Building sustainable chemical manufacturing in India through innovation, integration and incentives

pwc

ICC

MESSAGE

Shri Jagat Prakash Nadda ,

Hon'ble Union Minister for Chemicals and Fertilizers and Health & Family Welfare

I extend my warmest greetings for the 6th ICC Sustainability Conclave . This year's theme, "*Sustainable Chemical Manufacturing: Innovations, Integration, and Incentives* " sets the stage for insightful discussions and collaborations that I hope would contribute to sustainable growth of the Indian Chemical industry.

The Chemical industry has long been a cornerstone of progress, driving advancements across various sectors of the economy and enhancing the quality of life for people worldwide. In India, with the support of both Government initiatives and industry innovation, we are poised for exponential growth. The Chemical industry has a key role to play in realizing our Hon'ble Prime Minister's vision of propelling India to the stature of a Global Economic Power.

Furthermore, as the world embarks on a journey towards a more environmentally conscious future, our sector is experiencing a profound paradigm shift. We are witnessing a determined effort towards sustainable practices and innovative approaches, aligning with the imperative of reducing emissions and advancing sustainable development goals by 2030.

I am pleased to note that the conference will be dedicated to exploring the finest sustainable practices embraced by companies and the pursuit of alternative methods. It will delve into initiatives fostering a systematic transition to a circular economy, reflecting the commitment of the Government of India towards sustainable development.

I extend my best wishes to the Indian Chemical Council for resounding success of the event.

(Jagat Prakash Nadda)

December 3rd 2024
New Delhi

अनुप्रिया पटेल
ANUPRIYA PATEL

राज्य मंत्री
स्वास्थ्य एवं परिवार कल्याण
व रसायन एवं उर्वरक
भारत सरकार

MINISTER OF STATE
HEALTH & FAMILY WELFARE
AND CHEMICALS & FERTILISERS
GOVERNMENT OF INDIA

MESSAGE

I am delighted to note that the Department of Chemicals & Petrochemicals, Government of India jointly with the Indian Chemical Council is organizing 6th ICC Sustainability Conclave 2024. This year's theme, *"Sustainable Chemical Manufacturing: Innovations, Integration, and Incentives,"* profoundly resonates with the current trajectory of our nation's chemical sector. This event stands as a testament to the pivotal role played by the chemical industry in shaping our nation's path towards progress and prosperity.

The chemicals and petrochemicals sector can transform India into a global manufacturing hub in sync with Hon'ble Prime Minister, Shri Narendra Modi ji's vision of 'Make in India, Make for the World.' The Indian Chemical and Petrochemical industry holds substantial potential to play a significant role in boosting the nation's growth, thanks to the industry-friendly policies of the government and various initiatives taken to ease business operations in the country.

Recognizing India's status as a rising economy, it is evident that the Indian chemical and petrochemical industries possess vast potential to significantly contribute to the nation's growth.

I am happy to be a part of the Conference, where I look forward to interact with national and international industry representatives, all gathered under one roof promoting the noble and common good of sustainability.

I wish the event a great success and hope all the participants will benefit immensely from it.

(Anupriya Patel)

November 25, 2024
New Delhi

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NIVEDITA SHUKLA VERMA, IAS

सचिव
भारत सरकार
रसायन और उर्वरक मंत्रालय
रसायन और पेट्रोरसायन विभाग
Secretary
Government of India
Ministry of Chemicals & Fertilizers
Department of Chemicals & Petrochemicals

26th November 2024

Message

The chemicals and petrochemicals sector holds a pivotal position in driving economic growth, not only within India but also in economies worldwide. Guided by the dynamic leadership of our Hon'ble Prime Minister, the Indian government is steadfastly dedicated to fortifying this sector and propelling India towards becoming a global hub for chemicals and petrochemicals manufacturing.

The historic commitment made by India during the COP26 summit in Glasgow in 2021, is a landmark. India has pledged to achieve net-zero emissions by the year 2070, a pledge that significantly underpins the global effort to attain the ambitious goal of limiting global warming to 1.5°C. In this remarkable journey, the chemical sector is poised to play a foundational and indispensable role in aligning with both global and Indian objectives on the path to Net Zero.

The convergence of governmental initiatives, such as the enhancement of Ease of Doing Business, creation of World Level Infrastructure, the progressive reforms in the Corporate Tax regime, and unwavering support to the MSME sector, has transformed India into a destination for sustainable investments within the realm of the Chemicals and Petrochemicals industry.

In such a scenario it is imperative that the leaders of the chemical industry continue to lead the sustainability efforts in the industry adopting the best technologies and innovative processes.

I am confident that this conclave will generate meaningful dialogues among industry leaders. I look forward to the insights that will emerge and expect to be followed up, as they shape our future.

(Nivedita Shukla Verma)

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Message from ICC

Kartik Bharat Ram
President
ICC

The principle of sustainability has become deeply ingrained across various industries in modern times. In the chemical industry, sustainability is driven by both regulatory and voluntary initiatives. Due to the fundamental characteristics of chemicals, their utilisation has always been subject to stringent regulations. Simultaneously, at a global scale, the industry has developed a verifiable model of compliance that focuses on the product, community, safety and sustainability aspects. The Indian Chemical Council (ICC) is the proud flagbearer of this initiative called Responsible Care (RC).

As a premier chemicals industry association, ICC continues to actively work with both the industry and the government to ensure that the chemical industry contributes its fair share and plays an important role in the country's economic revival after the COVID-19 pandemic. This sustainability conclave exemplifies ICC's commitment towards promoting the cause of sustainability while also focusing on the growth potential for the industry.

I am happy that the foundation laid by ICC in November 2019 with the first edition of the conclave is being successfully followed this year despite the unforeseen challenges we are facing today. Growth should not come at a compromise – it must be achieved sustainably with society as the focal point.

The prosperity of business has become closely interlinked with sustainability due to increased focus and awareness on both environmental and social fronts. Sustainability for industries has become the pillar for growth and has been a key focus area for ICC, especially with the promotion of RC in the country. RC not only fosters the safe production of chemicals but also nurtures environmental sustainability, chemical security, and the well-being of employees and surrounding communities.

To provide some context, the global chemicals industry is responsible for approximately 5% of the world's greenhouse gas (GHG) emissions and is key to achieving net-zero targets.[1] Through initiatives like RC, the industry has made significant strides in reducing its environmental impact.

I am confident that ICC will endeavour to follow up and support the implementation of outcomes of this conclave. This two-day event serves as a compelling platform to champion the cause of sustainability throughout the complete life cycle of chemicals. I would like to express my deep appreciation to the Department of Chemicals and Petrochemicals, Ministry of Chemicals and Fertilizers, for adopting and supporting the initiative that will enable us to further strengthen the sustainability efforts in the sector.

I extend my heartfelt wishes for the success of the event.

1. https://www.weforum.org/press/2021/10/global-chemical-companies-collaborate-in-pivotal-move-to-net-zero/

Message from ICC

Ravi Kapoor
Chairman,
ICC Sustainability Committee, and
MD, Heubach Colour Pvt. Ltd

It is once again my pleasure and privilege to welcome you and introduce the sixth edition of ICC's Sustainability Conclave 2024 themed 'Sustainable chemical manufacturing: Innovations, integration and incentives' where we aim to navigate the challenges and explore the boundless opportunities that lie ahead.

The chemical industry of the world and India has a significant role in contributing to this task. Companies have a new and intense focus on ESG with stakeholders demanding that our industry must have a clear focus and strategy for environment, social and governance standards. For chemical companies to be considered as successful and valuable, it is no longer enough to show a growing top line and bottom line or even to come out with a great line of products. It is now more and more important to do all this in the most sustainable manner using the cleanest technology with least emissions in the safest manner and keeping in mind the larger good and social responsibilities.

The theme of the Conclave 2024 'Sustainable chemical manufacturing: Innovations, integration and incentives' is of paramount importance for long-term success of the industry and for the well-being of our planet. It enables the industry to address its challenges and seize opportunities for growth, innovation and making a positive societal impact while minimising harm to the environment and communities.

Once again, ICC is glad to collaborate with Department of Chemical and Petrochemical, GoI , UNEP and PwC, to bring about this event where we have a long list of illustrious speakers both from Government and industry, India and abroad. We hope you find this a useful and valuable event and our team at ICC will strive to continue to bring you similar events.

We sincerely appreciate your participation and solidarity with the cause of sustainable practices and together build a viable and thriving chemical industry in India.

Message from ICC

D Sothi Selvam
Director General
ICC

The Indian chemical industry stands as a pivotal and burgeoning cornerstone of the nation's economy. Spanning a vast spectrum of over 80,000 commercial products, this sector boasts of remarkable diversity, serving as a wellspring of essential raw materials for a multitude of crucial industries. With a workforce exceeding two million individuals,[2] it plays a significant role in propelling India towards the coveted milestone of achieving a USD 5 trillion economy.

The Department of Chemicals and Petrochemicals, under the Government of India, has ushered in a series of pivotal regulatory and policy initiatives aimed at fostering and catalysing the advancement of the chemical sector. As a consequence of these strategic interventions, India's chemical industry finds itself on a robust trajectory of growth and prosperity. Forecasts indicate that the market size of the chemical and petrochemical sector in India, currently valued at approximately USD 220 billion, is poised for substantial expansion and expected to reach USD 1 trillion by 2040.[3]

The Indian Chemical Council (ICC) is committed to advancing the chemical industry's interests through a comprehensive approach of responsible and sustainable growth. By proactively engaging with Government policies, ICC safeguards its members' well-being by sharing vital insights on safety, health and environmental concerns.

ICC takes a proactive role in fostering innovation, maintaining quality standards, and nurturing technology integration through training, research, and development initiatives. In addition, the organisation tirelessly works to build strong relationships among its members, Government authorities and the public, while endorsing energy conservation and responsible care initiatives.

I am happy to be part of the sixth edition of the ICC Sustainability Conclave 2024 being organised by the Department of Chemicals and Petrochemicals, Government of India, in collaboration with ICC. The conclave will be dedicated to exploring the finest sustainable practices embraced by companies and the pursuit of alternative methods fostering the creation of a thriving ecosystem.

Sustainable chemical manufacturing is not just a moral imperative – it is also a business imperative as consumers demand eco-friendly products, investors prioritise environmental, social and governance (ESG) aspects, and regulations increasingly focus on environmental stewardship.

Let us work together to create a sustainable chemical industry – for our planet's future and the long-term prosperity of our businesses.

I welcome you all to this event and hope all the participants will benefit immensely from it.

2 https://www.ibef.org/industry/chemical-industry-india

3 Ibid

Foreword by PwC

India's diverse chemical industry with over 80,000 commercial products, employs ~2 million people working in different capacities throughout the value chain. India plays a very important role in the global chemicals industry by representing 2.5% of worldwide chemical sales and exporting to over 175 countries. As the sixth-largest producer globally and third in Asia, the share of GVA in the manufacturing sector for India is about 9.88% at current prices.[4]

The industry has made considerable strides towards sustainability by shifting its focus from compliance to proactive global engagement, inspired by global chemical industry initiatives like Responsible Care and ICC's own initiative, Nicer Globe. Today, climate change, regulatory compliances, and consumer demands are driving chemical companies to integrate sustainable practices in their manufacturing and at the same time, improve their competitive advantage and brand image.

Against this backdrop, PwC and the Indian Chemical Council (ICC) present this knowledge paper, outlining a roadmap for sustainability in India's chemical manufacturing sector. Our 3I approach – innovation, integration and incentives – serves as the steppingstone for this transformation.

Innovation involves leveraging renewable resources, advancing green chemistry and adopting decarbonisation strategies to promote sustainability while ensuring profitability.

Integration focuses on building sustainable supply chains through responsible sourcing and considering the green chemistry principles in mind, to reduce waste and to create economic value.

Incentives and tools like green bonds and tax incentives provide the crucial encouragement to chemical companies towards usage of sustainable technologies.

The transformation of India's chemical industry requires a holistic approach, including feedstock diversification, decarbonisation and implementation of green chemistry principles. By strengthening supply chain resilience and utilising incentives, the industry can secure its future at the forefront of sustainability.

PwC India is committed to this journey, and to foster innovation, collaboration and sustainability initiatives to ensure that India's chemical sector achieves its sustainability goals and maintains its global competitiveness.

We invite industry leaders, policymakers, and stakeholders to join us in this endeavour towards building a sustainable future for India's chemical manufacturing industry.

Sandeep Kumar Mohanty
Partner – Climate and Sustainability Strategy
PwC India

Manas Majumdar
Partner – Energy and Chemicals Leader
PwC India

Mukund Devnani
Managing Director – Energy and Chemicals
PwC India

4 https://chemicals.gov.in

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1 Introduction

1.1 Contribution of the chemical sector

Spanning more than 80,000 commercial products, India's chemical sector's offerings are quite diverse. The sector directly employs about 2 million people across various roles, from production to research and development (R&D).[5] It also generates millions of indirect jobs within its supply chain and presents a wide-range of opportunities for logistics, distribution and retail sector.

Figure 1: Type of chemical industries

Chemicals

Bulk chemicals	Petrochemicals	Specialty chemicals
Bulk chemicals are produced in large quantities, have lower value and play a crucial role in downstream industries. They are categorised into three types: **alkali, organic, and inorganic.**	Petroleum distillates, derived from petroleum and natural gas through refining, include **polymers, synthetic fibers, and performance plastics.**	Specialty chemicals are high-value, low-production-volume chemicals, including **surfactants, paints and coatings,agrochemicals. battery chemicals, flavour and fragrances**

Source: https://chemicals.gov.in/sites/default/files/inline-files/Report_Understanding_Industry_Landscape.pdf

Figure 2: Highlights of Indian chemical industry

- India is the **sixth largest producer of chemicals in the world and third largest producer in Asia.**
- Indian chemical industry is expected to grow at a **CAGR of 11-12% by 2027.**
- Share of GVA in the manufacturing sector for India is about **9.88%** at current prices.
- **14th rank in exports and 8th in imports** for chemicals in world (except pharmaceuticals)
- **Fourth-largest producer of agrochemicals** after the United States, Japan and China
- An investment of **INR 8 lakh crore (USD 107.38 billion)** is estimated to be made by the Indian government in the Indian chemicals and petrochemicals sector by 2025

Source: https://www.ibef.org/industry/chemical-industry-india

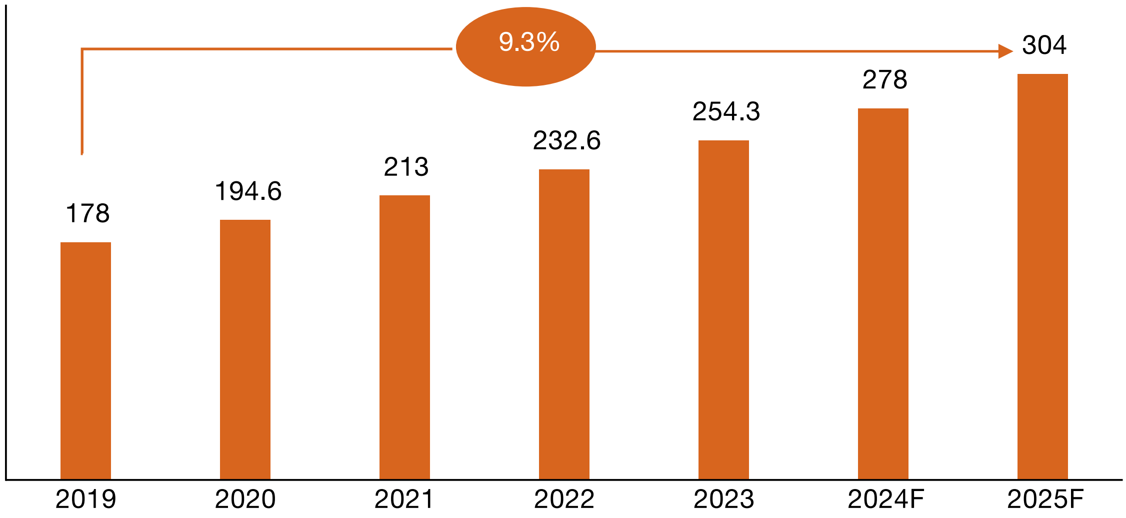
With considerable investments in this sector[6] the focus of the government is to enhance domestic production, reduce imports, and attract investments to ensure that India's chemicals and petrochemicals industry becomes self-reliant.

