year-on-year growth exceeding 150%.



Infrastructure development remains a critical enabler of this transition. India's public charging network is expanding, with over 29,000 operational charging stations as of March 2026, led by states such as Karnataka, Maharashtra and Delhi. However, future demand is expected to be much higher. Estimates suggest that India may require around 1.3 million charging stations by 2030, implying the need to install several hundred thousand new stations each year to keep pace with EV adoption.

5.2 Green Hydrogen Development

India has taken a policy-led approach to developing a green hydrogen ecosystem through the National Green Hydrogen Mission, launched in 2023. The mission sets a target of producing 5 million tonnes of green hydrogen annually by 2030, supported by the addition of around 125 GW of renewable energy capacity. Beyond climate benefits, the initiative is positioned as an economic opportunity with an expectation to attract investments of nearly Rs.8,00,000 crore (US$ 89 billion), generate over 6 lakh jobs, and reduce approximately 50 million metric tonnes of greenhouse gas emissions each year.

To support this transition, the government has allocated Rs.19,744 crore under the mission, with a major share directed toward the SIGHT (Strategic Interventions for Green Hydrogen Transition) programme. This includes incentives for both electrolyser manufacturing and hydrogen production, helping to build domestic capacity and reduce reliance on imports.

Green hydrogen is particularly relevant for sectors where emissions are difficult to reduce through conventional electrification. Hydrogen-consuming industries such as oil refining, fertilisers, and steel can shift to cleaner alternatives with relatively lower disruption. In the transport sector, hydrogen offers a potential solution for long-haul and heavy-duty applications, including trucks and buses, where battery-based technologies face range and weight limitations. Pilot projects are also being explored in areas such as railways, shipping, and ports, indicating broader applicability across the transport ecosystem. Additionally, hydrogen derivatives like green ammonia and methanol are gaining importance as they can serve both as fuels and as industrial feedstocks.

On the technology front, progress in storage and transport is addressing some of the key challenges associated with hydrogen use. Innovations such as high-pressure composite tanks, cryogenic liquid hydrogen storage, and solid-state storage materials (including metal hydrides and advanced porous materials) are improving safety and efficiency. At the same time, carriers like green ammonia and liquid organic hydrogen carriers (LOHCs) are emerging as practical solutions for transporting hydrogen over long distances and storing it for extended periods.

From an economic standpoint, the outlook for green hydrogen is gradually improving. Production costs are expected to decline as technology matures and scale increases, with current estimates already approaching below Rs.270 (US$ 3) per kg. Over the longer term, widespread adoption could significantly reduce India's dependence on energy imports, potentially saving around Rs.1,00,000 crore annually by 2030. Overall investments in the hydrogen ecosystem are projected to reach between Rs.8,00,000 and Rs.10,00,000 crore (US$ 89–111 billion), reflecting growing confidence in the sector's long-term viability.

5.3 Energy Storage Systems

India's energy storage sector is still at an early stage but is expected to grow quickly as renewable energy capacity increases. According to estimates from the Central Electricity Authority, the country may require around 32 GW (160 GWh) of battery storage by 2030 to effectively manage renewable integration and ensure grid stability. At present, pumped hydro remains the dominant form of storage, with about 4.8 GW installed, while large-scale battery deployment is only beginning to take shape.

Policy and institutional support are playing an important role in accelerating this transition. Public sector undertakings have already committed more than Rs.25,000 crore (around US$ 3 billion) toward storage-related investments over the next five to seven years. In parallel, the Production Linked Incentive (PLI) scheme for Advanced Chemistry Cell (ACC) batteries, with an allocation of Rs.18,100 crore, is aimed at building domestic manufacturing capacity and reducing import dependence in a critical segment of the value chain.

At the project level, momentum is gradually building across different storage technologies. Battery Energy Storage Systems (BESS) are being deployed in pilot and early commercial projects, including a 10 MWh installation in Delhi and a much larger 500 MWh project planned by SECI. Alongside lithium-ion batteries, alternative technologies such as flow batteries and hydrogen-based storage solutions are also being tested, indicating a shift toward a more diversified storage mix. Pumped hydro continues to expand as well, with over 15 GW of additional capacity currently under exploration.

The broader market outlook reflects this growing momentum. India's energy storage sector is projected to attract investments of nearly Rs.4,79,000 crore (US$ 56 billion) by 2032. Total storage demand is expected to rise sharply from about 16.13 GW by FY27 to nearly 73.93 GW (411.4 GWh) by FY32. At the same time, costs have declined significantly, improving the business case for deployment. Storage tariffs, for instance, have dropped from roughly Rs.10 lakh per MW per month to about Rs.2.5 lakh, making projects more commercially viable.

In the near term, deployment is set to accelerate further. Battery storage installations are projected to increase from around 507 MWh in 2025 to nearly 5 GWh in 2026. This growth is being supported by targeted government interventions, including viability gap funding of approximately Rs.5,400 crore, which is helping bridge cost gaps and encourage private sector participation.

5.4 Agrivoltaics (AgriPV): Integrating Agriculture and Solar Energy

Agrivoltaics (AgriPV) refers to the practice of using the same piece of land for both agriculture and solar power generation. Instead of competing for land, this approach allows crops and solar panels to coexist, improving overall land productivity. In a country like India-where agriculture supports over 42% of the population and contributes about 18% to GDP-this model is becoming increasingly relevant as the country works toward its target of 500 GW of non-fossil fuel capacity by 2030. With more than 120 million farmers, AgriPV offers not just clean energy generation, but also an additional and stable source of income at the farm level.

India's natural conditions make it well-suited for agrivoltaics deployment. The country has over 150 million hectares of agricultural land and receives abundant solar radiation-estimated at around 5,000 trillion units annually, with average daily radiation of 4–7 kWh per square metre. In practice, AgriPV systems involve installing solar panels at an elevated height (typically 2–3 metres), allowing crops to grow underneath while maintaining normal farming activities such as cultivation, grazing, or even biodiversity support. This dual-use approach can help address multiple challenges at once, including pressure on land, changing climate conditions, and rising energy demand, while also improving resource efficiency.

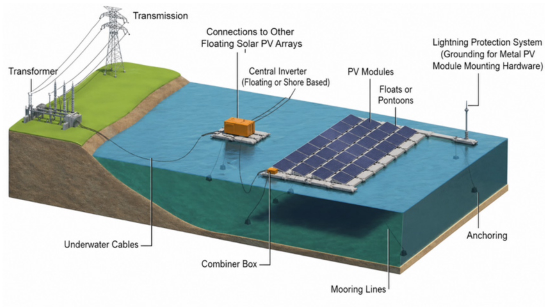
At the global level, agrivoltaics is gaining traction as a viable solution. The market is projected to grow at a CAGR of about 8.3% between 2024 and 2031, increasing from roughly Rs.37,500 crore (US$ 4.3 billion) to nearly Rs.66,000 crore (US$ 7.6 billion). North America currently holds a significant share of the market, but the Asia-Pacific region-including India-is expected to see the fastest growth, driven by rural electrification needs and advances in Agri-tech.

In India, policy support for solarisation in agriculture is already in place, even if agrivoltaics is not explicitly defined as a separate category. Schemes like PM-KUSUM aim to deploy decentralized solar capacity (up to 10 GW) through small-scale projects ranging from 500 kW to 2 MW. While primarily focused on solar pumps and grid-connected systems, the objectives-enhancing farmer income, reducing dependence on diesel, and promoting clean energy-align closely with the principles of AgriPV.

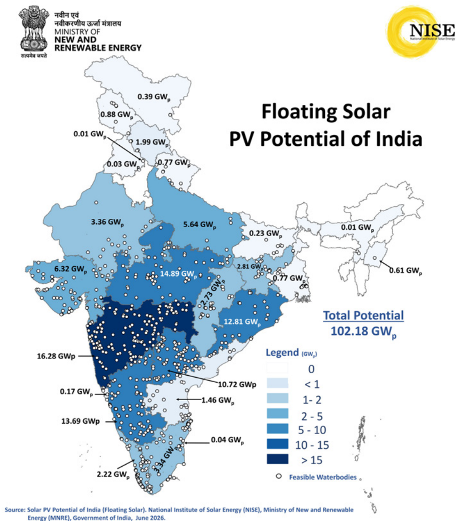
High upfront costs, evolving technology standards, and concerns around land use and crop compatibility continue to act as barriers in adopting agrivoltaics as a solution. However, these challenges are gradually being addressed through innovation and policy support. Given India's advantage of over 300 sunny days a year and its position as one of the world's leading solar markets, agrivoltaics has strong potential to bridge the gap between energy and agriculture. If scaled effectively, it can contribute to improved farm resilience, better resource use, and a more integrated approach to sustainability.

5.5 Floating Solar Photovoltaics (FSPV)

Floating Solar Photovoltaics (FSPV) is an emerging form of solar deployment



where panels are installed on water bodies such as reservoirs, dams, lakes, and ponds. Unlike conventional ground-mounted systems, FSPV makes use of otherwise underutilized water surfaces, offering an alternative pathway for scaling renewable energy. In India, this model is gaining attention not only for its land-saving advantage but also for its compatibility with existing hydropower infrastructure. Globally, floating solar has grown rapidly over the past few years, with installed capacity crossing 6–7 GW and annual growth rates exceeding 40%. Much of this expansion has been led by Asian countries, and India is increasingly positioning itself within this space. From an initial base of just a few megawatts, the country has scaled up to more than 200 MW of installed capacity, with an additional 2–3 GW under development or tendering. This pipeline reflects growing interest from both policymakers and investors.



India's FSPV potential, as depicted in the figure, is estimated at 102.18 GWp across identified reservoirs and feasible water bodies. The distribution is uneven, with southern and central states contributing the largest share of this capacity. The highest potential is concentrated in Maharashtra (16.28 GWp), Madhya Pradesh (14.89 GWp), Karnataka (13.69 GWp), Telangana (12.81 GWp), and Andhra Pradesh (10.72 GWp). Additional moderate contributions come from Gujarat (6.32 GWp) and Uttar Pradesh (5.64 GWp), while eastern states such as West Bengal (2.81 GWp) and Odisha (2.73 GWp) add smaller but notable capacities. In contrast, most northern and northeastern states have relatively low potential, generally below 2 GWp each. It highlights numerous feasible water bodies distributed across the country, reflecting the extensive reservoir base that supports floating solar deployment.

Overall, the data underscores that floating solar offers a scalable and land-efficient solution, particularly in high-potential regions, enabling significant expansion of solar capacity without additional pressure on land resources.

From a performance perspective, floating solar systems often have an edge over land-based installations. The presence of water helps cool the panels, typically lowering temperatures by 5–10°C. This results in efficiency improvements of roughly 5–15% and leads to higher capacity utilization factors (CUF) in the range of 20–25%, compared to 18–22% for ground-mounted systems. These gains are particularly relevant in a country like India, where high solar irradiation conditions already favour strong generation output.

Beyond electricity generation, FSPV systems also contribute to water resource management. By covering portions of water surfaces, they help reduce evaporation losses (estimated at 1.5 to 2 million cubic meters annually per square kilometre of coverage). This is significant in the Indian context, where evaporation leads to the loss of hundreds of cubic kilometres of water each year. In addition, reduced sunlight penetration can limit algae growth, improve water quality, and decrease dust accumulation on panels, lowering maintenance needs.

In economic terms, floating solar projects currently involve higher upfront costs, typically in the range of Rs.4–5 crore per MW (about 15–25% more than ground-mounted systems). However, this cost gap is gradually narrowing as technologies mature and scale increases. When deployed alongside hydropower projects, FSPV can offset some of these costs by using existing transmission infrastructure and avoiding land acquisition expenses, which are often a major component of project costs.

One of the most compelling aspects of floating solar is its integration with hydropower. Hybrid systems allow for complementary operation i.e. solar generation during the day and hydropower support during non-solar hours. This improves overall reliability, smoothens power output, and enhances grid stability. It also allows better utilization of transmission assets and supports peak demand management, making such systems well-suited to India's evolving electricity mix.

At the same time, certain challenges need to be addressed for wider adoption. These include higher initial investment requirements, engineering complexities related to anchoring and mooring, and operational considerations such as fluctuating water levels. Environmental impacts on aquatic ecosystems must also be carefully evaluated. Additionally, the domestic supply chain for floating structures is still developing, which may affect scalability in the near term.

Looking ahead, floating solar is expected to play an increasingly important role in India's energy transition. The country could potentially install more than 10 GW of FSPV capacity by 2030, contributing to its broader goal of achieving 500 GW of non-fossil fuel capacity. By reducing land pressures, conserving water, and improving system reliability, floating solar offers a practical and scalable solution for sustainable energy development, while also aligning with India's long-term net-zero target for 2070.

5.6 Carbon Capture, Utilisation and Storage (CCUS)

India's total CO_2 emissions are nearly 60% coming from large, point source sectors such as power and industry. These emissions are projected to rise to about 2,300 MTPA by 2030 due to economic growth. Importantly, over 30% of emissions come from industrial sectors like steel, cement, refineries, and chemicals, which are inherently difficult to electrify because fossil fuels are used not only for energy but also as part of the production process.

CCUS is indispensable for decarbonizing these hard-to-abate sectors. It identifies key industries where CCUS deployment is most relevant in India:

- Thermal power (due to continued reliance on coal, which supplies over 70% of electricity)
- Steel and cement (process emissions and fossil fuel dependency)
- Oil & gas, refineries, and petrochemicals

These sectors form the backbone of India's industrial economy, making CCUS essential for reducing emissions without compromising growth.

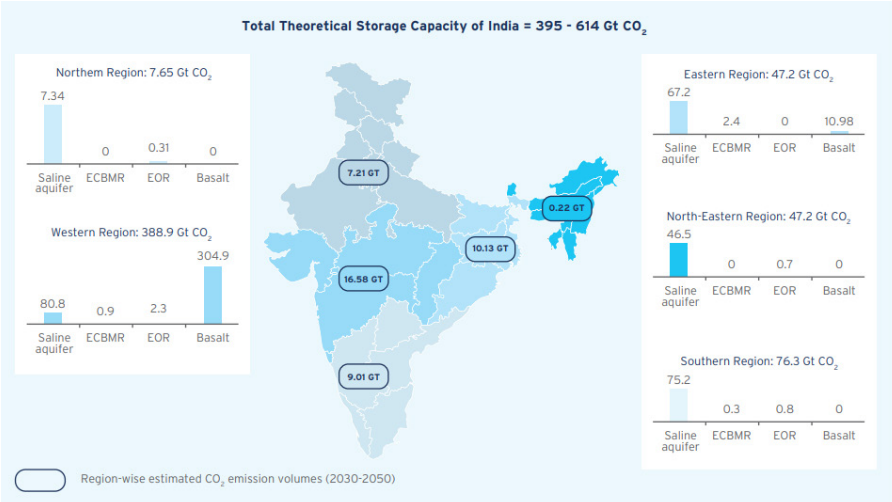
Even with India's ambitious renewable energy targets, such as achieving 500 GW of non-fossil capacity by 2030, fossil fuels will remain necessary to provide reliable baseload power due to the intermittent nature of solar and wind energy. CCUS can therefore help decarbonize existing coal-based infrastructure and avoid asset stranding of over 200 GW of thermal power capacity.

CCUS as a strategic enabler for emerging sectors in India. It can support:

- Development of a low-carbon hydrogen economy (especially blue hydrogen)
- Expansion of coal gasification using domestic coal resources
- Production of value-added products such as chemicals, fuels, and building materials from captured CO_2

This aligns with India's goal of becoming more self-reliant ("Atmanirbhar Bharat") by reducing import dependence while transitioning to cleaner technologies.

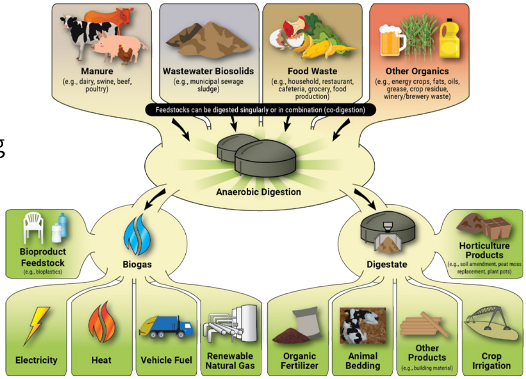
From a policy perspective, financial incentives and regulatory mechanisms are necessary because CCUS technologies are capital-intensive and require long-term infrastructure such as CO_2 transport and storage networks.



5.7 Biogas and Waste-to-Energy

One of the most practical solutions for enhancing energy security is the adoption of renewable energy technologies. Among these, biogas systems offer an effective and sustainable solution for industries, hostels, hotels, food courts, canteens, agricultural establishments and defence facilities that generate significant quantities of organic waste. By converting organic waste into clean fuel for cooking, heating and electricity generation, biogas plants simultaneously address energy needs and waste management challenges while producing valuable organic fertilizer as a by-product.

Biogas plants provide an efficient "waste-to-energy" solution by transforming food and organic waste into clean fuel, thereby reducing dependence on LPG and lowering fuel costs. They enable institutions to manage waste more effectively by minimizing disposal expenses and reducing landfill requirements. In addition, the nutrient-rich slurry produced during the process can be used as an organic fertilizer, supporting circular economy principles and decentralized energy

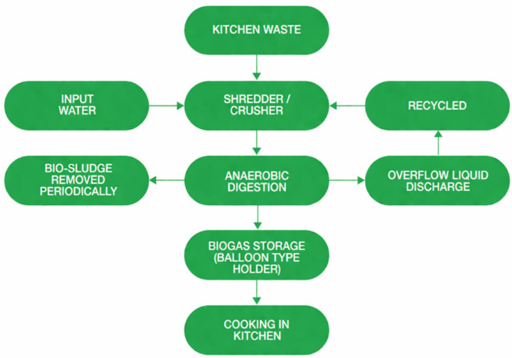


generation. From an environmental perspective, biogas systems capture methane emissions that would otherwise be released during the decomposition of organic waste, significantly reducing greenhouse gas emissions. They also contribute to lower carbon footprints and improved soil health through reduced reliance on chemical fertilizers.

5.7.1 The Science Behind Biogas Production: Anaerobic digestion is the core process responsible for biogas generation. It is a biological process in which microorganisms break down organic materials (such as food waste, animal manure, and wastewater biosolids) in the absence of oxygen. This process takes place inside a sealed vessel known as a digester or reactor, which can be designed in different configurations depending on site conditions and feedstock characteristics.

Within the digester, complex microbial communities decompose organic matter to produce biogas and digestate. Biogas is the gaseous output of the process, while digestate is the residual solid and liquid material remaining after digestion.

Biogas primarily consists of methane (CH_4), typically accounting for 50–75% of the gas composition, along with carbon dioxide (CO_2), hydrogen sulphide (H_2S), water vapour, and trace gases. Owing to its high methane content, biogas can be used similarly to natural gas for heat generation, electricity production, and cooling



applications. Biogas can also be upgraded by removing carbon dioxide, hydrogen sulphide, water vapour and other impurities to produce Renewable Natural Gas (RNG). This upgraded gas can be injected into natural gas distribution networks, compressed and used as vehicle fuel, or further processed into alternative fuels, energy products, and advanced biochemicals.

5.7.2 Value Addition Through Digestate: Digestate, the by-product of anaerobic digestion, consists of both solid and liquid fractions that can be separated and managed independently depending on end-use requirements. When properly processed, digestate offers several beneficial applications. The solid fraction can be utilized as animal bedding, organic compost, soil conditioner, or as a feedstock for bio-based products such as bioplastics. The liquid fraction, either independently or combined with solids, serves as a nutrient-rich organic fertilizer. In many cases, digestate is directly applied to agricultural land, helping improve soil fertility and supporting sustainable farming practices.