5 https://www.ibef.org/industry/chemical-industry-india

6 https://www.ibef.org/industry/chemical-industry-india

In the past few years, initiatives like the National Chemical Policy Petroleum, Chemicals and Investment Region (PCPIR) and a focus on hydrogen as a fuel have been introduced to boost the production capabilities of the chemical industry. There are also plans to upgrade the infrastructure and strengthen their competitiveness in both domestic and international markets. These undertakings are expected to position India's chemicals and petrochemicals sector as a significant player at the global stage.

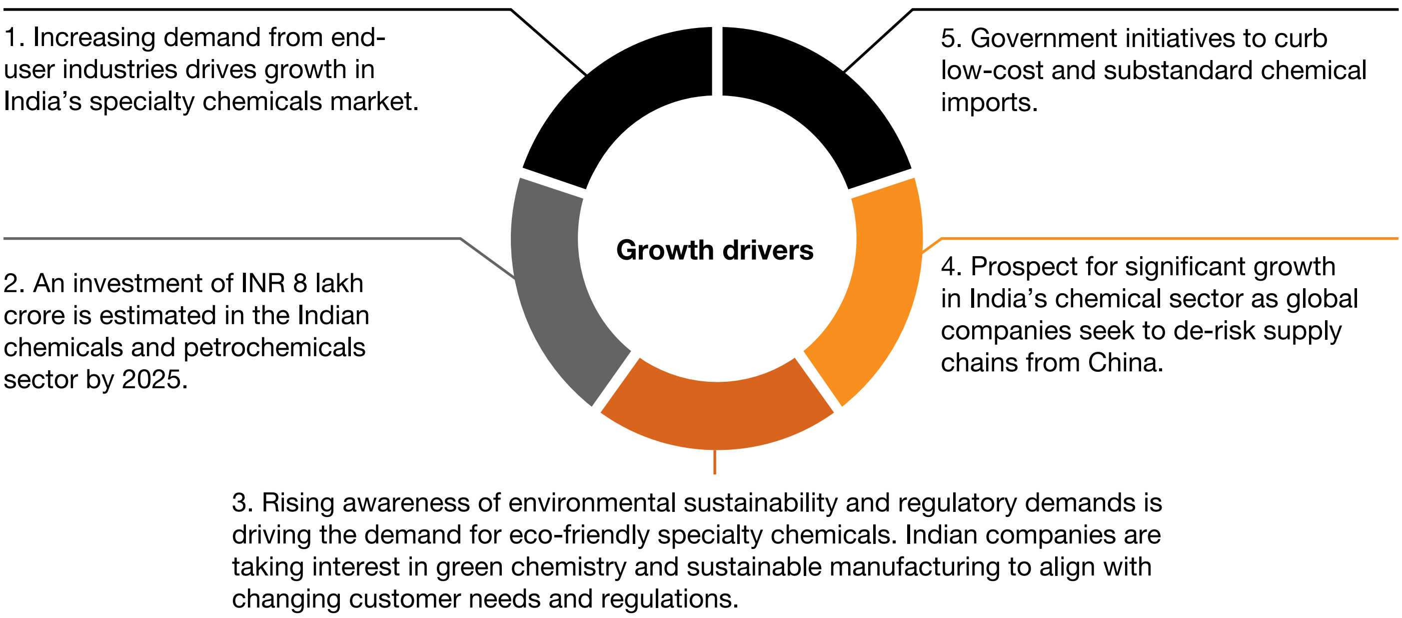
Figure 3: Market size of Indian chemical industry (USD billion)



Source: https://www.ibef.org/industry/chemical-industry-india

The Indian market for chemicals is estimated to reach USD 304 billion by 2025.[7] This notable growth indicates multiple factors driving demand as given in Figure 4.

Figure 4: Indian chemical market growth drivers



Source: https://www.commerce.gov.in; https://www.indianchemicalnews.com/assets/compendium_assets/Compendium_2024.pdf

7 https://www.ibef.org/industry/chemical-industry-india

1.2. Evolution of sustainability in the chemicals sector

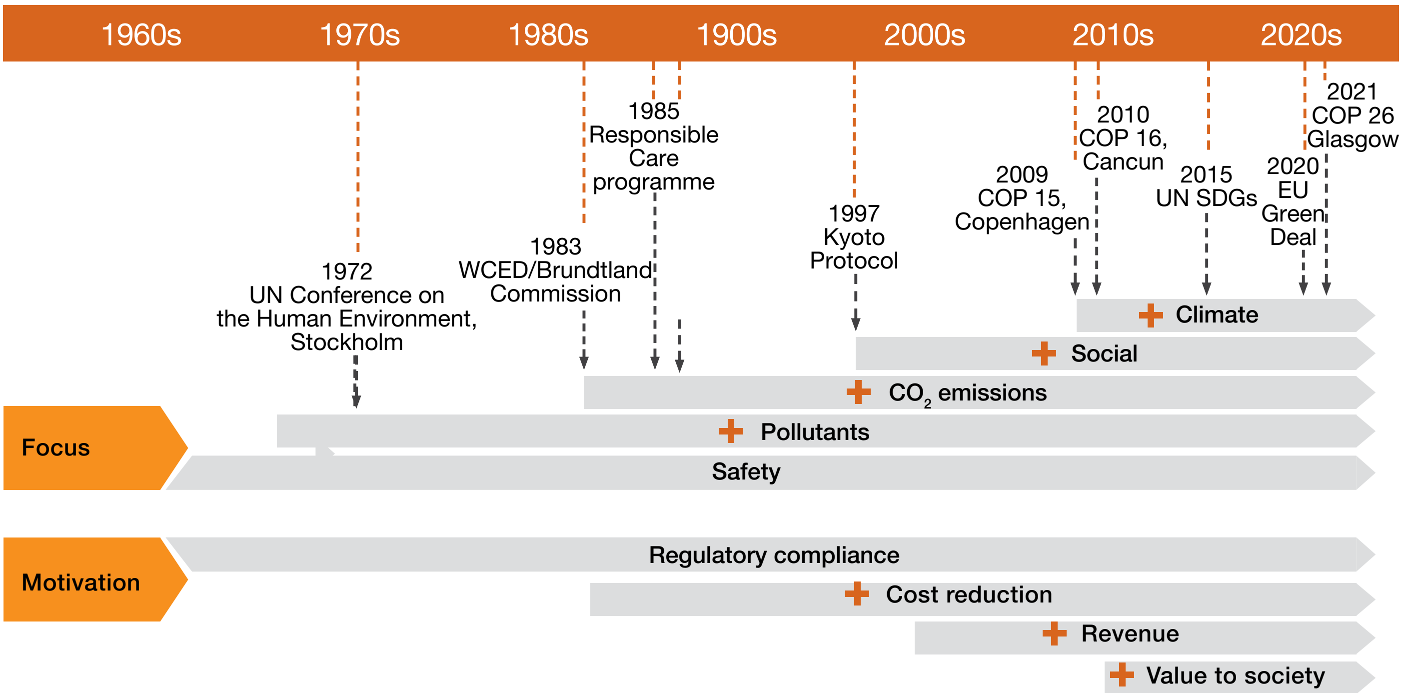
The chemicals sector has undergone significant transformation over the past few decades, evolving its approach to sustainability from compliance-driven practices to proactive strategies aimed at addressing global challenges.

The commitment to sustainability in the chemical industry can be traced back to the mid-1980s, notably with the launch of the Responsible Care initiative in 1985 by the Chemistry Industry Association of Canada (CIAC). This initiative was designed as a voluntary framework for continuous improvement in environmental, health, safety and security (EHS&S) performance. Since its inception, Responsible Care has been adopted by chemical associations globally, encompassing over 68 economies, including significant adoption in India through the Indian Chemical Council (ICC).[8]

In recent years, the role of the chemical industry has expanded to actively address major societal challenges, such as climate change, global food supply shortages and plastic waste management. Expectations for chemical companies have evolved with a growing emphasis on not only improving their own environmental footprint but also fostering sustainable solutions across various sectors. This includes innovations in new materials and processes that contribute to advancements in mobility, housing and food security. The industry's responsibility is to promote sustainable practices and drive innovation in every customer industry they serve.

A combination of regulatory compliance and increasing consumer demand for sustainable products is the new shift towards sustainability. Chemical companies are integrating sustainability into their core business strategies and focusing on creating value through sustainable innovation. This includes the adoption of green chemistry principles aimed at minimising hazardous substances and leveraging advancements in biotechnology, nanotechnology and materials science. The proactive approach to managing environmental, health and safety impacts, along with a strong emphasis on innovation, positions the chemical industry as a critical player in shaping a sustainable future.

Figure 5: Evolution of chemical industry's sustainability focus



Source: PwC analysis

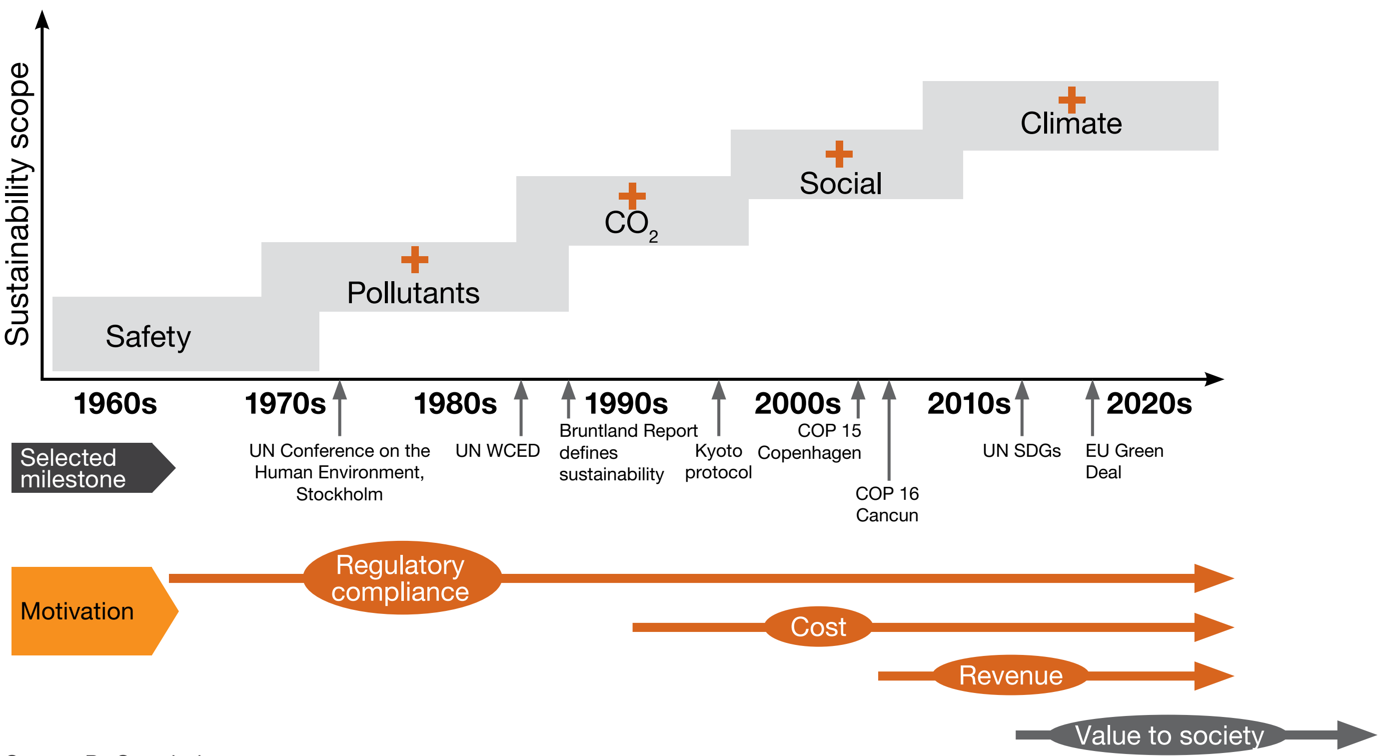
8 https://www.indianchemicalcouncil.com/about-responsible-care.htm

Current sustainability trends in the chemical industry are shaped by several interrelated factors. Climate change has become a major concern compelling companies to adopt measures aimed at reducing greenhouse gas (GHG) emissions linked to their reliance on fossil fuels for production and transportation. This shift is driven not only by regulatory compliance but also by mounting pressure from stakeholders and the general public to mitigate environmental impacts and improve air quality. Buyers' demands are also evolving, with consumers increasingly favouring brands which demonstrate a strong commitment to sustainability. This trend compels chemical companies to enhance transparency in their production processes and supply chains and integrate sustainable practices as a key competitive differentiator.

Furthermore, growing interest in sustainability is also reshaping marketing and public relations strategies as companies can leverage their sustainability initiatives to bolster brand image and position themselves as leaders in ESG practices. This also enhances consumer loyalty and generates positive reviews and endorsements. As stakeholder expectations rise with investors and customers becoming more informed about the implications of ESG practices on chemical supply chains, concerns over resource waste and energy consumption are driving companies to focus on reducing energy and water use while minimising waste production which, in turn, reinforces the industry's commitment to sustainability in an increasingly competitive marketplace.

The evolution of sustainability in the chemical sector represents a shift from regulatory compliance to a comprehensive, strategic approach which addresses critical global challenges. As the chemicals and petrochemicals industry continues to adapt to the demands of climate change, consumer expectations and stakeholder pressures, commitment to sustainability becomes not only a mere response to external pressures but an integral aspect of the industry's future trajectory. Chemical companies are poised to contribute significantly to a more sustainable and resilient world as they innovate and refine their operations.

Figure 6: Evolution of chemical industry's sustainability focus



Source: PwC analysis

1.3. Significance of sustainability in the sector

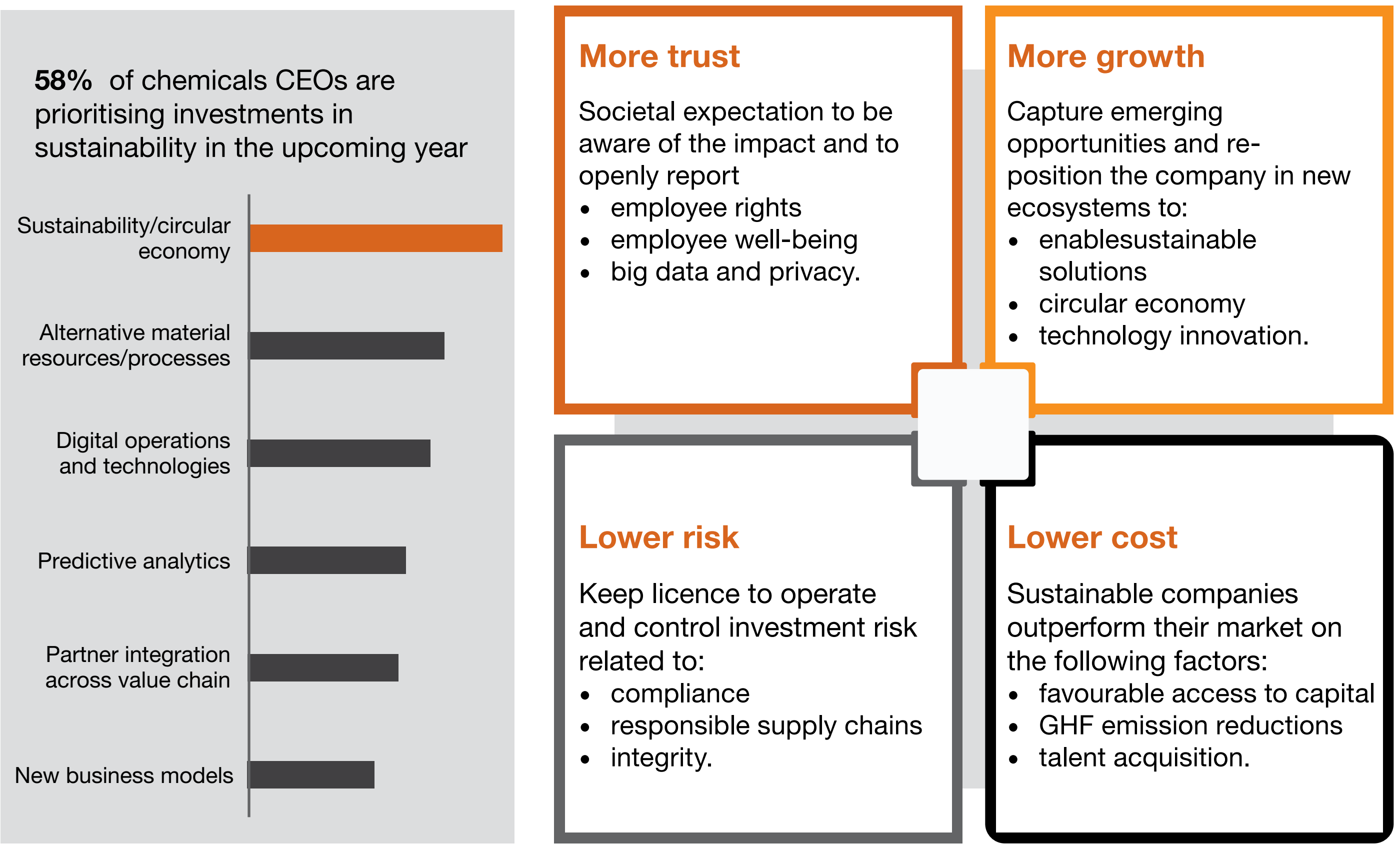
The traditional chemical manufacturing processes have a lasting impact on the environment due to high emissions, excessive waste and significant resource consumption. These challenges necessitate a shift towards sustainability practices which aim to reduce the adverse effects of their operations and guide the chemical industry towards a more environmentally responsible future. An important part of the sustainability movement is a commitment to address global sustainability goals, transcending mere regulatory compliance and aligning with the aspirations of the global community for a cleaner and healthier planet.