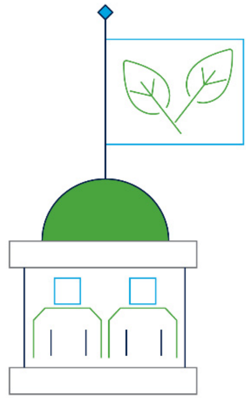
5.7.3 A Strategic Opportunity for Commercial Establishments: With rising fuel prices and growing concerns around energy security, biogas technology is emerging as a commercially viable and strategic solution for business establishments, particularly institutions with large kitchens such as hotels, canteens, food courts, hostels, and industrial facilities.

The technology offers considerable flexibility, accommodating a wide range of organic feedstocks while maintaining robust operational performance. Modern biogas systems are available in capacities ranging from as small as 25 kg/day to as large as 10 tonnes per day (TPD), making them suitable for both small-scale and large-scale applications.

As organizations increasingly seek cost-effective, sustainable, and resilient energy solutions, biogas presents a compelling opportunity to convert waste into value, reduce fuel dependence, lower environmental impact, and contribute to a more circular and resource-efficient economy.

Chapter 6 Carbon Footprint & Baseline

As net-zero commitments increasingly become part of core business strategy, companies are expected to better understand and manage their environmental impact. This includes not only contributing to global and national climate targets but also assessing their own exposure to climate-related risks and ESG performance. The idea that "what gets measured gets managed" has become particularly relevant in this context. As a result, carbon footprint measurement is now a fundamental part of corporate sustainability and decision-making. With rising regulatory requirements, growing investor focus, and increasing exposure to climate-related risks, organizations are under pressure to quantify and disclose their emissions more accurately. Standardized greenhouse gas (GHG) accounting frameworks make this possible by helping companies measure emissions, identify reduction opportunities, and align operations with broader decarbonization pathways. The widely used Scope 1, Scope 2, and Scope 3 framework developed under the Greenhouse Gas (GHG) Protocol provides a structured way to account for emissions across direct operations as well as the wider value chain.



6.1 History & Foundations of GHG Focus

The roots of carbon accounting can be traced back to the development of Life Cycle Assessment (LCA) methodologies in the late 1960s and 1970s. At the time, the focus was not on climate change but on improving energy efficiency and understanding resource use across product life cycles. Early adopters included large industrial and consumer goods companies, which used LCA to evaluate material flows and energy consumption. Although limited in scope, these efforts established the foundation for systematically measuring environmental impacts.

A major shift occurred in 1988 with the establishment of the Intergovernmental

Panel on Climate Change (IPCC). Through its assessment reports, six of which have been published so far, with the latest in 2022, the IPCC provided a scientific basis for understanding climate change, including the role of greenhouse gases and their cumulative impact on global warming. This growing body of evidence played a key role in shaping international climate policy.

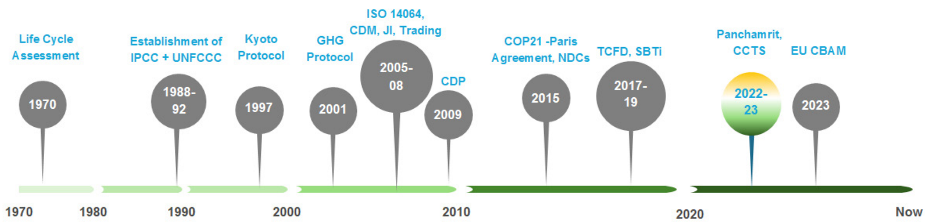
This momentum led to the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio Earth Summit in 1992. The convention formally recognized the need for countries to monitor and report greenhouse gas emissions, marking the beginning of structured national-level carbon accounting.

Subsequently, the Conference of the Parties (COP) became the central platform for global climate negotiations. A significant milestone was achieved at COP3 in Kyoto in 1997, where the Kyoto Protocol introduced legally binding emission reduction targets for developed countries under the principle of "common but differentiated responsibilities." Importantly, it established Measurement, Reporting, and Verification (MRV) as a core requirement, embedding emissions accounting into international climate governance.

To support implementation, mechanisms such as the Clean Development Mechanism (CDM) and Joint Implementation (JI) were introduced. These allowed countries to meet their targets through project-based emissions reductions, including cross-border initiatives. As a result, the need for consistent and credible methods to quantify emissions expanded beyond national inventories to include project and corporate-level accounting. Around the same time, the European Union launched the Emissions Trading System (EU ETS) in 2005, effectively turning carbon into a tradable commodity measured in tonnes of CO_2 equivalent.

The early 2000s saw the development of formal carbon accounting standards and frameworks, most notably the Greenhouse Gas (GHG) Protocol and ISO 14064. These frameworks established clear guidelines for defining organizational boundaries, calculating emissions, and ensuring consistency in reporting. They remain widely used today across both voluntary disclosures and regulatory reporting systems. Supporting initiatives such as the Carbon Disclosure Project (CDP) further encouraged transparency by enabling companies to publicly disclose their emissions and climate strategies.

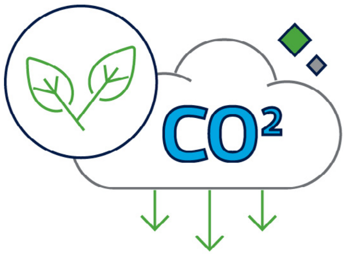
These developments ultimately converged under the Paris Agreement at COP21, which created a unified global framework for climate action. By bringing together countries under shared goals and accountability mechanisms, the agreement reinforced the importance of standardized emissions measurement and reporting as a foundation for tracking progress toward climate targets.



In the years following the Paris Agreement, carbon accounting has moved beyond environmental reporting to become closely linked with financial decision-making and corporate strategy. Frameworks such as the Task Force on Climate-related Financial Disclosures (TCFD) and initiatives like the Science Based Targets initiative (SBTi) have enabled companies to use emissions data for transition planning, scenario analysis, and investment decisions. As a result, carbon measurement now plays a role in assessing financial risk, guiding capital allocation, and influencing overall business valuation.

India has actively aligned with this global shift while balancing its development priorities. After committing to the Paris Agreement, the country introduced the Panchamrit targets (2021–22), focusing on emissions intensity reduction, expansion of renewable energy capacity, and long-term net-zero goals. More recently, mechanisms such as the Carbon Credit Trading Scheme (CCTS) have extended carbon accounting into compliance frameworks, particularly for energy-intensive sectors. This is helping create a more structured domestic carbon market, while also preparing Indian industries for evolving global mechanisms such as the EU Emissions Trading System (EU ETS) and the Carbon Border Adjustment Mechanism (CBAM), which increasingly link trade with carbon performance.

6.2 GHG Accounting Methodology



Greenhouse gas accounting is grounded in the systematic identification, measurement, and reporting of emissions associated with organizational activities. The objective is to ensure **consistency, comparability, completeness, transparency, and accuracy** in emissions reporting. Carbon accounting typically covers carbon dioxide (CO_2) as well as other greenhouse gases such as methane (CH_4), nitrous oxide (N_2O), and fluorinated gases, expressed in terms of **carbon dioxide equivalents (CO_2e)** using global warming potentials.

6.3 Scope 1: Direct Operational Emissions

Scope 1 emissions are considered as the first step within the greenhouse gas accounting framework because they directly capture emissions generated by an entity itself (either an individual organization, institution, or sovereign body). Scope 1 emissions refer to direct greenhouse gas emissions arising from sources that are owned or controlled by the reporting entity, indicating activities over which the entity has immediate operational responsibility.

Common sources of Scope 1 emissions include:

- Fuel combustion in boilers, furnaces, and generators (including non-fossil fuels such as biomass briquette, wood, biogas)

- Emissions from company-owned vehicles and transportation fleets
- On-site industrial processes and chemical reactions
- Fugitive emissions, such as refrigerant leakage

Scope 1 emissions are typically the most straightforward to measure, as fuel consumption data and operational records are usually directly available. From a strategic perspective, managing Scope 1 emissions provides organizations with direct levers for decarbonization, such as fuel switching, operational efficiency improvements, electrification, and process redesign.

6.4 Scope 2: Indirect Energy Emissions

Scope 2 emissions capture indirect greenhouse gas emissions arising from the generation of purchased energy, including electricity, steam, heating, and cooling consumed by an organization. While the emissions themselves occur at off-site energy generation facilities, they are assigned to the reporting entity because energy consumption decisions create the underlying demand responsible for those emissions.

Scope 2 accounting (usually for electricity-based emissions) is typically conducted using two approaches:

- **Location based method**, which reflects average grid emission factors
- **Market based method**, which accounts for contractual instruments such as renewable energy certificates or power purchase agreements

Scope 2 emissions are particularly significant for service-oriented industries, digital infrastructure providers, and urban commercial operations. Reducing Scope 2 emissions often involves energy efficiency measures, procurement of renewable electricity, and long-term decarbonized power sourcing strategies.

6.5 Scope 3: All Other Indirect Emissions (Upstream & Downstream)

6.5.1 Value Chain Emissions

Scope 3 emissions encompass all other indirect emissions occurring across the organization's value chain, both upstream and downstream. These emissions typically account for the largest share of total carbon footprint for certain sectors, especially for consumer goods, financial institutions, and infrastructure developers.

As per the GHG protocol definitions, Scope 3 has been segmented into 15 categories. These include upstream activities and downstream activities in an organization's value chain as shown below. Recent discussions have pointed to the potential introduction of an additional reporting category-tentatively referred to as Scope 3 Category 16: Other Value Chain Activities. This category would cover facilitated emissions generated by third-party activities in which a company earns direct transactional income but does not buy, sell, or own the underlying activity, including certain licensing arrangements.