The sustainability initiatives of the chemical industry should be aligned to the UN's Sustainable Development Goals. The commitment to these initiatives should extend beyond meeting the regulatory obligations and reflect a strategic vision for a cleaner, healthier environment. Technological advancements have enabled the production of various products which are essential for social development and economic prosperity, derived from inorganic, synthetic organic and biological sources through complex processes such as synthesis, distillation and fermentation. While these processes have significantly contributed to the space economic growth, they have also faced criticism for their environmental impact, particularly regarding resource consumption and waste. Thus, integrating sustainability into these operations is essential for reducing reliance on non-renewable resources and minimising the industry's ecological footprint.

India plays an important role in the global chemical market, representing about 2.5% of worldwide chemical sales and exporting chemicals to over 175 countries. As the sixth-largest producer globally and third largest producer of chemicals in Asia, the share of GVA in the manufacturing sector for India is about 9.88% at current prices. With projections indicating growth of approx. USD 304 billion by 2025 which is driven by a compound annual growth rate (CAGR) of 9.3%, particularly in specialty chemicals and petrochemicals, the industry has a compelling opportunity to lead the sustainability initiatives.[9] The involvement of chemical engineers is particularly important for the development of chemicals since their expertise in understanding molecular and micro-level processes enables them to integrate these insights into broader systems. Their skills in systems analysis, modeling and process optimisation are essential for developing sustainable solutions which can combine efficiency with environmental accountability which is important for transforming the chemicals industry into a sector which addresses current needs while safeguarding the environment for future generations.

The key pillars of sustainability in chemical manufacturing encompass several essential practices which can collectively enhance the industry's ESG performance. Eco-friendly manufacturing processes which are driven by concepts like green chemistry and renewable energy integration are transforming the chemical landscape by significantly reducing waste, emissions and the ecological footprint of the industry. This sustainability journey begins with responsible sourcing of raw materials, which emphasises ethical labour practices, minimal environmental impact, social responsibility to local communities and traceability throughout the supply chain. Furthermore, the adoption of circular economy practices represents a paradigm shift from the traditional linear 'take-make-dispose' model to a regenerative approach, wherein resources are recycled, reused and repurposed to maximise efficiency and minimise waste. The implementation of such practices not only leads to substantial reductions in GHG emissions but also delivers tangible benefits for chemical companies, including improved reputation and brand value, cost reductions through enhanced efficiency and waste minimisation and regulatory compliance that safeguards against legal repercussions. All of these sustainable practices align with global environmental goals and international agreements, such as the Paris Agreement and the Sustainable Development Goals (SDGs), reinforcing the industry's commitment to preserve the planet for future generations.

Figure 7: Sustainability values



Source: PwC analysis

9 https://www.ibef.org/industry/chemical-industry-india

1.4. Objective of the report

This report aims to provide a detailed roadmap for promoting sustainability within India's chemical manufacturing sector. As the industry evolves, it is imperative to adopt a holistic approach which uses a combination of innovative practices, integrated systems, and strategic incentives to achieve long-term environmental and economic goals. The report emphasises the need to focus on three major themes:

- **Innovation** is the cornerstone of sustainable chemical manufacturing. By utilising renewable raw materials, advancing green chemistry and implementing decarbonisation strategies, the industry can reduce its environmental footprint while maintaining profitability. Innovations in energy efficiency and process optimisation are also crucial for minimising resource consumption and enhancing operational efficiency. The report deep-dives into various technological advancements and case studies which demonstrate the successful application of innovative practices in the sector.
- **Integration** in the chemical industry is about building a cohesive and sustainable supply chain. This involves focusing on sustainable sourcing and procurement, risk management, and the adoption of circular economy principles. By integrating these practices, the chemical industry can reduce waste, lessen the environmental impact and create economic value. The report discusses the importance of life cycle assessments, zero waste strategies and the role of digitisation in achieving a circular economy. It also includes case studies of successful integration providing practical insights into how companies can implement these strategies effectively.
- **Incentives** are crucial for encouraging the adoption of sustainable practices. Financial tools like green bonds, sustainable loans and tax incentives can provide the necessary support for companies to invest in sustainable technologies and processes. The report covers the growing importance of environmental, social and governance (ESG) factors in investment strategies and the importance of green certifications. By highlighting the benefits of sustainable finance and the role of policy frameworks, the report emphasises the need for a supportive regulatory environment to help drive the shift towards sustainability.

This report aims to provide a detailed perspective on how these three themes can collectively drive the chemical industry towards a more sustainable future. By fostering innovation, promoting integration and leveraging incentives, the industry can successfully meet its sustainability targets while preserving its competitive position in the global market.

2. Innovation

The urgency with which environmental issues need to be resolved has shifted the focus for innovation in the chemicals sector towards sustainability. Companies are developing greener processes and products such as biodegradable plastics, renewable energy sources and eco-friendly chemicals. The developments in green chemistry, including enhanced efficiency in chemical synthesis to eliminate waste, are set to reduce the dependency on fossil-based products. Additionally, the adoption of circular economy principles is promoting the recycling and repurposing of chemical materials. These innovations and initiatives are helping the chemical industry in reducing the environmental impact of their operations and also opening up new market opportunities which can make the sector more viable in the long term.

2.1 Renewable raw Materials

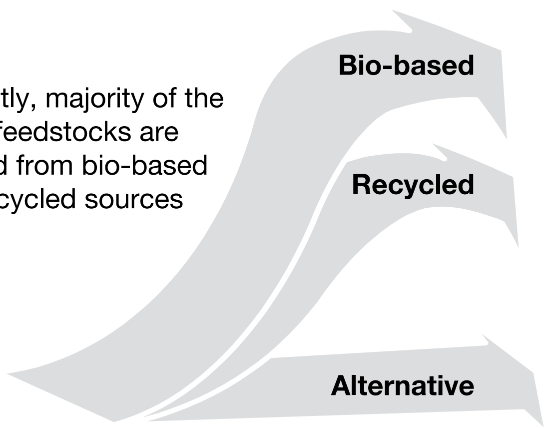
Green feedstocks are important to make chemical production more environment-friendly. By leveraging renewable resources such as agricultural products, forestry residues and algae, the industry can substantially cut down its reliance on fossil fuels, lower greenhouse gas emissions, and minimise the environmental impact of their operations. These feedstocks present a feasible option that only helps in conserving natural resources but also plays a supporting role in the development of safer, more efficient chemical processes. The use of green feedstocks aligns with global efforts to innovate and adopt sustainable pathways, ensuring a greener future for chemical production.

2.1.1. Sustainable pathways

Sustainable pathways are ranked based on level of adaption in the chemical industry.

Figure 8: Types of bio-based feedstocks

Currently, majority of the green feedstocks are derived from bio-based and recycled sources



Sustainable pathways

1. **Bio-based feedstocks** are derived from renewable biological sources, such as plants, algae, and agricultural waste.
2. **Recycled feedstocks** involve using post-consumer and post-industrial waste materials to produce new petrochemical products.
3. **Alternative feedstocks** include unconventional raw materials like carbon dioxide (CO_2), Methane, etc.

Source: PwC analysis

Sustainable pathway 1: Bio-based feedstocks

By tapping into bio-based feedstocks, manufacturers can significantly lessen their carbon footprint, improve energy efficiency and support a circular economy. Plant-derived feedstocks are set to become important in the journey toward sustainable chemical manufacturing.

Figure 9: Types of bio-based feedstocks

Wood-based	• Feedstock harvested from forests or forest residues • E.g. hardwood, softwood, sawdust, wood pellets, etc.
Agricultural crops and byproducts	• Feedstock harvested from agricultural residues and from crops specifically grown for energy production, oil content, biofuel production, etc. • E.g. bagasse, corn, canola, switchgrass, miscanthus, etc.
Marine-derived	• Feedstock derived from microscopic or macroscopic algae harvested from marine environment • E.g. spirulina, kelp, red algae, brown algae, etc.
Municipal and industrial waste	• Feedstock derived from municipal and industrial waste • E.g. food waste, fruit and vegetable peels, paper mill sludge, food processing residues
Biotechnology-derived	• Feedstock derived using fermentation process, where in microorganisms or Genetically Modified Organisms are used to drive the chemical synthesis • E.g. Ethanol, lysine and citric acid, sorbitol, other fatty acids can be fermentation derived

Source: PwC analysis

Sustainable pathway 2: Recycled feedstocks

Chemical recycling of plastic waste

Plastic waste has now become an urgent global environmental concern, as millions of tonnes of plastic are dumped in landfills and oceans. Chemical recycling can unlock promising opportunities by converting plastic waste into valuable feedstocks for chemical production. This approach not only helps reduce plastic pollution but also aligns with the principles of green chemistry. Given below are the few technologies that are currently available for chemically recycling plastic waste.

Figure 10: Various processes to chemically recycle plastic waste into feedstocks

Pyrolysis
Process: Pyrolysis involves heating plastic waste in the absence of oxygen to break it down into smaller hydrocarbons.
Products: Pyrolysis oil, char, and gases such as hydrogen and methane. Pyrolysis oil can be further refined into synthetic crude oil, which serves as a feedstock for producing chemicals and fuels.

Hydrogenation
Process: Involves adding hydrogen to plastic waste at high temperatures and pressures, often in the presence of a catalyst, to produce saturated hydrocarbons.

Products: Resulting hydrocarbons can be used as feedstocks to produce various chemicals and fuels, such as diesel and jet fuel.

Gasification
Process: Converts plastic waste into syngas (a mixture of hydrogen, carbon monoxide, and other gases) by exposing it to controlled amounts of oxygen and steam at high temperatures

Products: Wide range of chemicals, including methanol, ammonia, and synthetic natural gas.

Depolymerisation
Process: Involves breaking down polymers into their monomers or oligomers using chemical reactions such as hydrolysis, glycolysis or solvolysis.
Products: Polyethylene terephthalate (PET) can be depolymerised into terephthalic acid and ethylene glycol, which can be repolymerised into new PET or used as feedstocks for other chemical processes.

Source: PwC analysis

Sustainable pathway 3: Alternative feedstocks

The conversion of alternative feedstocks like CO_2 into chemicals is a unique and path breaking approach for sustainable chemical manufacturing. This innovative process helps reduce green-house gas emissions and is also aligned with the principles of green chemistry by utilising a waste product as a valuable feedstock.

A few pathways for converting CO_2 to valuable chemicals are given in the figure below:

Figure 11: Various processes to convert CO_2 into chemical products/feedstocks

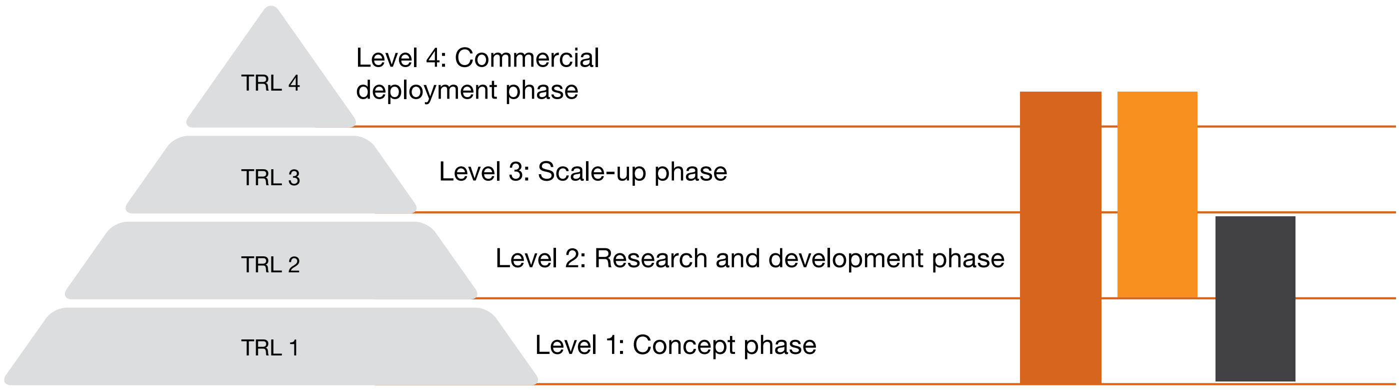
Carbon dioxide (CO_2)

Hydrogenation	Electrochemical reduction	Carboxylation	Biological conversion
Process: CO_2 is reacted with hydrogen (H_2) over a catalyst to produce chemicals such as methanol, formic acid, and methane. The hydrogen used can be sourced from renewable energy via water electrolysis.	**Process:** CO_2 is reduced electrochemically using renewable electricity to produce chemicals like carbon monoxide (CO), ethylene and ethanol.	**Process:** CO_2 is introduced into organic molecules to form carboxylic acids, carbonates and carbamates.	**Process:** Microorganisms such as algae or bacteria are engineered to convert CO_2 into organic compounds through metabolic pathways.
Products **Methanol:** A key feedstock for producing formaldehyde, acetic acid, and various plastics and resins. **Formic acid:** Used in leather tanning, textile dyeing and as a preservative. **Methane:** Can be used as a fuel or further processed into other chemicals.	**Products** **Carbon monoxide:** Can be used in the Fischer-Tropsch synthesis to produce hydrocarbons and in the production of acetic acid. **Ethylene:** A fundamental building block for polyethylene and other plastics. **Ethanol:** Used as a solvent, fuel and in the synthesis of various chemicals.	**Products** **Salicylic acid:** Precursor to aspirin and other pharmaceuticals. **Polycarbonates:** Used in the production of plastics and resins. **Urea:** Used as a fertiliser and in the production of resins and plastics.	**Products** **Bioplastics:** Biodegradable plastics produced from microbial processes. **Biofuels:** Renewable fuels produced from microbial fermentation processes. **Specialty chemicals:** High-value chemicals like isoprene and butanol.

Source: PwC analysis

2.1.2. Advancements in technology

Figure 12: Technology readiness levels of various renewable feedstocks for chemical synthesis



Recycled feedstocks

While some technologies like depolymerisation and pyrolysis are well established, technologies like hydrogenation are still in the concept phase. Reliance Industries has developed a chemical recycling technology which converts single-use plastics into pyrolysis oil. Reliance has already commercialised its ISCC-Plus certified products CircuRepol (PP) and CircuRelene (PE) which are chemically recycled.

Bio-based feedstocks

Bio-based feedstocks are one of the oldest green feedstocks and the technology is majorly well established. However, there have been recent advancements in biotechnology-based processes to produce bio-based feedstocks. Godavari Biorefineries and India Glycols are the two pioneers of bio-based feedstocks in India, commercially producing acetic acid and ethylene oxide derivatives respectively using bio-based

Alternative feedstocks

Technologies to derive chemicals from alternative feedstocks like carbon dioxide and methane are still at the scale-up phase in India. Biotech startups like String Bio have developed patented technologies to convert methane into products like biostimulants for crops and alternative protein synthesis using fermentation.

Source: PwC analysis, https://www.deccanherald.com/business/companies/reliance-turns-plastic-waste-into-high-quality-materials-for-new-plastic-2829337#:~:text=Its%20Jamnagar%20refinery%20in%20Gujarat,)%20and%20CircuRelene%20(Polyethylene)., https://www.indianchemical-news.com/assets/compendium_assets/Compendium_2024.pdf, https://www.outlookbusiness.com/news/biotech-start-up-string-bio-raises-20-million-from-investors-news-208291

Figure 13: Challenges and opportunities for using renewable feedstocks in India

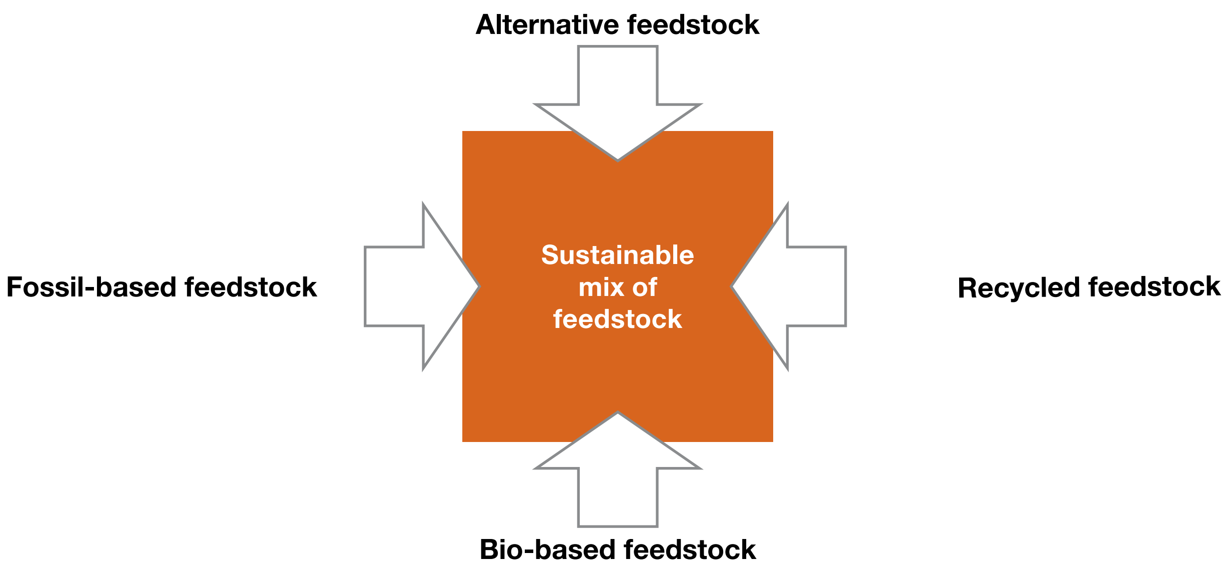
Challenges	Opportunities
Challenge 1 **Technology:** Developing efficient and scalable technologies for processing green feedstocks.	**Opportunity 1** **Influx of green chemistry startups:** Increasing number of startups like Proklean, StringBio and Sea6 Energy have designed patented technologies to indigenously produce bio-based feedstocks. Chemical manufacturers can partner with such innovative startups to procure and process green feedstocks in India.
Challenge 2 **Scalability and economic viability:** Scaling up the production of sustainable feedstocks to meet industry demands requires substantial investment and infrastructure development. The production cost of bio-based and recycled feedstocks can be higher than traditional fossil fuels.	Opp**ortunity 2** **Infrastructure development:** India is strategically enhancing the country's infrastructure to boost the chemical industry, and creating opportunities for international investors to establish green chemical manufacturing and research centers.
Challenge 3 **Feedstock availability and consistency:** Ensuring a consistent and reliable supply of green feedstocks, which can be affected by seasonal variations and other factors.	**Opportunity 3** **Abundant feedstock:** India's wealth of diverse feedstocks such as biomass, agricultural residues and renewable energy sources, puts the country favourable position for green chemical production. This abundant availability guarantees a reliable supply chain for green chemical manufacturers.
Challenge 4 **Supply chain complexity: I**ntegrating green feedstocks into existing supply chains, which are predominantly designed for fossil-based feedstocks. Securing biomass and agricultural waste source for developing green feedstocks is a challenge.	**Opportunity 4** **National Bioenergy Programme:** Government of India's initiative, meant to enable the use of cattle dung, biomass, urban and industrial biowaste for energy recovery will result in an improved supply chain infrastructure for bio-based feedstocks.

Source: PwC analysis, https://economictimes.indiatimes.com/tech/funding/cleantech-startup-proklean-technologies-raises-4-million-in-funding/articleshow/100821823.cms?from=mdr, https://www.outlookbusiness.com/news/biotech-start-up-string-bio-raises-20-million-from-investors-news-208291, https://www.business-standard.com/content/press-releases-ani/sea6-energy-launches-world-s-first-large-scale-mechanized-tropical-seaweed-farm-off-the-coast-of-lombok-indonesia-124030700338_1.html, https://mnre.gov.in/bio-energy/

2.1.4 Sustainable and profitable chemical manufacturing: The imperative of diversified feedstock utilisation

In today's rapidly evolving industrial landscape, the chemical manufacturing sector is at a crucial juncture where sustainability and economic viability must be balanced. To maintain this equilibrium, a strategic approach for feedstock utilisation is required by incorporating a diverse mix of sources which includes fossil-based feedstock, bio-based renewable feedstock, recycled feedstock, and alternative feedstock. By using such an approach, the industry can ensure a steady supply of necessary raw materials while supporting sustainable development goals.

Figure 14: Key to profitable and sustainable chemical manufacturing



Source: PwC analysis

Figure 15: Benchmarking different feedstock types on profitability and sustainability

	Fossil-based feedstock	Bio-based renewable feedstock	Recycled/reused feedstock	CO2-X based feedstock
Current relevance	Despite the growing emphasis on sustainability, fossil-based feedstock remains indispensable in the chemical manufacturing industry due to its established infrastructure, proven efficiency and high energy density.	Derived from renewable biological sources like plants, bio-based feedstock offers a sustainable alternative which can reduce the reliance on finite fossil resources.	Emphasising the reuse and recycling of materials aligns with the principles of a circular economy, where waste is minimised, and resources are maximised.	CO2-X based feedstock involves the capture and utilisation of carbon dioxide, transforming it into valuable chemical products.
Environmental Impact	Fossil-based feedstocks are associated with significant GHG emissions and environmental degradation, necessitating a strategic reduction to mitigate their impact.	Bio-based feedstocks contribute to lower GHG emissions and support a circular economy, enhancing environmental sustainability.	Recycled/reused feedstocks significantly reduce environmental impact by lowering raw material extraction and waste generation.	This innovative approach addresses the dual challenges of reducing GHG emissions and sourcing sustainable raw materials, contributing positively to climate change mitigation.
Economic viability	The established nature of fossil-based feedstock infrastructure ensures cost-effectiveness in many applications. However, market fluctuations and regulatory pressures can affect long-term viability.	Advancements in biotechnology and agricultural practices are making bio-based feedstock increasingly cost-competitive, enhancing the resilience and sustainability of chemical manufacturing processes. E.g. use of low cost and abundantly available agricultural residues as primary feedstock.	Technological innovations in recycling processes enable the conversion of waste into valuable feedstock, offering substantial cost savings and sustainability gains. E.g. gasification and hydrogenation of plastic waste.	While still emerging, the economic potential of CO2-X based feedstock is significant, with the ability to create high-value products from waste emissions representing substantial economic and environmental benefits.
Future outlook	While not entirely phased out, the use of fossil-based feedstocks will likely decline as industries adopt more sustainable practices, focusing on reducing their reliance to a logical minimum.	The role of bio-based feedstocks is expected to grow as technological advancements improve their efficiency and cost-effectiveness, making them a key component of sustainable chemical manufacturing.	As recycling technologies advance and become more widespread, recycled/ reused feedstocks will play an increasingly critical role in sustainable chemical manufacturing, optimising resource utilisation and waste reduction.	As technologies for carbon capture and utilisation advance, CO2-X based feedstock is poised to play a pivotal role in the sustainable transformation of the chemical industry, with increasing adoption expected over time.

Source: PwC analysis

Taking a balanced approach: A necessity for sustainability

The path to a sustainable chemical manufacturing industry is anything but straightforward. It demands a thoughtful blend of various feedstock types. Using a mix of fossil-based, bio-based, recycled/reused, and CO2-X feedstocks is important for the following reasons:

1. **Supply chain resilience:** By diversifying feedstock sources, companies can reduce the risk of supply-chain disruptions and ensure a steady flow of essential raw materials.
2. **Economic stability:** A varied feedstock portfolio helps businesses to adapt to the changes in the market as well as new regulations and keep them economically viable while they continue on their sustainability journey.
3. **Sector-specific thresholds:** Different sectors of the chemical industry have unique requirements for feedstock use. It's practical to reduce fossil-based feedstocks to an optimal level rather than eliminating them completely, which makes sustainability efforts more effective.

It is necessary to use various types of feedstocks strategically so that a sustainable method can be developed for the chemical industry. By adopting a balanced approach, companies can create a resilient supply chain and support economic and environmental sustainability. Achieving an equilibrium between sustainability and business profitability requires careful integration of fossil-based feedstocks with bio-based, recycled/reused, and alternative feedstocks. This strategy can pave the way for a future where economic and environmental goals can be combined.

2.2. Introduction to green chemistry

'Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances,' as defined by Paul T. Anastas and John C. Warner.[10] This definition highlights the primary objective of green chemistry – to improve the safety, efficiency and environmental sustainability of chemical production. Emphasising the prevention of pollution as its origin, the implementation of the green chemistry principles help in designing safer chemicals and processes from the outset, rather than managing pollution after it occurs. This innovative strategy helps in reducing the environmental and health risks linked to the production and utilisation of chemicals.

The 12 principles of green chemistry[11] as defined by the US's **Environmental Protection Agency (EPA)**, serve as a roadmap for designing safer, more efficient and environmentally friendly chemical processes and products, embodying the core mission of green chemistry.

Figure 16: 12 principles of green chemistry

Pollution prevention	Atom economy	Less hazardous chemical synthesis	Design safer chemicals
Safer solvents and auxiliaries	Design for energy efficiency	Use renewable feedstocks	Reduce derivatives
Catalysis	Design for degradation	Real-time analysis for pollution prevention	Inherently safer chemistry for accident prevention

Source: https://www.acs.org/greenchemistry/principles/12-principles-of-green-chemistry.html

10 https://www.epa.gov/greenchemistry/basics-green-chemistry#:~:text=Green%20chemistry%20is%20the%20design,%2C%20use%2C%20and%20ultimate%20disposal.

11 https://www.epa.gov/greenchemistry/basics-green-chemistry

2.2.1. Applications of green chemistry

Figure 17: Applications of green chemistry in chemical and pharmaceutical manufacturing

Applications of green chemistry in chemical and pharmaceutical manufacturing		
Use of renewable feedstock	Use of catalysts	Waste reduction using atom economy and by-product reutilisation
Use of green solvents or solvent-free systems	Using energy efficient modes of synthesis (like microwave-assisted synthesis)	Producing safer chemicals and products like non-toxic alternatives and biodegradable materials

Source: PwC analysis

Figure 18: Other applications of green chemistry

Other applications of green chemistry	
Agricultural	Creating **ecofriendly pesticides** that are less harmful for the environment and non-target species, reducing ecological impact
Dry cleaning	**Supercritical CO_2:** Replacement of perchloroethylene (PERC) with supercritical CO_2 and surfactants for cleaning garments.
Water treatment	Developing eco-friendly methods of water purification that are non-toxic, biodegradable, and cost-effective alternative to alum for purifying municipal and industrial wastewater.
Nanoscience and technology	**Green synthesis of nanomaterials:** Methods like citrate, tollens, ionic liquid, polysaccharide, ligand exchanging, and polyoxometalate methods for synthesising low-dimensional materials.
Plastics and polymers	**Biodegradable polymers:** Producing plastics that break down naturally in the environment, reducing plastic pollution
Energy science	Green formulations: Developing cosmetics and personal care products with natural, non-toxic ingredients
Cosmetics and personal care	**Solar cells, fuel cells, and batteries:** Development of innovative techniques for energy storage and generation.
Environmental remediation	**Green clean-up technologies:** Development of methods for cleaning up pollutants in a more effective and environmentally friendly manner.
Textile industry	Creating **ecofriendly dyes** that are less toxic and more sustainable, reducing the environmental impact of textile manufacturing. **Implementing processes** that use less water and energy and generate less waste.

Source: PwC analysis

2.2.2. Case studies related to the implementation of green chemistry

Company name	Green chemistry principle(s) leveraged	Product/process under focus	Impact
Dow[12]	1. Designing safer chemicals 2. Use of renewable feedstocks	Synthesis of bio-based plasticisers derived from plant-based feedstocks to replace traditional phthalate-based plasticisers used in flexible PVC applications	• Reduced environmental impact • Compliance with stringent regulatory standards • Adoption in products like flooring and wire/cable insulation • Comparable performance to traditional phthalates
Novozymes[13]	1. Designing safer chemicals 2. Use of renewable feedstocks 3. Design for degradation	Synthesis of enzyme-based detergents, replacing harsh detergents	• Reduced environmental and human health risks • Replacement of harsh chemicals with eco-friendly enzymes
Pakka Limited[14]	1. Use of renewable feedstocks 2. Design for degradation	Manufacturer of compostable packaging using bagasse (Sugarcane waste)	Eliminate the use of single-use plastic packaging

12 https://renewable-carbon.eu/news/dow-introduces-first-bio-based-plasticizers-for-wire-and-cable-applications/

13 https://www.business-standard.com/article/companies/denmark-based-enzyme-producer-novozymes-working-on-eco-friendly-detergents-119102000037_1.html

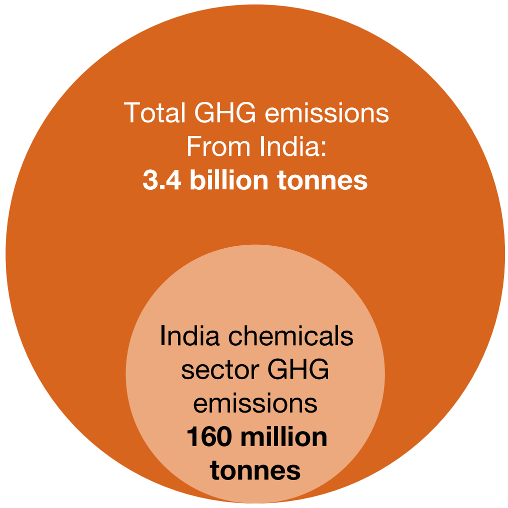
14 https://economictimes.indiatimes.com/small-biz/sustainability/we-aim-to-be-global-leader-in-regenerative-packaging-at-scale-by-2030-says-pranay-pasricha-pakka/articleshow/115755837.cms?from=mdr

2.3. Decarbonisation

2.3.1. Decoding the complexities of decarbonisation in the chemicals and petrochemicals sector

GHG emissions in India are a key environmental challenge and the primary sources of these emissions include energy production, industrial activities, agriculture and transportation. Although India is one of the world's fastest-growing economies, its annual per capita carbon emissions are only about one-third of the global average.[14, 15] India's total GHG emissions is ~3.4 billion tonnes of CO_2 equivalent (CO_2eq) in which the chemical, petrochemical and fertiliser industry account for ~5% and emits ~160 million tonnes CO_2eq of GHG annually.[16] Emissions from the production process as well as direct emissions for chemical reactions both contribute to this number.

Figure 19: India's GHG emissions



Source: https://www.ceew.in/publications/how-can-india-achieve-sustainable-fertilisers-production-and-reduce-carbon-emissions

Figure 20: Challenges in the chemical industry

The chemicals sector is considered a hard-to-abate sector due to the following reasons:

- Highly energy intensive industry which requires a lot of heat and pressure for chemical reactions.
- Fossil fuels and carbon rich raw materials are a major feedstock and fuel.
- Complex global value chain with trading of raw materials and finished goods across the globe.
- Emission of GHG as by-product of chemical reactions.

Source: PwC analysis

The chemicals and petrochemicals sector is integral to our daily lives as a majority of the everyday products have some materials from this sector. There are several technologies that are being developed to produce chemicals with net zero carbon emissions; however, not all of them are viable due to the availability of resources and clean/green energy, economies of scale for production and financial feasibility. Carbon capture, utilisation and storage is one such technology which is gaining prominence due to its applicability in emission reduction to help the industry attain its net zero goals.