Scope 3 categories include:

- Purchased goods & services, and Capital goods
- Fuel- and Energy-Related Activities
- Upstream & Downstream Transportation and Distribution
- Waste generated in operations
- Business travel and employee commuting
- Upstream and downstream leased assets

- Processing, Use and End-of-Life Treatment of sold products
- Investments & financed emissions, and Franchises

Unlike Scope 1 and Scope 2, Scope 3 emissions are characterized by **limited operational control, data uncertainty, and measurement complexity**. Usually, quantification of Scope 3 emissions is done by industry experts on newly available software/ tools. Due to the complexity of the Scope 3 categories, the tools' accuracy might be underwhelming compared to manual estimation.

6.6 Carbon Accounting Methodology and Tools

Carbon accounting relies on standardized methodologies that link **activity data** (such as fuel consumption or electricity use) with **emission factors** that reflect the carbon intensity of those activities. The general calculation approach follows:

Emissions = Activity Data × Emission Factor

Organizations employ a range of tools and systems to implement carbon accounting, including:

- GHG inventory management software
- Life Cycle Assessment (LCA) tools
- Industry-specific calculation models
- Third-party verification and assurance frameworks

The predominant databases for estimation of GHG emission factors are IPCC, DEFRA (UK-based), LCA bases such as Eco Invent, & country-specific databases such as US EPA GHG Emission Factor Hub & CEA emission factors by India's Central Electricity Authority.

Data quality, system boundaries, and methodological consistency are central challenges, particularly for Scope 3 emissions. As digitalization advances, automated data integration and supplier reporting platforms are increasingly adopted to enhance accuracy and reduce reporting burdens.

A gamut of GHG, environmental & ESG streamlining software platforms have been availed by companies with the focus of decreasing time-heavy and erroneous data collection & reporting.

6.7 Strategic Importance of Carbon Measurement

Carbon footprint measurement has evolved from a compliance exercise into a **strategic management tool**. Accurate emissions data enable organizations to:

- Identify decarbonization priorities and cost effective mitigation actions – This is the most commonly approached aspect of carbon/ GHG measurement.
- Manage regulatory, financial, and reputational risks
- Access sustainable finance instruments such as green and sustainability linked bonds
- Enhance resilience against climate related transition and physical risks

From an ESG and investor perspective, carbon measurement underpins credibility in climate commitments and net-zero targets. Institutions increasingly use emissions data to price climate risk, allocate capital, and assess long-term enterprise value. As climate policies tighten and disclosure standards converge globally, robust carbon accounting is becoming indispensable for maintaining competitiveness and securing investor confidence.

Chapter 7 ESG Maturity and Double Materiality

7.1 ESG Maturity Assessment

An ESG maturity and materiality assessment helps connect how well an organization is governed on ESG issues with how effectively it identifies and manages its most important sustainability impacts. In practice, this means linking internal capabilities–such as data systems, accountability, and decision-making processes–with external priorities like risk management and value creation. This connection becomes especially important for frameworks such as GRI and BRSR, where strong ESG maturity ensures that material topics are backed by credible data, clear ownership, and insights that can support both compliance and strategic decisions.

External ESG ratings and benchmarks also provide a useful lens to assess this maturity. Indices such as the Dow Jones Sustainability Index (DJSI), along with MSCI ESG Ratings and Sustainalytics, evaluate companies across a broad set of parameters, including governance practices, risk management, environmental performance, and social impact. These assessments offer an independent perspective on how deeply ESG considerations are embedded into day-to-day operations and long-term strategy.

For example, the DJSI [based on S&P Global's Corporate Sustainability Assessment (CSA)] scores companies across industry-specific ESG criteria. These scores reflect not only the presence of policies but also how effectively they are implemented. Organizations with higher scores typically demonstrate stronger systems, clearer accountability, and better integration of sustainability into core business decisions. As a result, such ratings are often used by investors and other stakeholders as indicators of ESG maturity, while also helping companies compare their performance with peers and identify areas for improvement.

At its core, an ESG maturity assessment is a way to understand where an organization stands in its sustainability journey. It looks at how well ESG principles are integrated into strategy, operations, and decision-making processes. The exercise helps organizations take stock of current practices, identify gaps, and prioritize actions, ultimately guiding them toward more consistent and long-term value creation.

This process is often supported by a Sustainability Maturity Model, which outlines different stages of progress. These stages typically range from basic, compliance-driven approaches to more advanced levels where sustainability is fully embedded into business strategy and drives value. By providing a clear structure, the model helps create a shared understanding of what "maturity" looks like and allows for consistent comparison across teams, business units, or even across organizations.

Typical **ESG maturity levels** include:

1. **Initial / Ad Hoc**
   - ESG activities are informal, reactive, and fragmented.
   - Limited awareness and minimal documentation.
2. **Developing**
   - Initial policies and procedures exist.
   - ESG actions are often compliance driven and inconsistently applied.
3. **Defined**
   - Formal ESG frameworks, metrics, and responsibilities are established.
   - Reporting practices align with recognized standards.
4. **Integrated**
   - ESG is integrated into business strategy, risk management, and operations.

- Performance is measured, tracked, and used for decision making.

5. **Leading / Optimized**

- ESG drives innovation, long-term value creation, and competitive advantage.
- Continuous improvement and external leadership are evident.

Organizations are assessed against a defined set of ESG dimensions across environmental, social, and governance pillars. The assessment typically combines **document reviews, data analysis, stakeholder interviews, and benchmarking** against regulatory requirements and leading practices.

Key dimensions assessed include:

7.1.1 Policies & Procedures

This dimension evaluates whether the organization has formal, documented ESG policies and operating procedures in place. It assesses clarity, coverage, alignment with international standards, communication, and implementation across the organization.

7.1.2 Compliance

Compliance focuses on adherence to applicable ESG-related laws, regulations, and industry standards. This includes environmental regulations, labour and human rights laws, data privacy, ethical conduct, and reporting obligations. The assessment examines both compliance mechanisms and evidence of monitoring.

7.1.3 Metrics and Measurement

This area reviews how ESG performance is measured and tracked. It examines the quality, consistency, and completeness of ESG data, alignment with recognized reporting frameworks, and the use of metrics to monitor performance over time.

7.1.4 Targets and Goals

Target setting assesses whether the organization has defined, measurable ESG goals. This includes short-term and long-term targets, science- or evidence-based goals, alignment with business objectives, and progress tracking mechanisms.

7.1.5 Governance and Responsibility

This dimension evaluates leadership oversight and accountability for ESG. It looks at board and executive involvement, defined roles and responsibilities, incentive structures, escalation mechanisms, and integration of ESG into enterprise governance.

7.1.6 Initiatives and Programs

This area focuses on the actions and initiatives implemented to improve ESG performance. It assesses the scale, effectiveness, and impact of programs across environmental management, social responsibility, and ethical governance, as well as how outcomes are reviewed and improved.

The result of an ESG maturity assessment is a **clear maturity profile**, highlighting strengths, gaps, and priority improvement areas across ESG dimensions. Organizations typically receive maturity scores or ratings, peer benchmarking insights, and a **practical roadmap** outlining actions needed to progress to higher levels of ESG maturity and long-term sustainability leadership.

7.2 Double Materiality

In the ESG context, materiality refers to the sustainability issues that matter most to a company and its stakeholders. These include topics that can influence financial performance, risk exposure, reputation, and long-term value creation, as well as areas where the company itself has a significant impact on the economy, environment, or society. Material topics are therefore those that require focused management attention, transparent disclosure, and meaningful action.

An **ESG materiality assessment** is a systematic process to identify and prioritize environmental, social, and governance topics that are most significant to a company and its stakeholders. The effectiveness of materiality assessment is closely linked to **ESG maturity**–organizations with higher maturity have stronger data quality, governance, and decision-making processes, enabling more accurate identification of truly material issues and better integration into strategy and reporting.

7.2.1 Companies conduct materiality assessments to:

- Focus resources on the ESG issues that matter most
- Strengthen risk management and regulatory compliance (e.g., BRSR, GRI)
- Enhance transparency and credibility of ESG disclosures
- Align sustainability priorities with business strategy and stakeholder expectations
- Support informed decision making and long term value creation

Materiality helps avoid a "check-the-box" ESG approach and instead drives strategic relevance.

7.2.2 Common approaches and general steps:

- **Financial Materiality:** Focuses on ESG issues that affect the company's financial performance or enterprise value.
- **Impact Materiality:** Considers the company's impacts on society and the environment.

- **Double Materiality:** Combines both financial and impact perspectives, increasingly required under evolving regulatory frameworks.
- **Identification of ESG Topics** – Develop a long list of ESG issues based on regulations, standards, peer analysis, and internal context.
- **Impact Assessment** – Assess the severity and likelihood of the company's impacts on people and the environment.
- **Financial Risk & Opportunity Assessment** – Evaluate how ESG topics create financial risks or opportunities for the business.
- **Stakeholder Engagement** – Gather input from key stakeholders to validate priorities.
- **Scoring and Prioritization** – Rank topics using defined criteria and thresholds.
- **Validation and Governance Review** – Review and approve results with senior management or the board.

7.2.3 The results of a materiality assessment typically include:

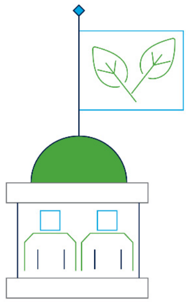
- A **prioritized list of material ESG topics**
- Defined **strategic ESG targets and KPIs** aligned to material issues
- A **sustainability roadmap** outlining actions, timelines, and responsibilities
- Clear linkage to ESG reporting, risk management, and assurance processes

Overall, a robust materiality assessment, supported by strong ESG maturity, enables organizations to move from compliance-driven sustainability to strategic, impact-oriented ESG management.

8.1 History & Evolution of Sustainability Reporting

Sustainability reporting has gradually shifted from largely voluntary, narrative-based disclosures to more structured systems built around measurable data, comparability, and accountability. This transition has been driven in large part by investor demand for clearer visibility into how environmental, social, and governance (ESG) factors affect financial risk, valuation, and capital allocation decisions.

The origins of modern ESG reporting can be traced back to the late 20th century, when the importance of non-financial disclosures began to gain recognition. A key milestone came in 1997 with the launch of the Global Reporting Initiative (GRI) by CERES and the Tellus Institute, with support from UNEP. GRI introduced one of the first widely accepted frameworks for reporting environmental and social impacts in a structured way.



Over time, additional frameworks emerged across regions and sectors to address evolving concerns such as climate change, corporate governance, and social responsibility. Today, more than three-quarters of the world's largest companies use at least one ESG reporting framework, making sustainability disclosure a standard part of corporate reporting. Increasingly, these frameworks link ESG performance with financial materiality and risk assessment, reflecting stronger expectations from both investors and regulators.

The timeline below highlights key global and India-specific ESG, & sustainability-related frameworks developed:

Year	Framework / Standards	Focus / Disclosures
1997	CERES – Global Reporting Initiative (GRI)	Comprehensive sustainability disclosures
2000	UN Global Compact (UNGC)	Human rights, labour, environment, anti-corruption
2002	Carbon Disclosure Project (CDP)	Climate, water, and forest disclosures
2006	UN Principles for Responsible Investment (UN PRI)	ESG in investment decisions
2011	SASB	Industry-specific, financial materiality
2015	TCFD	Climate risk — governance, strategy, risk, metrics
2019	EU Taxonomy	Classification of sustainable activities
2021	ISSB (by IFRS Foundation)	Global sustainability disclosure convergence
2021	BRSR (SEBI)	Mandatory ESG disclosures for top 1000 Indian companies
2024	CSRD/ESRS	Mandatory double materiality reporting standard replacing NFRD

One of the most significant recent developments is the Corporate Sustainability Reporting Directive (CSRD) in the European Union. Effective from 2024, it requires over 50,000 companies [including non-EU firms with substantial EU operations] to disclose sustainability information in line with the European Sustainability Reporting Standards (ESRS). This marks a shift toward more detailed, standardized, and enforceable ESG reporting.

At the same time, the focus of sustainability reporting has expanded beyond historical impact disclosures to include forward-looking assessments. Companies are now expected to evaluate transition risks, resilience, and long-term value creation in the context of climate change. This broader approach has also influenced national frameworks such as India's Business Responsibility and Sustainability Reporting (BRSR), which integrates global best practices with country-specific priorities.

8.2 BRSR Framework and Regulatory Landscape in India

To bring more structure and consistency to non-financial disclosures, SEBI introduced the Business Responsibility Report (BRR) framework in 2012. It was largely based on the National Voluntary Guidelines (NVGs) issued by the Ministry of Corporate Affairs in 2011, which outlined principles for responsible business conduct across economic, environmental, and social dimensions. Initially applicable to the top 100 listed companies, and later extended to the top 500, the BRR marked India's first formal move toward institutionalizing ESG-related reporting.

Recognizing the need for more comprehensive and decision-useful disclosures, SEBI replaced BRR with the Business Responsibility and Sustainability Reporting (BRSR) framework in 2021. Built on the National Guidelines on Responsible Business Conduct (NGRBC) released in 2019, BRSR is now mandatory for the top 1,000 listed entities by market capitalization. Compared to BRR, it significantly broadens both the scope and depth of reporting by introducing measurable ESG indicators alongside qualitative, policy-level disclosures.

One of the defining features of BRSR is its nine-principle structure, which simplifies the overall framework while still requiring detailed disclosures. Unlike many global standards, such as GRI or the ESRS under CSRD, which can be more complex in structure, BRSR adopts a phased approach. This allows companies to gradually expand reporting coverage, including value chain disclosures and assurance requirements, rather than adopting full-scale compliance immediately.

Another notable aspect is its digital-first design. BRSR requires disclosures to be submitted using an XBRL-based taxonomy, enabling better standardization, comparability, and data analysis. While global frameworks are also moving in this direction, BRSR is among the early country-level frameworks to operationalize taxonomy-based ESG reporting in practice.

The implementation timeline reflects this phased approach. Requirements related to applicability, third-party assurance (particularly under BRSR Core), and value chain reporting have been introduced in stages based on company size and readiness. This has given organizations time to strengthen internal data systems, improve supplier engagement, and build stronger governance processes to support high-quality ESG disclosures.

Year	Reporting	Assurance	Value Chain (Voluntary)
FY2023-24	Top 1000	Top 150	-
FY2024-25	Top 1000	Top 250	-
FY2025-26	Top 1000	Top 500	Top 250
FY2026-27	Top 1000	Top 1000	Top 250 (voluntary assurance)

The BRSR framework is organized into three sections designed to capture how ESG considerations are reflected across a company's operations, governance structures, and stakeholder impacts.

8.2.1 Section A: General Disclosures

This section provides the basic profile of the organization, including details such as its operations, listing status, and value chain coverage. A key component is Disclosure A.26, which requires companies to identify their material ESG issues along with associated risks, impacts, and opportunities. This forms the starting point for ESG integration, as it links the identification of material topics to the targets and initiatives defined in later sections, and ultimately to performance tracking.

8.2.2 Section B: Management and Process Disclosures

Section B focuses on how ESG priorities are managed within the organization. It outlines governance structures, including board oversight, management responsibility, and the extent to which ESG policies are implemented in practice. Specific disclosures such as B5 and B6 require companies to define sustainability goals, especially net-zero commitments, and explain the systems in place to achieve and monitor them. In essence, this section examines whether ESG considerations are embedded in decision-making, risk management, and long-term business strategy.

8.2.3 Section C: Principle-wise Performance Disclosures

This section forms the core of BRSR reporting and is aligned with the nine principles of the NGRBC. It covers a wide range of areas, including business ethics, environmental performance, employee well-being, and community engagement. Companies are required to report both qualitative information and quantitative metrics, such as emissions data, safety indicators, and diversity figures. In total, Section C includes 98 essential (mandatory) indicators and 42 leadership indicators, allowing for both baseline compliance and more advanced disclosures.

To strengthen the credibility of reported data, SEBI introduced **BRSR Core** in December 2023. This includes a defined set of key ESG indicators that are subject to third-party assurance, marking a shift toward more reliable and verifiable sustainability reporting.

8.2.4 Principle 6: Environmental Responsibility

Principle 6 of the BRSR framework focuses on environmental responsibility, requiring companies to assess, disclose, and manage their environmental footprint. **This principle explicitly covers metrics and initiatives for management & abatement of:**

- Greenhouse gas emissions
- Energy consumption
- Water consumption & discharge
- Waste management (generation, disposal & circular economy)

- Resource efficiency
- Biodiversity

Principle 6 is considered the central pillar for carbon accounting and climate / environment- related reporting within BRSR.

Organizations are encouraged to move beyond compliance-oriented disclosure toward proactive environmental management within the principle 6 section, including emissions mitigation, renewable energy adoption, and circular economy practices.

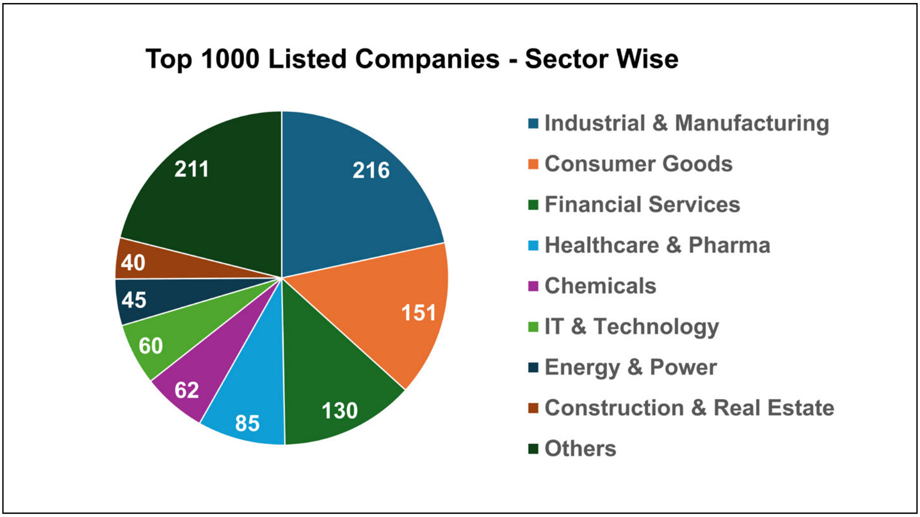
8.3 BRSR – Top 1000 Companies: Key Trends and Insights (2023-25)

Reviewing BRSR disclosures through the lens of ESG maturity and materiality provides a clearer picture of how meaningful and reliable these disclosures actually are. Although BRSR offers a standardized structure, the quality of reporting differs widely across companies. Organizations with more advanced ESG practices tend to identify relevant issues more clearly, define accountability, and report data that can support decision-making and assurance.

Materiality plays a central role in this process. When done well, it ensures that disclosures focus on the ESG issues that truly matter to the business and its stakeholders, rather than being generic or purely compliance driven. In more mature organizations, these material topics are backed by measurable indicators, clear targets, and structured data systems-making them better prepared for BRSR Core requirements and third-party assurance.

On the other hand, companies at earlier stages of ESG maturity often show gaps such as limited data, unclear ownership, inconsistent reporting, and weak or absent targets. These differences become more visible when comparing disclosures across the Top 1000 listed companies, and especially within the Top 250.

Looking at BRSR through this combined lens of maturity and materiality helps distinguish between companies that are genuinely integrating sustainability into their strategy and those that are primarily treating it as a reporting requirement. It also provides a more grounded view of how well organizations are prepared to manage risks, meet regulatory expectations, and create long-term value.



8.3.1 BRSR Section A: General Disclosures

Section A of the BRSR captures general information of the company & highlights strategic disclosure such as materiality issues in A-26. ESG Ratings providers (ERP) evaluate how materiality issues are addressed by companies via ESG strategy and performance. In our analysis of Top 1000 companies, it was observed that more than 90% of the companies are publishing their material issues and identification of risk & opportunities. Materiality assessments have emerged as one of the most in-demand ESG advisory services in India, as companies seek to identify and act on their most critical sustainability risks and opportunities. Many companies have yet to consider climate change as a major risk, missing the opportunity to disclose their strategic plans for mitigation.