15 https://pib.gov.in/PressReleasePage.aspx?PRID=2034915

16 https://www.ceew.in/publications/how-can-india-achieve-sustainable-fertilisers-production-and-reduce-carbon-emissions

2.3.2. Carbon capture potential and routes for utilisation

2.3.2.1. Carbon capture potential

In 2020, India's power and industrial sectors were responsible for approximately 60% of the nation's total emissions (~2,600 million tonnes).[17] To achieve decarbonisation in these critical areas, carbon capture, utilisation and storage (CCUS) technology is indispensable since there is tremendous potential for carbon capture in the following sectors:

Thermal power: Despite the significant expansion in renewable energy capacity, coal-based power is projected to continue to meet the majority of India's electricity demand. Capturing CO_2 will be essential to mitigate the environmental impact of the industry's operations.

Steel: CCUS technology will not only facilitate the capture of CO2 emissions from industrial processes but also enable the conversion of waste gases into Blue Hydrogen, offering a dual benefit for sustainable energy solutions.

Cement: Capture, utilisation and sequestration of CO_2 to aggregates or usage of CO_2 as curing agent

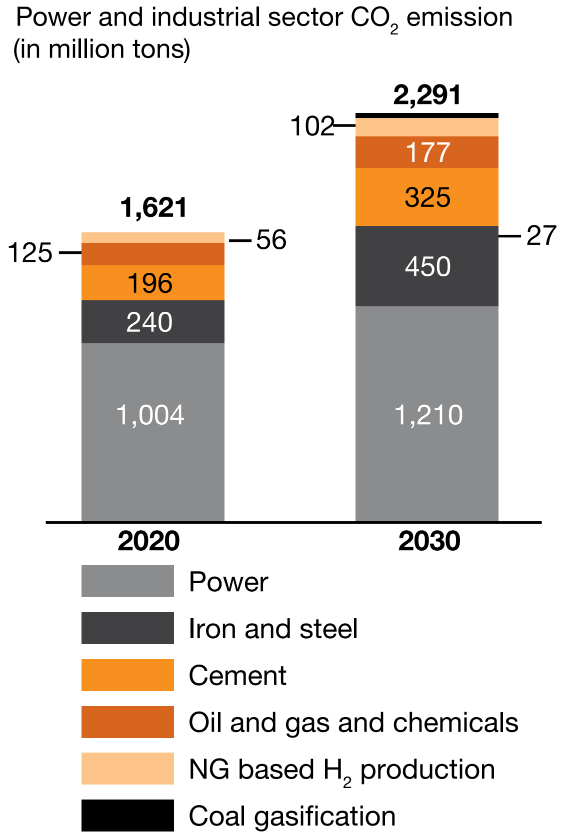
Oil and gas and chemicals: Carbon capture and utilisation will be key to decarbonise this hard-to-abate sector.

Hydrogen production: Achieving cost-competitive production of Blue Hydrogen is crucial to unlock the potential of a future Hydrogen economy.

Coal gasification: By integrating CCUS technology, CO_2 emissions from coal gasification can be significantly reduced, transforming the process into a cleaner method of energy production.

There are two major routes of utilisation of CO_2
1) direct use of CO_2
2) indirect use of CO_2 or conversion of CO_2 to chemicals/fuels.

Figure 21: Power and industrial sector's CO_2 emissions (million tonnes)

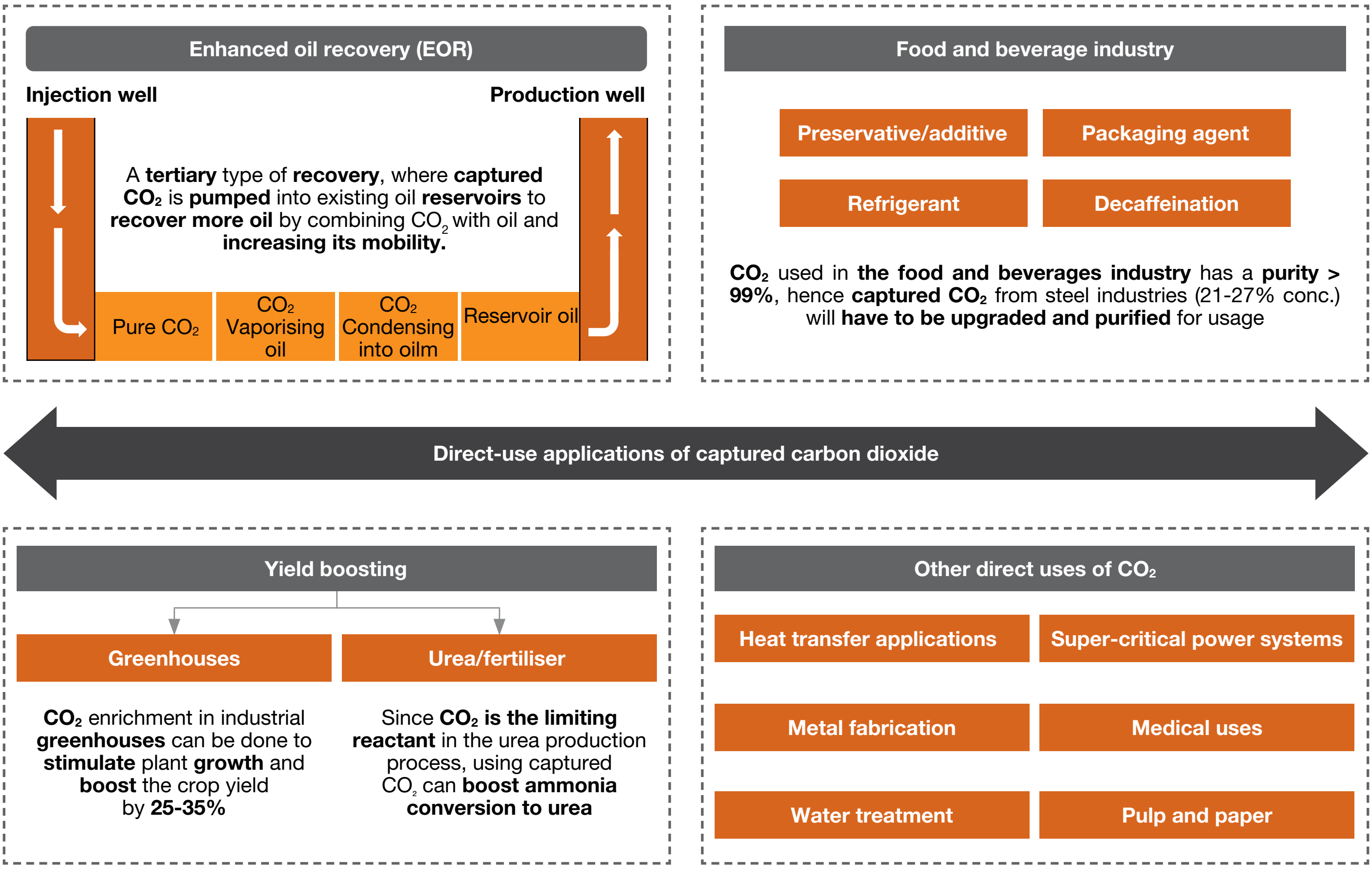


Source: https://www.niti.gov.in/sites/default/files/2022-11/CCUS-Report.pdf

17 https://www.niti.gov.in/sites/default/files/2022-11/CCUS-Report.pdf

2.3.2.2. Direct utilisation of CO_2

Figure 22: Direct use applications of captured carbon dioxide



Source: PwC analysis

Yield boosting:

Currently, the highest demand for CO_2 is in the production of urea. Most fertiliser companies in India use natural gas to produce ammonia which emits CO_2 and these two raw materials are used for the production of urea. Urea industry in India consumes ~18 million metric tonnes per annum (MMTA) of CO_2. However, a major challenge with this application is that ammonia produces more CO_2 than the amount of CO_2 which is required to produce urea.[18]

Food and beverage:

CO_2 is majorly used in carbonated drinks (alcoholic beverages, soft drinks, etc.) and demand for CO_2 in carbonated drinks is ~200 KTPA in India. Liquid CO_2 is required for carbonation and must have a purity of more than 99.9%.[19]

Enhanced oil recovery:

Enhanced oil recovery (EOR) is at a very nascent stage in India and can be done by three methods based on the physical and chemical properties of oil field:

- CO_2 injection
- low saline water flooding
- chemical injection.

There are several challenges related to adopting EOR in India such as:

- unavailability of CO_2 at economical price
- absence of infrastructure to transport CO_2 to oil fields
- purity of CO_2 required is >97%
- lack of suitable legal and regulatory framework.

18 https://www.ceew.in/sites/default/files/ceew-giz-economic-feasibility-of-green-ammonia-use-in-indias-fertiliser-sector.pdf
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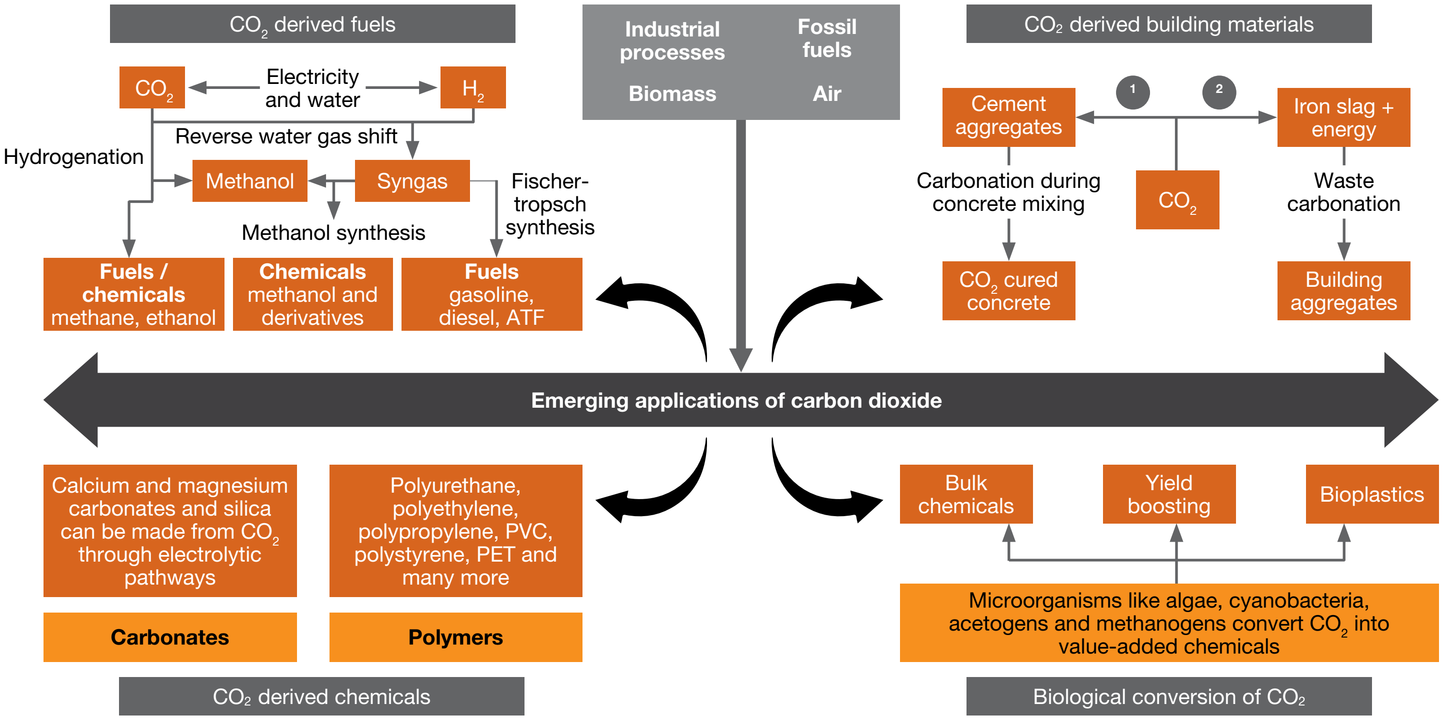
2.3.2.3. Indirect use of CO_2

Figure 23: Emerging applications of carbon dioxide



Source: PwC analysis

CO_2 derived fuels and chemicals: Jawaharlal Nehru Centre for Advanced Scientific Research has developed a highly efficient photocatalyst capable of converting CO_2 into high-value products like methanol and ethylene, which are key fuels and essential components for the polymer industry.[20] They are currently setting up India's first plant dedicated to converting CO_2 into methanol, located at a power plant in Telangana. This groundbreaking facility is anticipated to be operational by the end of 2024.

Should the plant demonstrate success and economic viability at a commercial scale, it could profoundly impact the country's chemical value chain. By enabling domestic production of methanol, which is currently imported in significant quantities (~3,200 KT in 2023) due to lower import prices, India could reduce its reliance on imports.[21] This shift would also pave the way for the production of acetic acid and other downstream products, enhancing the overall value chain.

CO_2 to microalgae: CO_2 can be used to produce dry microalgae biomass.[22] Currently, open pond system is widely used for large scale microalgae cultivation due to its relatively cheaper construction and maintenance cost. The open pond system however requires a large piece of land on which the microalgae can be cultivated, therefore, the output is limited.

A new technology to produce microalgae biomass is photobioreactor systems where growth factors such as CO_2, light intensity, pH and others can be controlled. These controlled growth conditions increase the metabolic efficiency which translates into higher productivity. Photobioreactor systems offer a higher yield with lower area requirement; however, this technology is currently at a nascent stage and there are limited large-scale commercial plants operating globally.

CO_2 derived building materials: CO_2 can be used as a curing agent during the mixing of aggregate and cement. It reduces the amount of cement needed by 4–6% and water by 17–20%; however, 1 MT of concrete absorbs only 0.007 MT of CO_2. Carboclave, Solidia Technologies and CarbonCure Technologies are few technology suppliers operating in this space.

CO_2 as aggregate is used to precipitate carbonates or it is used to reduce calcium oxide present in iron slag to precipitate carbonates. It has potential to trap more CO_2 (~0.44 MT CO2) per MT of concrete than the curing process; however, CO_2 based aggregates technologies are still at a nascent stage and not yet commercialised.[24] Carbicrete, Carbon8, Blue Planet Systems and OCO Technologies are few technology suppliers operating in this space.

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2.3.3. Strategies to decarbonise

While the journey to decarbonise the chemical industry is still extensive, several initiatives can pave the way towards achieving net-zero emissions:

- electrification of high-temperature processes can help reduce the chemical industry's carbon footprint, reduce costs and stabilize power grids
- use of **green hydrogen** from renewable power
- usage of **bio-based/low carbon feedstock** compared to fossil fuels
- CCUS to store/sequester CO_2, use directly or convert CO_2 to chemicals
- companies can transition from fossil based fuels to r**enewable energy sources like solar, wind and biomass** to power its operations
- improve **energy efficiency** through adoption/retrofitting of energy efficient boilers, heat recovery systems and process optimisation.

2.3.4. Relevant case studies

Company name	Technology	Product(s)	Outcome
NTPC Energy Technology Research Alliance (NETRA), Carbon Clean and Green Power International Pvt. Ltd. and Jakson Green[25]	Carbon capture and utilisation plant at NTPC Vindhyachal	CO_2 capture and conversion to methanol	To capture 20 MT of CO2 per day. The captured CO2 will eventually be combined with hydrogen to produce 10 MTPD of methanol.
Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASE) and Central Mine Planning and Design Institute Ltd. (CMPDI)[26]	Carbon capture and utilisation plant in Telangana	CO_2 capture and conversion to methanol	Aim to produce 1 MT per day of methanol.

24 PwC analysis

25 https://www.thehindubusinessline.com/companies/jakson-green-partners-with-ntpc-to-set-up-methanol-plant/article66705921.ece

26 https://timesofindia.indiatimes.com/business/india-business/lab2market-jncasr-to-set-up-indias-first-co2-to-methanol-plant-in-telangana/articleshow/105541212.cms

2.4. Energy efficiency

Selection of an energy source is typically based on resource availability, geographical location and associated costs. Hence, conventional sources like coal, oil and natural gas account for a majority of fuel sources for energy consumption in the industrial sector due to their cost and availability.

Decarbonisation efforts of chemical companies could largely rely on the benefits of energy efficiency solutions. Energy efficiency is key to minimising energy losses during operations. The relative ease of implementation and lower capital intensity makes them a good option as these solutions can yield significant financial benefits.