8.3.2 BRSR Section B: Management Disclosure

In India, SEBI has well-articulated the structure and content of the Business Responsibility and Sustainability Report (BRSR), with Section B dedicated to sustainability-related policies, commitments, and governance mechanisms. This section mandates that disclosures be owned, reviewed, and reported by management representatives, ensuring a high level of leadership accountability.

Among the top 1,000 listed companies, nearly all have disclosed their sustainability policies in compliance with Section B, reinforcing ESG accountability and fulfilling SEBI's mandatory requirements.

8.3.3 BRSR Section C: Principle – wise Disclosure

Section C of the BRSR requires companies to disclose performance against the nine principles of the National Guidelines on Responsible Business Conduct (NGRBC). Each principle aligns with specific ESG themes and helps assess the company's operational sustainability, social responsibility, governance integrity & ethical conduct. The nine principles of BRSR section-C ensure that businesses embed ESG across all aspects from supply chains and employee welfare to climate impact and customer engagement contributing to a responsible and resilient corporate ecosystem.

8.3.4 Environmental Disclosures (Principles 2, 6)

BRSR Principle 2 focuses on the environmental impact of products, requiring companies to disclose practices related to Life Cycle Assessment (LCA), Extended Producer Responsibility (EPR), sustainable sourcing, and packaging. Principle 6 addresses the environmental footprint of production processes, mandating disclosures on energy consumption, GHG emissions (Scope 1, 2, and 3), waste management, and water usage.

- **Energy Consumption:** Total Energy consumption metric is a key indicator, which is directly linked to operational efficiency and carbon emissions. Also, the carbon footprint can be deduced along with the energy intensity. Sectors like Industrial & Manufacturing and Consumer Goods showed strong compliance, with more than 90% of companies reporting their annual & specific energy consumption.

- **GHG Emissions – Scope 1, 2, & 3:** GHG emissions are one of the key factors responsible for climate change, and reporting Scope 1 (direct emissions from fuel combustion), Scope 2 (indirect emissions from purchased electricity) and Scope 3 (all other indirect emissions across the value chain) emissions is crucial for assessing a company's environmental impact and emission intensity. Among the top 1,000 listed companies, most of them have reported Scope 1 & 2 emissions, reflecting growing alignment, awareness, and compliance. However, in BRSR, the Scope 3 reporting is a leadership indicator (not mandatory), and this shows a significant gap at the industry level, with only about 30% of companies disclosing this data, often citing challenges in estimation and supplier engagement.

- **Water Consumption & Management:** For water consumption (a critical natural resource), our analysis shows high disclosure levels with more than 95% of companies among the top 1000 companies reporting against disclosure. The Industrial, Consumer Goods, and Healthcare sectors led the disclosures. In contrast, service-based sectors like Financial Services and IT had lower disclosure rates, often due to a lack of water monitoring mechanisms.

- **Waste Management:** It has been observed that the retail & Textile sector showed stronger compliance with most reporting against waste management practices, including plastic waste, e-waste handling, and Extended Producer Responsibility (EPR) requirements, reflecting a more organised and responsible approach towards managing resources and meeting sustainability expectations.

- **Environmental impact of Product:** Principle 2 covers the environmental impact of products & services, one such parameter being Life Cycle Assessment (LCA). Chemical, Consumer Goods, and Automotive sectors showed relatively better adoption of LCAs, on either customer expectations or following global peer benchmarks.

8.3.5 Social Disclosures (Principles 3, 4, 5, 8)

The indicators across the social pillar, as outlined in BRSR Principles 3 (employee well-being), 4 (stakeholder engagement), 5 (human rights), and 8 (inclusive growth), emphasize the need for equity, inclusion, and responsible value chain across business operations with ESG ratings and global frameworks increasingly focusing diversity, equality and inclusion within their operations and disclosures.

- **Workforce Inclusion and Employment Generation:** Social performance begins with inclusivity in employment. India's top 1,000 companies collectively employ over 1.3 crore individuals, including approximately 18 lakh women and nearly 35,000 persons with disabilities. While Financial Services leads in total employment numbers, representation in sectors like Construction and Engineering remains disproportionately low, indicating a need for focused diversity efforts.

- **Occupational Health & Safety (OHS) Performance:** Employee well-being is one of the key aspects of OHS maturity. The average Lost Time Injury Frequency Rate (LTIFR) among the top 1000 companies stands at 0.65, but high-risk sectors such as Industrial & Manufacturing report an LTIFR of 1.39, reflecting hazardous work conditions. In addition, most of the reported fatalities were concentrated in just three sectors: Energy, Industrial, and Logistics, despite well-established safety management systems in these sectors.

- **Employee Training and Capacity Building:** Employee upskilling is essential for long-term ESG integration. Despite its importance, training disclosures remain limited: only about 9% of companies reported training 100% of their workforce. This gap suggests the absence of structured capacity-building programs.

- **Inclusive Sourcing from MSMEs:** Higher sourcing of materials from MSMEs indicates inclusive growth and regional development. Among the top 1000 companies, average material sourcing from MSMEs stood at ~16%, with Cement, Chemicals, and Healthcare sectors leading in inclusive procurement. However, the Retail and Energy sectors reported low integration of MSME suppliers, often due to centralized procurement systems or a lack of inclusive sourcing frameworks.

8.3.6 Governance Disclosures (Principles 1, 7, 9)

For concretizing ESG maturity in a company, ESG governance needs to be established, which is reflected in BRSR Principles 1 (Ethical Governance), 7 (Policy Advocacy), and 9 (Customer and Stakeholder Responsiveness) with emphasis on ethical conduct, inclusive decision-making, and transparent operations. BRSR's framework is aligned to CSRD/ ESRS regarding data privacy, which is covered in customer/ stakeholder engagement (Principle 9). While companies are making progress in select areas like board structure, gaps remain in assurance practices, grievance redressal, and supplier engagement.

- **Third-Party Assurance and ESG Verification:** Independent assurance is a key driver of trust and credibility in non-financial disclosures. In FY 2024–25, more than 250 of the top 1,000 listed companies undertook third-party ESG assurance, with additional 250 companies expected to undergo assurance for FY2025-26, in alignment with SEBI's phased BRSR Core roadmap. Sectors like IT and Consumer Goods have shown leadership with higher adoption of assurance.

- **Customer Grievance Redressal and Responsiveness:** Grievance redressal mechanisms demonstrate a company's commitment to stakeholder engagement and customer satisfaction. Sectors such as Media, Manufacturing, and Finance demonstrated high consumer complaints as well as resolution rates (due to their well-established redressal systems), whereas unresolved cases were significantly higher in Logistics and Transportation.

- **Supplier Accountability & Payment Practices:** Fairness and transparency across the value chain are core expectations as per the guidelines. Ensuring timely payments and ethical treatment of suppliers, especially MSMEs is essential for promoting resilience and sustainability within the broader business ecosystem. Among the top 1000 companies, more than 40% of companies reported settling accounts payable within 60 days, which supports supplier liquidity and trust, especially for MSMEs. However, around 16% of companies did not disclose this metric, and around 20% exceeded 90-day payment cycles; mostly in capital-heavy sectors, indicating systemic delays and strain on smaller suppliers.

8.4 Global Climate-based Frameworks: CDP, TCFD, SBTi

Three widely used climate-focused frameworks that companies rely on to address climate risks, mitigation, adaptation, and transition planning are the Carbon Disclosure Project (CDP), the Task Force on Climate-related Financial Disclosures (TCFD), and the Science Based Targets initiative (SBTi).

The CDP framework was one of the earliest platforms encouraging companies to disclose information on greenhouse gas emissions, climate-related risks and opportunities, and governance practices. Over time, its scope has expanded beyond climate to include areas such as water, forests, biodiversity, and plastics. Participating organizations are expected to report across key dimensions, including governance, risk management, strategy (along with financial implications), and metrics and targets. To date, more than 22,000 companies globally have reported through CDP. In India, over 700 companies are now participating, with only a small proportion achieving the top 'A' rating, reflecting leadership in environmental transparency and performance.

CDP disclosures have progressively aligned with the TCFD framework, which was established by the Financial Stability Board. TCFD is structured around four core pillars: governance, strategy, risk management, and metrics and targets. Its influence has been significant, shaping the design of several global reporting standards. Frameworks such as IFRS/ISSB standards have formally incorporated TCFD recommendations, while others like GRI and TNFD show strong alignment in structure and intent.

Another important initiative is the Science Based Targets initiative (SBTi), which focuses on aligning corporate climate targets with the Paris Agreement goal of limiting global warming to 1.5°C. Under SBTi, companies are required to set emissions reduction targets based on scientifically defined pathways rather than internal benchmarks. The initiative provides sector-specific decarbonization pathways, near-term target guidance, and net-zero standards to support companies in setting credible targets.

Globally, more than 10,000 companies have engaged with SBTi, with over 2,700 having established validated net-zero targets. In India, over 300 companies have validated targets under SBTi, including around 70 with net-zero commitments, while many others have committed to aligning their targets soon.

8.5 Implementation Challenges and Data Governance

Despite steady progress, companies still face practical challenges in implementing strong environmental and Net Zero disclosures within GRI-aligned BRSR frameworks. One of the biggest hurdles is data availability-particularly for Scope 3 emissions, where fragmented supply chains and varying levels of supplier maturity make data collection difficult. Maintaining consistency across subsidiaries, business units, and reporting periods further adds to the complexity, requiring well-defined internal processes and oversight.

In this context, effective data governance has become essential for credible sustainability reporting. Organizations need to clearly define data ownership, adopt standardized calculation methods, and put in place robust validation and verification processes, similar to those used in financial reporting. As regulatory expectations tighten and third-party assurance becomes more common, the quality of environmental data is no longer just a reporting issue. It is increasingly viewed as a core element of governance and risk management, highlighting the importance of a well-aligned GRI—BRSR approach.