Energy management systems

To reduce CO_2 emissions, the use of fossil fuels as energy source in the chemical and petrochemical industry should decrease as the sector is energy intensive, with chemical processes often operating at high temperature and/or pressure conditions. Effective energy management is crucial and can yield substantial bottom-line benefits. By implementing operations planning and process optimisation, even the most advanced plants can achieve savings of 5-10% without requiring significant capital investments.[27] Chemical plants can use a variety of techniques to reduce energy consumption and improve efficiency, namely:

- waste heat recovery through capture of excess heat and using it for heating or generating energy
- identifying areas of inefficiency through energy audits and improvement of process efficiencies through energy integration, equipment upgrade, efficient separation, etc.
- use of automation and advanced control systems to optimise energy usage through monitoring and controlling real-time data
- production of electricity and heat through cogeneration from a single source
- use of renewable energy like solar and wind energy.

2.4.1. Process optimisation techniques

Process optimisation is the practice of identifying and addressing deficiencies within existing processes, as well as designing more efficient workflows to enhance profitability. Process optimisation boosts the yield of desired products, reduces waste and energy consumption, and improves process safety. To ensure steady quality of output, several process optimisation techniques can be employed:

- implementing robust quality control and strict adherence to safety standards
- utilising process simulation, advanced process control, and automation
- addition of catalysts to accelerate the chemical reaction
- conducting regular maintenance of equipment
- using linear programming for optimising plant design, production schedules, product mix, process control and inventory management
- adopting statistical methods like design of experiments (DOE) and statistical process control (SPC) to identify factors that influence process performance and optimising process parameters.

Digitisation is also rapidly becoming integral for process optimisation solutions. Artificial intelligence (AI) and machine learning (ML) techniques are increasingly being utilised in chemical process design and optimisation to enhance process efficiency, reduce costs, and enhance product quality.

2.4.2. Innovation in heat integration

Heat integration helps to improve energy efficiency and reduce costs while also reducing environmental impact. It is a crucial component in the design of chemical and petrochemical plants. A common methodology used to minimise energy consumption of chemical processes by optimising the use of heat and energy is pinch analysis. Heat integration through integration of the heat exchanger network can be done for multiple plants to improve energy efficiency by optimising heat recovery and utilisation of thermal energy. Innovative techniques are being developed for heat integration:

- smart heat exchangers that are equipped with sensors and control systems to monitor and optimise the heat transfer in real time
- nano surface heat exchangers that can improve heat transfer by modifying the surface of the heat exchanger to increase the surface area, improve thermal conductivity, and reduce pressure drop.

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3. Integration

Integration in the chemical sector through the creation of a cohesive and sustainable supply chain is pivotal for enhancing efficiency and reducing environmental impact. By fostering collaboration across the value chain, companies can streamline operations, minimise waste and ensure the responsible sourcing of materials. Implementing technologies for transparency and traceability, and adopting circular economy practices, such as recycling and reusing chemical products, further contributes to sustainability. This integrated approach not only helps in meeting regulatory requirements and customer expectations for greener products but also drives innovation and long-term profitability by reducing costs and enhancing resource efficiency throughout the supply chain.

3.1. Sustainable supply chain

Supply chain management has been a fundamental element for handling the entire production flow of a good or service in order to maximise quality, delivery, customer experience and profitability. This shift is driven by several factors, including increasing environmental regulations, rising consumer demand for eco-friendly products and the industry's commitment to minimising its carbon footprint. This section addresses the key drivers of a sustainable supply chain along with ESG risks and opportunities unique to the chemical industry. Additionally, it aims to examine effective risk management strategies and present case studies that showcase successful sustainability initiatives, with a particular emphasis on the Indian chemical industry.

3.1.1. Key drivers of sustainable supply chains

Climate change[28]

Organisations rely on numerous supply chain assets, all of which are vulnerable to climate change. A disruption caused by climate hazards can significantly affect daily operations. Therefore, understanding these potential impacts is essential for any effective sustainability strategy.

Impact Area	Description
Raw materials	• Impacts resource availability, making it difficult to source commodities
Transportation	• Affects infrastructure and erodes resiliency. • Inhibits trade routes and increases wait times, causing disruptions
Suppliers	• Extreme weather events interrupt supply chains. • Disrupts business continuity and causes cascading product disruptions downstream.
Manufacturing	• Drought and heat stress halt water-intensive manufacturing. • Impacts energy infrastructure.
Distribution	• Weather impacts distribution centers serving downstream retailers. • Causes significant losses through disruptions and physical damage to warehouses and inventory.
Retailers	• Extreme weather events damage building assets. • Leads to store closures and inventory damage.
Consumers	• Direct costs passed down to buyers make it hard to stay competitive. • Volatile climates influence consumer habits, complicating demand prediction.

Climate change significantly disrupts the chemical supply chain in India by affecting availability of raw materials such as petroleum and natural gas due to extreme weather events. For example, hurricanes can halt refinery operations, leading to shortages of critical inputs for plastics and fertilisers. Furthermore, erratic monsoons can impact the availability of agricultural chemicals, hindering crop protection products. Moreover, rising temperatures can strain cooling systems in chemical plants, causing production delays. These disruptions not only drive up costs but also create uncertainty in delivery schedules, making it challenging for Indian chemical manufacturers to maintain competitiveness in the global market. To combat the negative effects of climate change, it is imperative from a simple mitigation strategy towards both physical and transition risks to a more holistic approach which includes developing adaptation and climate resilience measures for businesses and their supply chains.

The need for decarbonisation[29]

As discussed above, climate change is a pressing global threat, with targets set at COP21 in 2015 still unmet as of 2024. Supply chains are significant contributors to this issue, with just eight global chains responsible for over 50% of annual greenhouse gas emissions. In India, the chemical sector accounts for substantial amounts of total manufacturing emissions, with ammonia production being one of the largest emitter due to its energy-intensive nature. Given India's reliance on nitrogen-based fertilsers, the chemical industry not only contributes to CO_2 emissions but also to methane and nitrogen oxides through its products. As a USD 220 billion sector and the sixth-largest chemical producer globally, it plays a vital role in combating climate change. Therefore, it is necessary to decarbonise these supply chains to meet international climate goals and address the growing consumer demand for sustainable products. With increasing pressure from governments, investors and stakeholders to achieve net zero by 2070, the need for transformation in the chemical industry has never been more urgent.

The importance of embracing circularity[30, 31, 32]

In India, about 4.43 million tonnes of hazardous waste is generated annually, out of which 71,833 tonnes are incinerable, as per the reports of State Pollution Control Boards (SPCBs) submitted to the Supreme Court of India. The chemical industry contributes a significant amount of this waste. Moreover, the waste economy United Nations Environment Program (UNEP's) 2019 Global Resources Outlook,[33] which reveals that resource extraction and processing account for over 90% of global biodiversity loss and water stress, along with more than half of climate

28 https://www.indianchemicalcouncil.com/docs/ERM-ICC-Knowledge-papers-10-12-21.pdf

29 https://www.weforum.org/publications/net-zero-challenge-the-supply-chain-opportunity/

30 https://www.weforum.org/agenda/2024/02/how-manufacturers-could-lead-the-way-in-building-the-circulawhy is it important to uphold human rights in a chemical industry's supply chain

31 https://www.weforum.org/agenda/2024/02/how-manufacturers-could-lead-the-way-in-building-the-circular-economy/#:~:text=The%20circular%20approach%20compels%20manufacturers,value%20and%20reducing%20environmental%20impact

32 https://cefic.org/media-corner/newsroom/a-circular-economy-opens-up-opportunities-for-the-chemicals-sector/

33 https://www.resourcepanel.org/global-resources-outlook-2019

change impacts. Additionally, the detrimental effects of pollution on human health are becoming an increasing concern for mankind. Therefore, it is crucial that the chemical industry addresses these issues in order to promote sustainability and protect both the environment and public health.

Circular economy principles offer a transformative solution by shifting from a linear take-make-dispose model to one that prioritises reuse and recycling. This approach would allow the chemical industry to minimise raw material consumption and reduce dependence on costly primary resources. Adoption of cleaner production techniques and optimisation of resource efficiency would help companies cut waste, lower energy consumption, and decrease production costs.[34] Ultimately, circularity not only mitigates environmental harm but also enhances market competitiveness and profitability, paving the way for a more sustainable future.

The imperative of upholding human rights [35, 36]

In the case of the chemical sector, some major stakeholder engagement and management issues that require attention are listed below:

Issue	Description
Employee health and safety	• Risks from exposure to hazardous chemicals (carcinogens, organic solvents, metals) • Issues with machinery, fire, explosions, ergonomics • Inadequate training and safety information
Employment and labor standards	• Hazards particularly for young workers • Long working hours
Community health and safety	• Local population exposure to waste, noise, dust, emissions • Risks from storage and transport of hazardous materials • Potential contamination of natural resources affecting health
Communicable diseases	• Risks of disease transmission from workforce to local populations
Land acquisition	• Displacement of populations leading to loss of livelihood and assets • Insufficient consultation and compensation can result in community backlash

3.1.2. Building resilience

This section explores how companies in the chemical sector are de-risking their supply chains to build long-term resilience. Here are some key initiatives they are implementing:

Supplier selection and evaluation

Selecting ideal suppliers for the chemical industry is the primary step towards building resilience against environmental and social impacts. Businesses use several key criteria to ensure they choose the right partners by assessing the quality of chemicals, ensuring that their potential suppliers adhere to global standards and regulatory compliance, such as Food and Drug Administration (FDA) guidelines. They consider suppliers' experience and reputation, conduct direct visits to distribution warehouses to evaluate conditions and maintenance and verify normative compliance and certifications. Additionally, they examine technological capacity, financial stability, production capacity and fulfilment of delivery deadlines to ensure a resilient supply chain.

Moreover, the chemical industry also recognises that risk assessment is important when sourcing suppliers. They thoroughly analyse the risks associated with each potential partner, focusing on supply chain management, chemical safety and environmental impact. Companies also employ rigorous methods such as on-site audits, process reviews, and reference checks to ensure a comprehensive and reliable evaluation. Further, they assess suppliers' environmental and safety compliance history, crisis management and emergency response capabilities and the integrity and ethics of their operations, along with the efficiency of transport logistics.

Similarly, the industry evaluates existing suppliers on the basis of not only economic criteria but also ESG standards. This assessment occurs annually, semi-annually or quarterly, depending on company policy, and involves circulating questionnaires and conducting internal audits. Specific risk assessments are performed after identifying relevant risks, taking into account both country and industry-specific factors, as well as the company's

34 PwC analysis

35 https://www.indianchemicalcouncil.com

36 https://www.indianchemicalcouncil.com/docs/ERM-ICC-Knowledge-papers-10-12-21.pdf

influence. Suppliers are evaluated on compliance with product specifications, safety and environmental standards, financial stability, geopolitical risks, and their capacity to innovate. Lastly, companies also maintain a quality incident chart for regular checks on the production line.

Supplier code of conduct

A supplier code of conduct is established in the chemical industry to align with internationally recognized guidelines, including the principles of the United Nations' Global Compact, the U.N. Guiding Principles on Business and Human Rights, and International Labour Organization (ILO) conventions. This code ensures that suppliers maintain high standards of safe working conditions, fair treatment of employees, and ethical practices. Key components of the code include compliance with human rights, the exclusion of child and forced labor, adherence to labor and social standards, anti-discrimination and anti-corruption policies, and a commitment to environmental protection. Additionally, businesses also conduct audits and assessments to ensure that suppliers comply with all applicable laws, rules, and standards. They maintain the right to terminate business relationships if suppliers fail to adhere to international principles, do not correct violations, or exhibit patterns of noncompliance.

3.1.3. Sustainable sourcing and procurement

The chemical industry is increasingly focusing on responsible sourcing by developing bio-based products that serve as sustainable alternatives to conventional raw materials. Innovations include bio-based plastics made from renewable plant materials, which decompose more quickly than traditional plastics; bio-lubricants derived from plant oils that provide eco-friendly lubrication options; and biofuels, such as sugarcane, which have a low carbon footprint. Additionally, biopesticides and bio-based surfactants are being used for their reduced toxicity and biodegradability. These advancements reflect the industry's commitment to sustainability and reducing environmental impact.

Supplier Scope 3 mapping

In the chemical industry, Scope 3 emissions account for a substantial 70–75% of total greenhouse gas emissions, making them a critical component of a company's carbon footprint.[37] To effectively manage these indirect emissions, businesses are adopting a range of initiatives. They are building tailored roadmaps to track and reduce Scope 3 emissions through innovation and collaboration, while also identifying specific sources of these emissions and investing in tools and resources early on. Many companies are creating internal dashboards to regularly update and share Scope 3 emissions data with their teams. Additionally, they are developing life-cycle assessments (LCAs) and product carbon footprints (PCFs) for their offerings, as well as devising supplier engagement strategies that encourage suppliers to disclose their emissions data. These companies are promoting a standardised approach to tracking emissions and improving data-sharing practices by collaborating with industry groups. A systems-level approach is being emphasised, with outreach efforts directed towards tier-1 suppliers, customers and other stakeholders in the value chain to foster discussions aimed at achieving common climate goals.

37 https://cefic.org/media-corner/newsroom/measuring-the-emissions-impact-in-the-chemical-sector-a-guide-on-product-carbon-footprint/

3.1.4. Risk management in supply chains

Supplier climate risk and human rights assessment

Chemical companies assess supplier climate change risks through various evaluations to ensure a resilient supply chain. They conduct physical risk assessments to understand potential damages from extreme weather and perform transition risk assessments to analyse impacts from shifts to a low-carbon economy. A technology review focuses on emerging low-emission alternatives like biofuels and carbon capture. Companies also evaluate reputational risks related to stakeholder concerns and changing consumer preferences. Lastly, market and regulatory analyses track carbon pricing and trading developments. These comprehensive assessments enable proactive risk management and foster sustainability throughout the supply chain.

The chemical industry conducts human rights assessments through a structured internal framework called due diligence assessment. This process involves identifying a series of potential issues that may arise across different locations and products, such as labour rights violations, environmental impacts and community health concerns. A salience assessment helps prioritise these issues based on their likelihood of risk and potential impact, ensuring that the most critical areas are addressed. Due diligence policies and practices are implemented to establish measurable outcomes and a robust governance framework, enabling companies to effectively monitor and manage human rights risks. Human rights impact assessments may vary by company, ranging from standalone evaluations to comprehensive analyses that consider a combination of identified issues. This multifaceted approach ensures that the industry remains proactive in safeguarding human rights throughout its operations.

Deglobalised/indigenous production

Most of the chemical companies in India are increasingly adopting local sourcing as a strategy that aligns with ESG principles. Companies prioritise proximity over factors like cost or variety, which helps create shorter, more efficient supply chains by procuring goods, materials and services from suppliers within the same country or region. This approach not only reduces transportation emissions, contributing to environmental sustainability, but also strengthens local economies and fosters community relationships, enhancing social governance. Furthermore, local sourcing can improve supply chain resilience and transparency, which makes it easier for companies to uphold high ethical standards and compliance with ESG criteria.

Other initiatives implemented by the Indian chemical industry to build sustainable supply chain [38, 39, 40]

a. TfS: The Together for Sustainability (TfS) initiative is a global initiative in the chemical industry aimed at promoting sustainable supply chain practices. It was launched in 2011, and focuses on integrating sustainability into procurement processes and fostering collaboration among companies to improve social, environmental and economic standards across the supply chain. It features a common assessment framework that enables suppliers to evaluate their sustainability performance against established criteria. TfS promotes supplier engagement by encouraging companies to share best practices and conduct audits. Collaboration among member companies is central to the initiative, allowing for aligned goals and knowledge sharing. With companies and suppliers setting and achieving sustainability targets, continuous improvement is emphasised. Finally, transparency in the supply chain is prioritised to ensure stakeholders understand the sustainability practices and impacts of suppliers.

b. Responsible Care: Responsible Care is a global initiative launched in the chemical industry aimed at improving health, safety and environmental performance. The initiative encourages companies to operate sustainably and transparently while engaging with stakeholders. It promotes a commitment to the continuous improvement and tracking of performance metrics for benchmarking. Safety and security are prioritised to protect employees and communities, while stakeholder engagement fosters transparency and trust. Environmental stewardship is central, encouraging companies to minimise their ecological impact through sustainable practices. The initiative also advocates for responsible management throughout the supply chain and emphasises the importance of training and education to cultivate a culture of safety and responsibility among employees and stakeholders.

c. EcoVadis assessment: This is a sustainability evaluation tool widely used in the chemical industry to assess the performance of companies and their supply chains. EcoVadis provides companies with a comprehensive scorecard that evaluates their sustainability practices based on criteria such as environmental impact, labour practices, ethics and sustainable procurement. This assessment is closely related to sustainable supply chain practices, as it enables companies to identify risks, benchmark their performance against peers, and engage suppliers in improving their sustainability efforts. By leveraging the EcoVadis assessment, organisations can foster greater transparency, accountability and collaboration within their supply chains, ultimately driving progress towards more sustainable and responsible business practices.

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38 https://supplychaindigital.com/sustainability/tfs-chemical-supply-chain-transparency-solution

39 https://icca-chem.org/

40 https://supplychaindigital.com/articles/ecovadis-how-can-supply-chains-adapt-to-csddd-regulations

3.1.5. Case studies of successful integration

Several Indian chemical companies have successfully integrated sustainability into their supply chains, demonstrating the tangible benefits of adopting sustainable practices.[41]

BASF is committed to fostering a sustainable supply chain through a robust framework of policies, practices and assessments across the ESG aspects. In the realm of environmental sustainability, BASF implements several policies including the supplier code of conduct, palm sourcing policy, BASF climate-neutral policy and supplier CO2 management.

On the social front, BASF invests substantial amount in public health and education, supports supplier diversity, and prioritises occupational health and safety. Governance-wise, BASF upholds ethical practices through its Code of Conduct, conducts regular audits, and collaborates with initiatives like Together for Sustainability and EcoVadis to assess environmental and human rights standards. The company therefore is committed to exceeding sustainability expectations, integrating these values into its global supply chain through rigorous oversight and dedicated teams.

Similarly, **Tata Chemicals** is dedicated to establishing a sustainable supply chain through an integrated framework of policies, practices and assessments that focus on ESG aspects. In the environmental domain, Tata Chemicals has implemented robust policies addressing climate change, circular economy and decarbonisation.

Several companies exemplify a strong commitment to sustainability through innovative approaches to supplier management. **Pidilite Industries** prioritises regular audits and close collaboration with suppliers to ensure adherence to high environmental and social standards. This proactive strategy has not only enhanced the company's sustainability profile but also strengthened relationships, fostering long-term partnerships. Similarly, **GHCL Ltd.** adopts a proactive approach to risk management, diversifying its supplier base and leveraging predictive analytics to mitigate potential disruptions. This strategy ensures operational continuity while reinforcing its sustainability commitment.

In conclusion, the shift toward a responsible supply chain in the chemical industry is driven by the urgent need to address climate change, uphold human rights and embrace circularity. The complexities of modern supply chains necessitate a comprehensive understanding of the environmental and social impacts associated with production processes. Companies can not only mitigate risks associated with climate disruptions but also enhance their resilience against future challenges by adopting sustainable practices. Key strategies such as responsible sourcing, supplier evaluations and adherence to ethical standards are critical in fostering a more sustainable chemical sector. Initiatives like the TfS and Responsible Care exemplify the collective efforts within the industry to prioritise environmental stewardship and social responsibility. Furthermore, as consumer demand for eco-friendly products rises, the imperative for decarbonisation and resource efficiency becomes increasingly pressing. The Indian chemical industry can not only meet global sustainability goals but also ensure its competitiveness in an evolving market through collaboration and innovation. Ultimately, the path toward a responsible supply chain is not merely a regulatory requirement but an essential strategy for long-term success that will foster a healthier planet and society for future generations.

41 PwC analysis

3.2. Circularity

The concept of circularity is growing beyond a limited emphasis on recycling to include a broader perspective. This expanded scope includes adopting sustainable sourcing, waste minimisation practices and end-of-life management. This concept is strongly connected to the circular economy.

Unlike the traditional linear model of 'take, make, dispose', a **circular economy** emphasises closed-loop systems that focus on decreasing waste and making the most of available resources. This approach helps in creating products that are durable, repairable and recyclable, reducing adverse environmental impact and conserving valuable resources.[42]

The principles of a circular economy are important and chemical companies are integrating these values into their long-term strategies and operational processes.

Figure 23: Emerging applications of carbon dioxide

1. Regenerate

Regenerating natural systems involves setting up processes that benefit the environment instead of harming it. This includes utilising renewable feedstocks and minimizing environmental impact.

Producing bio-based chemicals from agricultural resources and turning waste into valuable products like biochar can restore and enhance soil health.

2. Eliminate

Designing waste and pollutants focuses on preventing waste and hazardous substances from the initial phase with techniques like process intensification that improve efficiency and minimise waste

Microreactors improve reaction efficiency and reduce by-products.

3. Circulate

Keeping products and materials in use by staying focused on extending their life cycle through reuse, repair and recycle

Chemical recycling by breaking down waste plastics into monomers for reuse

Source: PwC analysis

42 PwC analysis

Figure 25: Policies driving Circularity in India

National Policy on Resource Efficiency (NPRE)	Swachh Bharat Mission (SBM)	Extended Producer Responsibility (EPR)
The NPRE, under the Ministry of Environment, Forest and Climate Change (MoEFCC), aims to enhance resource efficiency and encourage sustainable consumption and production practices in various industries. **It outlines strategies for improved resource recovery, waste management, practices and integration of sustainable practices into industrial processes, aiming to minimise environmental impact and promote a circular economy.**	SBM, launched in 2014, is a cleanliness initiative designed to increase the awareness of sanitation and waste management across the country. The mission **focuses on solid waste management and enhances waste-to-resource technologies, including composting and recycling, to transform waste into valuable resources. This effort seeks to create cleaner and healthier communities while fostering sustainable waste practices.**	The Plastic Waste Management Rules and EPR mandate that producers are responsible for managing their products at the end of their life cycle. EPR incentivises producers to design products for recyclability and establish systems for the collection and recycling of used items. This approach aims to **reduce plastic waste and enhances circular economy by encouraging manufacturers to consider the entire life cycle of their products.**

Atal Mission for Rejuvenation and Urban Transformation (AMRUT)	National Clean Air Programme (NCAP)	Startup India and Make in India
AMRUT plans to enhance urban infrastructure, specifically targeting water supply and sanitation improvements in India. The mission also incorporates waste management and resource recovery components, which contribute to creating more sustainable urban environments. By dealing with these key areas, AMRUT seeks to **promote overall urban development while ensuring environmental sustainability.**	The NCAP, launched in 2019, seeks to enhance air quality in Indian cities through strategies that reduce industrial emissions and vehicular pollution. By promoting cleaner technologies and improved waste management practices, the **NCAP aligns with circular economy principles, aiming to minimise pollution and optimise resource use.** This approach not only addresses air quality issues but also fosters sustainable urban development.	These initiatives promote innovation and manufacturing in India by fostering the development of sustainable technologies and circular economy solutions. **They boost startups and established companies to prioritise sustainable and resource-efficient practices**, contributing to a more environmentally responsible economic landscape.

Source: http://moef.gov.in/draft-national-resource-efficiency-policy2019-inviting-comments-and-suggestions-of-stakeholders-including-publicprivate-organization-experts-and-concerned-citizens/, https://swachhbharatmission.ddws.gov.in/, https://eprplastic.cpcb.gov.in/#/plastic/home; https://pib.gov.in/PressReleasePage.aspx?PRID=1885837; https://www.makeinindia.com/

3.2.1. Industrial applications and case studies

India's progress towards circularity is important for fostering sustainability across various sectors, including automotive, fashion, electronics, construction, food and beverage, energy and chemicals.

The adoption of circularity in the Indian chemical industry is gaining attention as companies recognise the benefits of sustainable practices. **The chemicals and plastics industry can also promote circularity through chemical recycling technologies, sustainable sourcing and focusing on waste and product lifecycle management.**

The National Circular Economy Framework (NCEF), introduced by the Indian government, establishes a clear and consistent roadmap for transitioning to a circular economy and aims to support the countrywide adoption of circular economy practices

Figure 26: NCEF framework

Prevention: Avoid generating waste - this can be achieved through designing products by reusing, repeating, refurbishing and re-manufacturing components.

Upcycling: Waste should be upcycled if possible. This means converting waste into new products of higher value. For example, plastic waste can be upcycled into new plastic products.

Recycling: Waste should be recycled if possible. This means converting waste to make new products. For example, paper and metal waste can be recycled to new paper and metal products respectively.

Energy recovery: : Waste that cannot be recycled or upcycled should be used to generate energy. This can be done by burning waste to generate electricity, or by converting waste to biogas.

Source: https://www.ciiwaste2worth.com/pdf/national-circular-economy-framework-compressed.pdf

Companies are reporting their progress via sustainability reports, highlighting their commitment to circular economy practices.[43]

Indian consumers are becoming aware of environmental issues and the importance of sustainable products. This growing consciousness among consumers is one of the reasons behind Indian chemical companies making future strategies to implement circularity in an effective manner.

Figure 27: Chemical industries' plan in the next 10 years to adopt circularity

Source: PwC analysis

43 PwC analysis

Case studies

Company name	Details
Tata chemicals [44]	Tata Chemicals aim to achieve zero waste by improving their recycling and recovery processes. They focus on sustainable practices across all their operations and have ambitious targets for waste reduction by the next decade.
Godrej Industries	Godrej Industries has a sustainability strategy which includes waste minimisation and recycling. The company focuses on reducing their environmental footprint across their chemical manufacturing processes. The company also focuses on cross-industry collaboration to encourage innovation and reduce emissions and is actively working across the value chain to collectively promote a circular economy.
Reliance[45]	Reliance is investing considerably in incorporating circular economy principles in its operations, which includes waste management and recycling. It aims to reduce waste generation and increase the use of recycled materials in its products. Reliance has various projects centred around circularity, including the development of R-Elan fabric to meet the increasing consumer demand for eco-friendly products. The company also announced that it is the first Indian company to convert pyrolysis oil from plastic waste into circular polymers, as certified by the International Sustainability and Carbon Certification (ISCC)-Plus.
Dow	Dow's strategy to transform plastic waste into valuable products has unlocked the economic potential of circularity. The company also aims to commercialise millions of metric tonnes of circular and renewable solutions, indicating the significant market opportunities associated with circularity.

Overall, India's shift towards circularity by its chemical sector is essential for encouraging resource efficiency, reducing waste and supporting sustainable economic growth.

3.2.1 Economic and environmental benefits

Circular economy offers an appealing solution to India's resource availability challenges. By implementing circular practices, India can reduce resource extraction, increase utilisation, and prolong their lifespan through reuse, repair and recycle.

Figure 28: Economic and environmental preservation from circular economy

Economic value creation from circular economy

Estimated job creation potential
10 million jobs by 2050

Projected economic value
USD 2 trillion by 2050

Environmental preservation from circular economy

Potential carbon emission
reduction 40% by 2050

Water conservation
20% reduction in water consumption by 2050

Reduced waste generation
50% reduction in waste generation by 2050

Source: https://www.ciiwaste2worth.com/pdf/national-circular-economy-framework-compressed.pdf

Considering environmental benefits, adopting circular economy principles reduces the chemical industry's carbon footprint and helps conserve natural resources. This approach tackles the urgent need of waste management, particularly related to plastic waste, by turning it into a resource. In India, where industrial activities increasingly impact the environment, shifting to circularity is both a strategic necessity and a moral imperative.

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44 https://economictimes.indiatimes.com/industry/indl-goods/svs/chem-/-fertilisers/tata-chemicals-committed-to-reduce-carbon-emission-by-30-by-2030-chandrasekaran/articleshow/92706776.cms?from=mdr

45 https://economictimes.indiatimes.com/industry/indl-goods/svs/chem-/-fertilisers/reliance-becomes-first-in-india-to-use-chemical-recycling-for-circular-polymers/articleshow/106381520.cms?from=mdr

3.3. Waste reduction

3.3.1. Regulatory frameworks and compliance

In India, the regulation of hazardous waste falls within the authority of the **Central Pollution Control Board**, with implementation conducted by state pollution control boards. Various laws and frameworks have been set up to ensure the safe handling, treatment, disposal and recycling of hazardous waste, thereby protecting both the environment and public health.

Some key frameworks to manage waste in India:

- **Solid waste management:** It mandates segregation of waste at its origin stage into biodegradable, non-biodegradable and domestic hazardous waste.
- **Extended producer responsibility (EPR):** It requires manufacturers, dealers and brand owners to manage end-of-life products – particularly, electronics and plastic packaging.
- **E-Waste (management) Rules:** Introduced in 2016, it regulates the handling, collection, processing and disposal of electronic waste.

Improper handling of hazardous waste in India can have severe consequences, pertaining to legal, financial, health and environmental liabilities. These may manifest as penalties, clean-up costs, loss of business reputation and compensation for damages.

To support the chemical industry's transition towards zero waste, India's regulatory framework enforces stringent regulations, provides incentives for sustainable practices and promotes innovative waste management solutions. In addition to minimising waste production, compliance with these regulations makes the industry more sustainable.

3.3.2. Zero waste strategies

Zero waste focuses on reducing consumption and ensuring products are reusable, repairable or recyclable.

The Indian chemical industry is one of the forerunners of adopting zero waste strategies. Chemical waste generated can include **solvents, by-products, sludges** and **other hazardous materials**. Initiatives like energy-efficient manufacturing, water recycling systems and waste-to-energy projects are important to ensure sustainable chemical production.

By leveraging the combination of incentive, infrastructure and enforcement, a zero waste model could be conceptualised to help make the chemical industry more sustainable.

Incentive	Incentives can be provided either through direct financial means or periodic area-based rankings/ratings, which might indirectly increase the value of the land or rental prices.
Infrastructure	Infrastructure can operate on a micro level, such as waste management in housing complexes, or on a macro level, including projects like refurbishing parks, building bio-digester plants and implementing plasma incineration systems.
Enforcement	An enforcement model to reduce chemical waste should include IT-based surveillance, penal provisions, clearly defined prohibitions and the use of penalty funds.

3.3.3. Case studies and best practices adopted by major Indian players

Company name	Initiatives	Details
Tata chemicals[46]	Waste recycling through co-processing	Shifted to co-processing of hazardous waste, instead of landfilling, at their Cuddalore unit Substantial quantities of waste diverted from landfilling towards co-processing
Pidilite[47]	Implementing sites 'Zero waste to landfill'	For all Pidilite plants in Himachal Pradesh (HP) i.e. Baddi, Kalaamb and Nalagarh, the hazardous waste generated is disposed of to authorised recyclers. They, in turn, prepare compost and recycle the waste back as fuel for the cement industry. All their Himachal Pradesh plants are declared as 'zero waste to landfill' sites.
Reliance[48]	Water recycling	Hazardous waste from Reliance operations is recycled as alternative fuels and raw material for the cement industry. The company is also developing an in-house technology for chemical recycling (pyrolysis oil).

3.3.4. Role of digitisation in circularity and waste reduction

Several innovative startups in India are making strides towards the digitalisation of circular economy by focusing on waste reduction, resource recycling and other sustainable practices.

Example:

Recykal, a digital platform based in Hyderabad, links waste generators with recyclers and manufacturers. Recykal streamlines the recycling process and facilitates transparent, efficient circular supply chains for plastic, paper and electronic waste.[49]

Similarly, Indian chemical industries should partner with such pioneering startups to meet their circularity goals.

46 PwC analysis

47 PwC analysis

48 https://www.financialexpress.com/business/industry/reliance-turns-plastic-waste-into-high-quality-materials-for-new-plastic/3351043/

49 https://timesofindia.indiatimes.com/business/india-business/recykal-raises-rs-110-crore-in-pre-series-b-round-from-360-one-asset/articleshow/109202526.cms

3.4. Life cycle assessment (LCA)

LCA is a crucial tool for evaluating the environmental impact of products and processes within the chemical industry. By analysing the entire life cycle of a product – from raw material extraction through production, usage and disposal – LCA helps organisations to identify opportunities for reducing environmental footprints and enhancing sustainability. In this section, we highlight a few case studies in the chemical industry in terms of LCA and its application in product development, showcasing how companies leverage LCA to drive sustainable innovation.

3.4.1. LCA in product development

Increasing consumer demand and evolving regulations for sustainable products have compelled chemical companies to re-think their product development strategies and increase focus on product stewardship. Chemicals are the primary raw material for any industry; hence, there is a high onus on chemical manufacturers to decarbonise their products.