8.6 ESG Ratings as Instruments of Corporate Accountability

ESG ratings assess how effectively a company manages environmental, social, and governance risks and opportunities, translating non-financial performance into a standardized score for investors and stakeholders. The process begins with data collection from public disclosures such as annual reports, sustainability reports, regulatory filings, company questionnaires, and third-party sources including news and controversy databases. Rating agencies then evaluate performance across the three pillars: Environmental (emissions, resource use), Social (labour practices, community impact), and Governance (board structure, ethics), using proprietary methodologies. Scores are benchmarked against industry peers and may be adjusted for risk exposure, controversial events, and forward-looking indicators.

ESG ratings offer dual benefits: improving access to capital by attracting ESG-focused investors and potentially reducing the cost of capital. Strong ratings enhance reputation and stakeholder trust while helping companies identify gaps in sustainability performance. Increasingly, ESG ratings influence executive compensation, and lending terms. Leading global ESG rating providers include MSCI ESG Ratings, Sustainalytics, S&P Global ESG Scores, and CDP. However, differences in methodologies often result in varied scores for the same company.

In India, ESG reporting has gained significant momentum through SEBI's Business Responsibility and Sustainability Reporting (BRSR) framework, which requires the top listed companies to disclose ESG-related information. Aligned partly with global standards such as GRI, BRSR improves transparency, consistency, and comparability of sustainability data. Both domestic and international rating agencies assess Indian companies, reflecting growing investor interest in ESG-focused investments. The NSE rating framework with focus on SEBI's BRSR framework further influences investor perception by evaluating governance standards, transparency, and ESG performance alongside financial strength.

To maximize the value of ESG ratings, companies should move beyond compliance by strengthening data governance, improving disclosure quality, and embedding sustainability into business strategy. Regular engagement with rating agencies, transparent reporting of material ESG issues, and alignment with globally accepted frameworks can enhance outcomes thereby viewing ESG ratings as a continuous improvement tool. As investors increasingly prioritize responsible businesses, companies with stronger ESG ratings and better disclosures are often viewed as more attractive investment opportunities, encouraging greater focus on sustainability reporting and performance.

Chapter 9 Case Studies – Renewable Energy & ESG Implementation

9.1 Performance Optimization of a Grid-Connected Solar Power Plant

9.1.1 Business Rationale: RSM India initiated the technical audit to validate whether the solar portfolio was performing in line with design expectations, identify any hidden inefficiencies, and strengthen investor confidence by demonstrating operational reliability and sustainability alignment.

9.1.2 Situation: A utility-scale solar photovoltaic portfolio located in southern India, developed in phases, was operating in a high solar potential region. While the plants followed a standardized design and engineering approach, the rapid scale of deployment necessitated an independent evaluation of actual performance against simulated benchmarks.

9.1.3 Task: The objective was to assess plant performance, benchmark key operational indicators, identify system losses across DC and AC components, and evaluate the effectiveness of operation and maintenance practices in sustaining efficiency and reliability.

9.1.4 Action: A comprehensive technical audit was conducted using a combination of physical inspections, supervisory control data, energy metering, and weather monitoring inputs. Performance indicators such as performance ratio, capacity utilization, and energy generation efficiency were analysed. Loss assessments were carried out across system components, while maintenance practices were reviewed, including preventive protocols, thermal inspections, and the integration of robotic cleaning systems to address dust-related inefficiencies.

9.1.5 Result: The audit revealed that the portfolio was operating within a very narrow deviation range compared to simulated performance, with performance levels exceeding expected benchmarks by a small percentage margin. System losses on both DC and AC sides remained within acceptable percentage thresholds, indicating stable and controlled operations. Preventive maintenance and automated cleaning contributed to sustained efficiency improvements and reduced performance degradation over time.

9.1.6 **How it helped the company:** The audit reinforced the technical soundness and operational stability of the portfolio, enhancing investor confidence and positioning the asset as low risk. It also provided actionable insights to further optimize maintenance strategies, improve long-term performance by incremental percentage gains, and strengthen eligibility for sustainable financing opportunities.

9.2 ESG Maturity: A Game Changer for a Leading Auto Component Maker

9.2.1 **Project Rationale:** The company initiated the ESG transformation to respond to increasing expectations from OEMs, evolving regulatory requirements, and investor scrutiny. Sustainability was becoming a critical factor in supplier evaluation, making it essential to transition from a fragmented, compliance-driven approach to a structured and strategic ESG framework.

9.2.2 **Situation:** A leading Indian automotive components manufacturer with strong operational capabilities, particularly in occupational health and safety, was facing inconsistencies in its overall ESG performance. While certain areas were well-developed, the broader ESG framework lacked integration, with gaps in governance, environmental performance, and human rights practices. ESG efforts were dispersed across functions, with limited coordination and inconsistent data management.

9.2.3 **Task:** The objective was to establish a cohesive ESG framework, improve overall ESG performance across key dimensions, strengthen governance mechanisms, and align the organization with regulatory requirements and global customer expectations. Additionally, the company aimed to embed ESG into operational processes and enhance data-driven decision-making.

9.2.4 Action: A structured ESG transformation program was implemented, beginning with a comprehensive diagnostic assessment of existing practices, systems, and awareness levels. A phased roadmap was developed, aligned with regulatory frameworks such as Business Responsibility and Sustainability Reporting and global OEM expectations. The company introduced robust data management systems to track energy, emissions, and resource usage, replacing fragmented monitoring practices. Governance structures were strengthened through clearer policies, defined roles, and enhanced oversight. Simultaneously, organization-wide capacity building initiatives were undertaken to align cross-functional teams with ESG objectives and implementation approaches.

9.2.5 Result: The company achieved a significant improvement in ESG performance, with the overall score increasing by approximately 65% over the assessment period. Governance performance more than doubled, while environmental and human rights indicators showed strong upward trends. Occupational health and safety reached near optimal levels. Operationally, energy efficiency measures resulted in a reduction of approximately five to eight percent in consumption, generating substantial cost savings. Streamlined data systems reduced manual effort by approximately 30–35%, improving efficiency in reporting and compliance processes.

9.2.6 How it helped the company: The transformation strengthened the company's position as a preferred supplier by enhancing its ESG credentials, contributing to incremental business retention and growth by a small percentage margin. It also reduced compliance risks, improved operational efficiency, and delivered measurable cost savings. More importantly, it enabled a shift toward a proactive, value-driven approach, positioning the company for long-term competitiveness and resilience in a sustainability-focused automotive ecosystem.

9.3 Integrated Value Chain Assessment for a Leading Jewellery Manufacturer

9.3.1 Project Rationale: The client undertook this initiative to address increasing complexity in ESG compliance across its supply chain, driven by overlapping global frameworks and rising expectations from international buyers. There was a clear need to streamline processes, reduce inefficiencies, and strengthen traceability and transparency in sourcing practices.

9.3.2 Situation: A globally active jewellery manufacturer operating in a highly regulated and trust-driven industry was managing multiple ESG frameworks, including responsible sourcing and due diligence standards. While internal ESG systems were well-established, supplier-level compliance was fragmented and resource-intensive. Suppliers were required to respond to repeated and overlapping data requests, leading to inefficiencies, inconsistent data quality, and operational strain on both internal teams and external partners.

9.3.3 Task: The objective was to simplify ESG requirements across the value chain, reduce duplication in data collection, improve supplier engagement, and enhance visibility into supply chain risks. At the same time, the company aimed to maintain alignment with global standards while improving efficiency and reducing compliance-related costs.

9.3.4 Action: A comprehensive mapping of all applicable ESG frameworks and requirements was conducted to identify overlaps and redundancies. Based on this, the company rationalized data requirements, significantly reducing the number of indicators while retaining alignment with global standards. The streamlined dataset was converted into a concise supplier assessment format covering key ESG dimensions. The supplier onboarding process was redesigned into a structured, integrated approach, embedding ESG considerations into standard workflows. Additionally, a risk-based assessment mechanism was introduced to prioritize high-risk suppliers and enable targeted interventions.

9.3.5 Result: The initiative led to a substantial reduction in complexity, with ESG data requirements decreasing by approximately seventy five percent. Supplier response rates improved by approximately twenty to twenty five percent, resulting in better data quality and reduced follow-up efforts. Consolidation of frameworks minimized the need for multiple audits, leading to significant cost savings. Overall, the company achieved meaningful cost optimization, with efficiency gains realized across data management, supplier engagement, and compliance processes.

9.3.6 How it helped the company: The streamlined approach enhanced supply chain visibility and enabled more proactive risk management, strengthening the company's ability to address sourcing and compliance challenges. It also improved credibility with international buyers, supporting incremental competitiveness in export markets by a small percentage margin. Beyond cost and efficiency gains, the initiative repositioned ESG as a strategic enabler, improving operational clarity and reinforcing the company's standing in a highly scrutinized global industry.

9.4 Climate Risk & Net-Zero Roadmap for a Sustainable Highway Project

9.4.1 Project Rationale: The client initiated the engagement to respond to increasing expectations from investors, lenders, and regulators around climate accountability. There was a need to quantify emissions, assess climate-related risks under different future scenarios, and define a structured, financially viable pathway toward net-zero while ensuring long-term asset resilience.

9.4.2 Situation: A major highway and toll operator managing a large infrastructure corridor was operating without a consolidated view of its greenhouse gas emissions and climate exposure. Emissions were distributed across multiple operational sources, and climate risks-particularly those related to changing weather patterns-had not been formally assessed. As scrutiny increased, the absence of a structured framework limited the organization's ability to make informed, forward-looking decisions.

9.4.3 Task: The objective was to develop a comprehensive greenhouse gas inventory, conduct a climate risk assessment across short-term and long-term horizons using scenario analysis, and create a phased net-zero roadmap. The assessment also aimed to identify key risk parameters and prioritize interventions that balance environmental impact with financial feasibility.

9.4.4 Action: A detailed emissions assessment was conducted covering operational activities such as energy consumption, fuel usage, and contractor operations, leading to the development of a structured greenhouse gas inventory. In parallel, a climate risk assessment was undertaken using multiple parameters across Representative Concentration Pathway and Shared Socioeconomic Pathway scenarios, evaluated over both short-term and long-term horizons. Key risks (including heat stress and water depletion) and its impact on infrastructure performance and maintenance were identified and prioritized.

Building on these insights, a phased net-zero roadmap was developed. Short-term actions focused on energy efficiency measures and partial renewable energy adoption. Medium-term interventions included scaling renewable energy usage and gradual fleet electrification. Long-term strategies addressed deeper decarbonization opportunities such as low-carbon materials, contractor engagement, and selective use of offsets. Financial analysis was integrated to assess investment requirements, savings potential, and payback periods.

9.4.5 Result: The organization established a clear emissions baseline and identified reduction opportunities of approximately fifteen to twenty percent in the short term, with cumulative reduction potential reaching approximately sixty to seventy percent over the long term. Climate risk assessment enabled prioritization of high-impact risks such as heat exposure, improving preparedness and resilience planning. Energy efficiency and renewable interventions demonstrated strong financial viability, with projected savings contributing to a favourable payback period. Additionally, the project strengthened its alignment with climate-focused financing frameworks.

9.4.6 How it helped the company: The initiative enhanced the company's ability to manage both transition and physical climate risks, improving long-term asset resilience. It enabled data-driven decision-making, reduced exposure to future regulatory and carbon pricing risks, and strengthened access to sustainable financing. Overall, the roadmap positioned the organization to achieve incremental efficiency gains and long-term value creation while aligning with evolving global climate expectations.

9.5 Emission Reduction Opportunities by LCA for a Leading Agro-Consumer Product Manufacturer

9.5.1 Project Rationale: The client initiated the engagement in response to increasing requests from international clients to quantify and reduce product-level carbon footprints and lifecycle impacts. There was a clear need to move beyond operational boundaries and develop a comprehensive understanding of emissions across the entire value chain to remain competitive in sustainability-driven markets.

9.5.2 Situation: A leading agro-consumer product manufacturer with established internal processes faced limited visibility into emissions beyond its manufacturing operations. Upstream raw material impacts and downstream usage-phase emissions were not systematically assessed, making it challenging to respond to client queries, participate in sustainable procurement programs, and identify meaningful emission reduction opportunities.

9.5.3 Task: The objective was to conduct a comprehensive cradle-to-grave life cycle assessment for key product categories, quantify emissions across all lifecycle stages, and identify opportunities to reduce product-level carbon footprints. Additionally, the company aimed to strengthen its ability to meet international client expectations and enhance transparency in environmental performance.

9.5.4 Action: A detailed life cycle assessment was carried out in line with internationally recognized standards, covering stages from raw material sourcing and manufacturing to transportation, product use, and end-of-life treatment. Data collection involved cross-functional collaboration, supplier engagement, and the use of secondary datasets to address data gaps. The analysis enabled identification of emission hotspots across the value chain, particularly in upstream and downstream stages. Based on these insights, targeted interventions were developed, including optimization of raw material selection, increased adoption of lower-carbon inputs, process efficiency improvements, and engagement with logistics partners to reduce transportation impacts. Product design considerations were also evaluated to minimize emissions during the usage phase.

9.5.5 Result: The assessment revealed that approximately 65 to 75% of total emissions originated outside direct manufacturing operations. Targeted interventions were estimated to deliver a reduction of approximately ~15-25% in product-level emissions over the near to medium term. Operational efficiencies contributed to cost savings, while improved resource utilization enhanced overall process performance. The company also established a robust, data-driven foundation for lifecycle emissions tracking and reporting.

9.5.6 How it helped the company: The initiative significantly strengthened the company's ability to respond to client requirements and align with global sustainability expectations, supporting revenue protection and growth by a small percentage margin in key export markets. It improved transparency, enabled participation in sustainability-focused procurement programs, and enhanced internal decision-making by clearly identifying emission hotspots. Overall, the company transitioned from limited visibility to a strategic, lifecycle-based approach, positioning sustainability as a driver of both environmental performance and long-term business value.

Chapter 10 Consulting as a Catalyst in Renewable Energy

The primary challenge in adopting renewable energy lies not in meeting compliance requirements, but in enabling organizations to navigate and understand a rapidly changing and complex landscape.

Services like technical due diligence, regulatory advisory, performance benchmarking, and compliance audits give developers and asset owners the clarity they need to navigate policies, schemes, and obligations such as RPOs and open access rules. Instead of treating regulations as constraints, consultants help turn them into opportunities, ensuring projects stay compliant while also maximizing incentives and aligning with broader goals like net-zero and national climate commitments.

At the same time, consultants play a key role in connecting organizations with global sustainability expectations. Through ESG advisory, carbon management and sustainability reporting, they help businesses speak the same language as international frameworks and investors. This not only ensures transparency but also positions companies to actively participate in global climate initiatives, strengthening their credibility in an increasingly sustainability-driven market.

Another important role consultants play is bridging the gap between theory and practice. While academic research and technological innovation continue to advance rapidly, translating those developments into real-world performance is not always straightforward. By leveraging tools like performance analytics, energy yield assessments, and SCADA data insights, consultants evaluate what truly works in the field. They help organizations adopt the right technologies, optimize operations, and continuously improve performance based on real data rather than assumptions.

From an investor's perspective, consultants bring much needed confidence and transparency. Independent engineering reviews, asset valuation, ESG assessments and risk analysis provide a clear picture of a project's health and potential. This helps investors make informed decisions, reduces uncertainty and improves access to green financing.

Strong benchmarking and credible data also contribute to better ESG ratings, which are increasingly influencing investment flows.

Ultimately, consultants act as connectors across multiple dimensions – policy, technology, finance, and sustainability. They translate regulations into actionable steps, align global frameworks with on-ground execution, and turn innovative ideas into scalable solutions. By balancing technical expertise with regulatory insight and financial understanding, they ensure renewable energy projects are not only compliant but also efficient, resilient, and aligned with long-term climate goals.

Appendix

1. ESG and Sustainability Services

- **Elevate your business through ESG / Sustainability**

ESG Assessment, Strategy & Roadmap	ESG Policy, Governance & Performance	GHG Inventory, Net Zero Strategy & Decarbonisation	ESG Report / Disclosures & Assurance	ESG Workshops, Due Diligence, LCA & EPR
■ Gap / Maturity Assessment ■ Stakeholder Engagement ■ Materiality Assessment ■ ESG Risk, Opportunity Analysis ■ ESG Strategic Roadmap ■ Peer comparison & Industry Benchmarks ■ EcoVadis Assessment	■ Policy mapping & Development ■ ESG Governance Structure Framework ■ Integration of ESG, ISO14001, ISO45001 & ISO50001 ■ ESG Key Performance Indicators (KPI) ■ KPI Monitoring Template & ESG Best Practices Implementation	■ GHG Inventory & Carbon Footprint ■ Climate Risk Scenario Analysis ■ Establish measures & mitigation strategies ■ Decarbonization roadmap to Net Zero using SBTi ■ GHG Validation & Verification (ISO 14064) ■ Energy Audit & Efficiency Strategy	■ Data templates and Data collection ■ ESG Initiatives, Success Stories & Case Studies ■ Map & Align CDP, DJSI, UNSDGs ■ Internal Audit for ESG Reporting ■ ESG Draft Report (BRSR/GRI/TCFD) ■ ESG / Sustainability Report Assurance (AA1000, ISAE3000)	■ ESG / Sustainability Training & Workshop ■ ESG Due Diligence ■ HSE Audits & Road Safety Audit (IRC/IS) ■ Life Cycle Assessment (LCA) ■ Extended Producer Responsibility (EPR) ■ Environmental & Social Impact Assessment (ESIA) ■ Sustainable Finance Consulting

2. Renewable Energy Services

- **Re-engineering Energy for a Sustainable Tomorrow**

| Solar | Wind | Green Hydrogen | CBG | BESS | CCUS |

Decarbonization Policy & Strategy	Project Life Cycle Support	Technical & Performance Review	Internal Audit RE Review
■ Current Operations: Gap Identification ■ RE Strategy & Net-Zero Roadmap ■ Review Energy Policy & Regulatory Framework ■ Technology/ Market Analysis	■ Site Screening & Interconnection Feasibility (IFC/ WB) ■ E&S Impact Assessment ■ Techno-Commercial Feasibility & Project Report Validation ■ Tendering & Bid Review ■ Life Cycle Assessment	■ SCADA Assessment ■ Loss/ Degradation Study ■ Predictive Maintenance & Reliability Analysis ■ Power System Studies & Electrical Testing ■ Soil & Water Testing ■ Operational Efficiency & CCTS Evaluation	■ Capacity-Building ■ Energy Diagnosis ■ RE Waste Management & Circular Economy ■ Cloud-based Data Assessment ■ Assurance Support

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Gurugram
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MG Road, Gurugram - 122002

Chennai
2nd & 4th floor, Apex Towers
R.A. Puram, Chennai - 600 028

Bengaluru
3rd floor, Jubilee Building
45, Museum Road
Bengaluru - 560 025

Hyderabad
1208, Gowra Fountainhead
Huda Techno Enclave, Hitec City
Hyderabad - 500 081

Kolkata
5th floor, J K Millennium Centre
Jawaharlal Nehru Road
Kolkata - 700 071

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Gujarat Hira Bourse
Ichhapore-2, Surat - 394 510

Ahmedabad
B/211, 2nd floor, Mondeal Heights
Opp. Karnavati Club, S.G. Highway
Ahmedabad - 380 015

Pune
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Ganesh Khind Road
Opp. NIC University Chowk
Pune - 411 016

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206, Sunshine Arcade II
Plot No. 37, Sector 8
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