Regulators are also increasingly focusing on supply chain emissions, with SEBI's Business Responsibility and Sustainability Reporting (BRSR) – which is mandatory for the Top 1,000 listed companies – to report on LCA studies performed in the reporting year along with their impacts and product-wise disclosures.[50] This move by the market regulator forces companies in the high environmental impact sectors – such as chemicals manufacturing – to consider LCA as vital cog of the enterprise risk and sustainability strategy. The BRSR framework will eventually evolve to include value chain disclosures which will require reporting organisations to demonstrate value chain engagement and decarbonisation efforts, thus making LCA a necessary tool for the resource-intensive industries.[51]

In addition to local regulations, ESG rating agencies such as S&P Global CSA, MSCI, Sustainalytics and CDP, consider product stewardship initiatives and strategy as an important dimension to evaluate the companies. With increasing investor focus on ESG ratings, chemical companies will be eventually forced to develop sustainable products to get better ratings which can potentially open doors to sustainable financing options and increased investor interest.[52]

As a starting point for sustainable product development, LCA provides a scientific basis for evaluating the environmental trade-offs of different materials, production methods and product designs, thereby enabling companies to make informed decisions that balance performance, cost and sustainability.

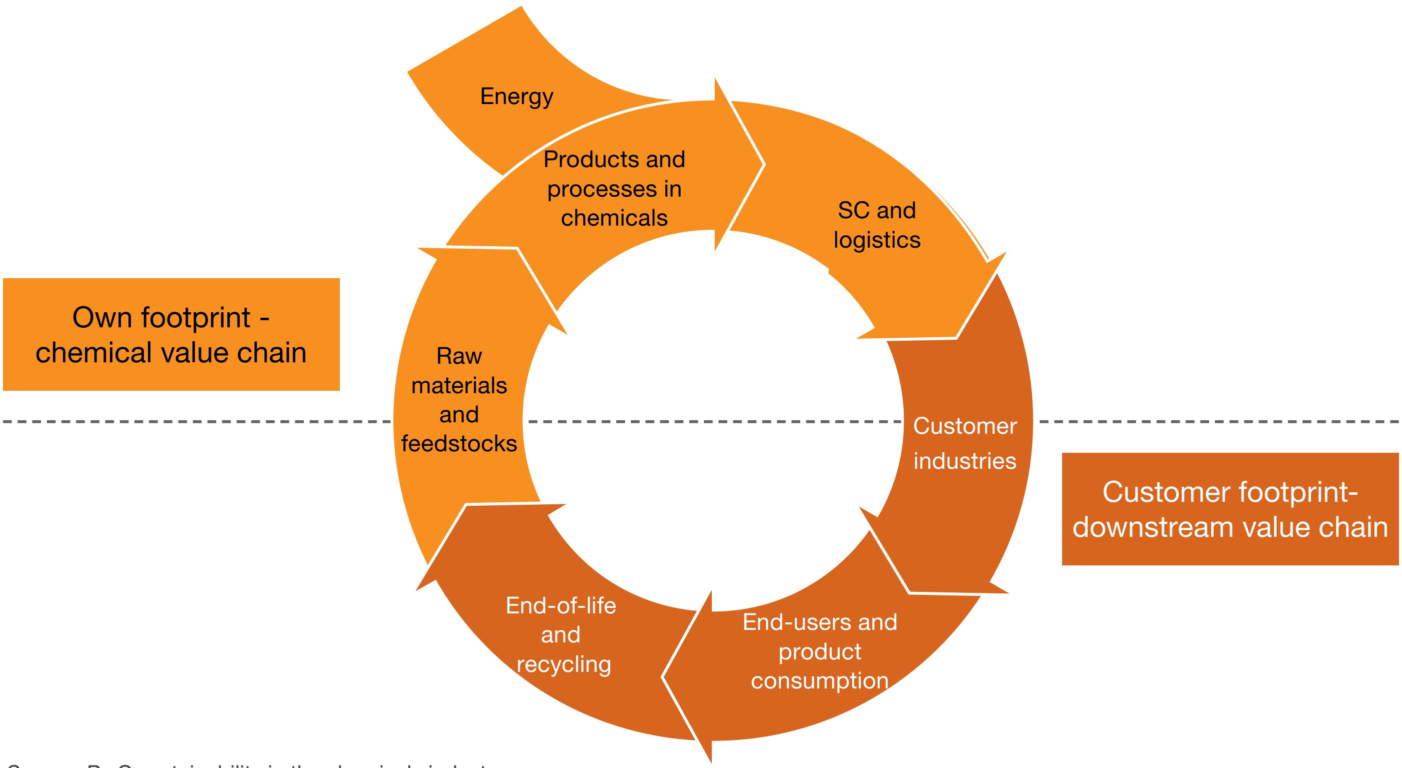
50 https://www.sebi.gov.in/sebi_data/commondocs/jul-2023/Annexure_II-Updated-BRSR_p.PDF

51 https://www.sebi.gov.in/legal/circulars/jul-2023/brsr-core-framework-for-assurance-and-esg-disclosures-for-value-chain_73854.html

52 PwC analysis

LCA value chain

Figure 29: LCA value chain



Source: PwC sustainability in the chemicals industry

Figure 30: LCA value chain

LCA as a product design tool:

During product development, LCA can be used to evaluate the environmental impacts of various design options. For instance, when developing a new chemical product, a company may use LCA to compare the environmental impact of different raw materials, production processes and end-of-life disposal methods. This analysis will provide insights to identify the most sustainable option without compromising on the desired performance, guiding the design process towards minimising environmental impacts. Additionally, LCA during product development provides chemical manufacturers with an opportunity to engage with their upstream value chain for developing sustainable raw materials.

For example, LCA studies have pivoted industries to transition to green solvents as they consume less energy and are less toxic compared to conventional solvents.

Eco-design and circularity:

LCA also plays a crucial role in eco-design, which is a product development approach focused on minimising environmental impacts throughout the product's life cycle. By evaluating the potential environmental impacts of a product during the R&D phase, companies can identify opportunities to improve resource efficiency, reduce waste and enhance product recyclability.

For example, LCA can be used to assess the recyclability of different packaging materials, guiding the selection of materials that are easier to recycle and have a lower environmental impact. This approach supports the chemical industry's shift towards a circular economy, where products are designed with their end-of-life in mind, promoting reuse, recycle and reduction of waste.

Regulatory compliance:

LCA studies during the design phase have also become crucial from the perspective of regulatory compliance. The EU's registration, evaluation, authorisation and restriction of chemicals (REACH) regulation focuses on protecting human health and the environment. REACH specifically restricts use of substances of very high concern (SVHC) as the pose significant risks to human beings and the environment.LCA is therefore the most appropriate tool for the chemical sector to evaluate its products and productions processes in order to identify SVHC and replace them with alternative raw materials.

Source: https://environment.ec.europa.eu/topics/chemicals/reach-regulation_en

The adoption of LCA in product development is not just limited to individual companies; industry-wide initiatives are also promoting the use of LCA as a standard practice. The World Business Council for Sustainable Development (WBCSD) has developed guidelines for the chemical sector to standardise LCA practices and encourage the use of life cycle thinking in product development.[54] The Product Carbon Footprint (PCF) guidelines released by Together for Sustainability (TfS), an initiative by a group of leading chemical manufacturers, demonstrates leadership by the industry itself to steer itself towards development of sustainable and low carbon products.[55] These guidelines will provide an extensive knowledge base for the chemical companies to align their product development processes with global sustainability goals, ensuring that new products contribute to a more sustainable future.

3.4.2. Case studies of LCA in the sector

LCA has been increasingly adopted by leading chemical companies to assess the environmental impact of their products and processes. Through detailed analysis, LCA provides insights into the most environmentally impactful stages of a product's life cycle, enabling targeted improvements. Several case studies highlight the effectiveness of LCA in driving sustainable practices within the chemical industry.

- **BASF –** Haptex is a renowned brand of sustainable synthetic leather range from BASF targeted to for applications such as automotive seating, furniture, and fashion accessories like bags and caps. To highlight the lower environmental footprint of this product, BASF commissioned a third-party LCA assessment. The LCA analysis indicates that Haptex significantly outperformed conventional synthetic leathers, including those produced through solvent-based and waterborne methods, in terms of carbon emissions. Specifically, Haptex production generates 52% less greenhouse gas emissions compared to traditional synthetic leather. Additionally, it reduces energy consumption by over 20% for its production. This improvement is largely attributed to the removal of the wet line in the production process, leading to a 30% decrease in water usage compared to typical solvent-based polyurethane production techniques[56]. The latest iteration of Haptex is 100% recyclable, further bolstering its ecological advantage.

54 https://www.weforum.org/organizations/world-business-council-for-sustainable-development-wbcsd/

55 https://supplychaindigital.com/sustainability/tfs-chemical-supply-chain-transparency-solution

56 https://www.plastemart.com/news-plastics-information/basfs-haptex%C2%AE-4-0-innovative-pu-for-recyclable-synthetic-leather/72561

- **India Glycols Ltd. (IGL):** IGL is a leading chemicals manufacturer which specialises in green technology chemicals. It actively adopts new technologies to develop sustainable products. Before product launches, the company ensures thorough life cycle analysis and biodegradability evaluations. IGL performed a comparative LCA of bio-mono ethylene glycol (Bio-MEG) derived from molasses versus fossil fuels. This assessment adhered to ISO 14044-2006 standards and evaluated various environmental impacts, including the carbon footprint. The LCA concluded that producing MEG from renewable raw materials is more sustainable than using conventional petrochemical methods in India, the US and Europe. Additionally, IGL carried out similar LCAs for other products, including bioethanol, bio-ethylene oxide, bio-glycols, bio-glycol ethers and bio-polyethylene glycols. [57]

3.4.3. Role of digitisation and AI in LCA

The advancements and adoption of machine learning (ML) and AI technologies have the potential to make LCA studies more reliable and less time consuming. AI/ML-driven LCA models, when trained adequately, can undertake analysis of large data sets, multiple scenario analysis and provide real-time insights during the product design stage.[58]

Nevertheless, development of AI models for LCA is still in its nascent stages, requiring significant training of AI/ML algorithms on the existing LCA datasets before the chemical industry can benefit from this. However, integration of AI/ML with LCA models can have a disruptive effect on the chemical industry, giving it a much-needed impetus towards sustainable product development.

The chemical sector is still working towards developing sustainable products as a higher percentage of its overall product portfolio. Presently, the sector primarily acts as a raw materials supplier for virtually every other industry, making product economics a major factor to maintain its competitive edge and financial health. Sustainable chemicals or products often come at a higher cost than their counterparts. This makes it harder to justify the investments for the development of these products, especially if the consumer base is in price-sensitive markets. Moreover, there are no special incentives provided by the government to improve the competitiveness of sustainable products, which can spur innovation in this arena. The PLI scheme proposed by the Government of India covers only basic and agrochemicals.[59] Without clear financial incentives in sight, the chemical sector currently has no major incentive to transition to sustainable products beyond compliance with applicable regulations.

LCA can act as stepping stone for the development of sustainable products, but only if the tangible and intangible benefits have an impact on business financials. Chemical manufacturers are approaching an inflection point wherein they are well poised to leverage the LCA approach to decarbonise their products and value chain, optimise formulations and reduce overall product toxicity. Improving the environmental footprint of chemicals will have a long-term positive impact on human health, soil health, aquatic systems and biodiversity in addition to potential new revenue streams for the industry.

57 https://www.ieabioenergy.com/wp-content/uploads/2020/02/Bio-based-chemicals-a-2020-update-final-200213.pdf

58 PwC analysis

59 https://www.thehindubusinessline.com/economy/proposed-pli-scheme-for-chemicals-may-cover-agrochemicals-pharma-intermediates/article67524551.ece

4. Incentives

The adoption of sustainability practices in the chemicals sector is being actively encouraged through a variety of incentives aimed at fostering environmentally responsible practices. The Indian government, along with various state authorities, offers tax benefits, subsidies and grants to companies that invest in green technologies and sustainable processes – e.g. the Perform, Achieve and Trade (PAT) scheme incentivises energy efficiency improvements. Financial institutions are also increasingly supporting sustainable projects with favourable financing options. These incentives are designed to alleviate the cost burden of transitioning to sustainable operations, promote innovation and ensure that the Indian chemicals sector aligns with global environmental standards, thereby contributing to the country's broader climate goals.

4.1. Sustainable finance

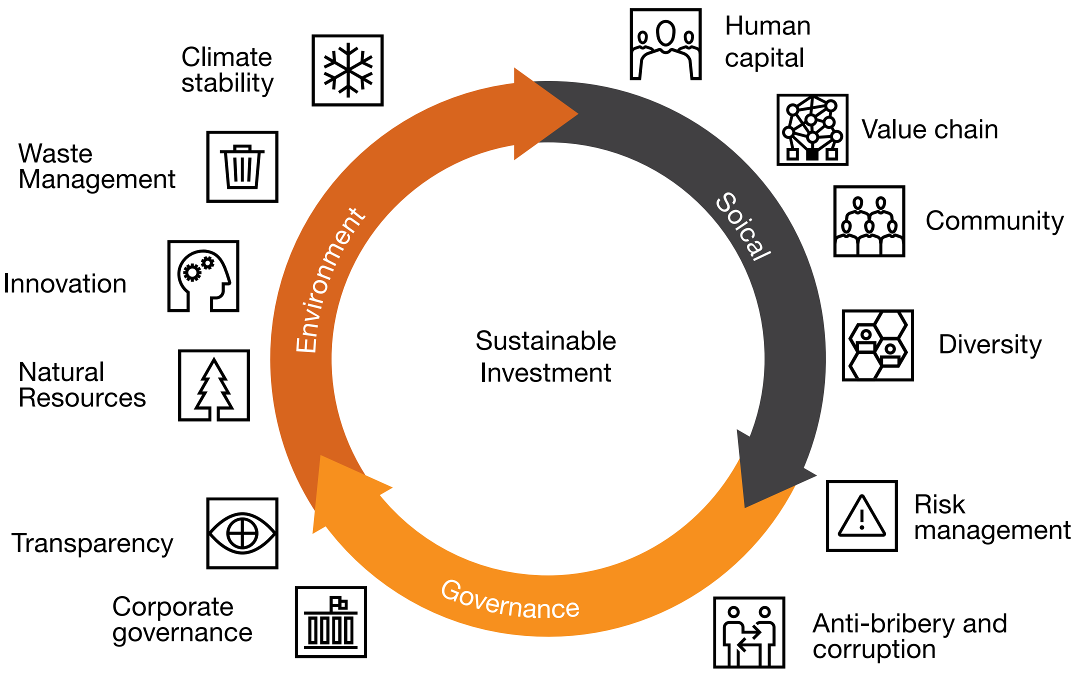
The chemical sector has a significant opportunity to lead sustainability efforts across various industries aiming to cut emissions. Achieving a decarbonised economy will require considerable capital investments, particularly through green finance. These investments are essential for supporting initiatives that reduce GHG emissions and help businesses adapt to the impacts of climate change. In this section, we will examine how both emerging and established green finance strategies are vital in mobilising the necessary funds to support the chemical sector's sustainability efforts.

> While there is no single, universally accepted definition of sustainable finance, it is commonly understood as the integration of ESG considerations into financial decision-making processes, leading to long-term investments in sustainable economic activities and projects.[60]

4.1.1. The Rising Role of ESG in Investment Strategies

Institutional investors, funds and financial institutions are increasingly integrating ESG criteria into their investment decisions. According to a 2019 PwC Private Equity Responsible Investment Survey, 91% of respondents have already adopted or are currently developing a responsible investment or ESG policy.[61] More recently, a 2023 survey of over 150 private equity (PE) firms indicated that considering ESG factors has become standard practice throughout the investment process – from sourcing opportunities and conducting due diligence to forming post-acquisition plans and negotiating deal terms.[62]

Figure 32: Linking ESG criteria to sustainable investment



Source: PwC, EU Sustainable Finance and the increasing importance of ESG factors in accessing finance

Banks and investors will periodically increase their ESG requests – i.e. more detailed sustainability reports, enhanced transparency in governance practices and stronger commitment to social responsibilities.

Consequently, companies that prioritise and effectively manage their ESG performance will be better positioned to meet these evolving demands.

This could lead to improved access to capital, more favourable financing terms and enhanced reputational benefits. Moreover, companies that understand how sustainability affects their business can leverage this knowledge to their advantage. By improving existing products and creating new ones that are more sustainable, these companies can not only meet investor expectations but also drive innovation and achieve competitive differentiation in the market.

60 https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en

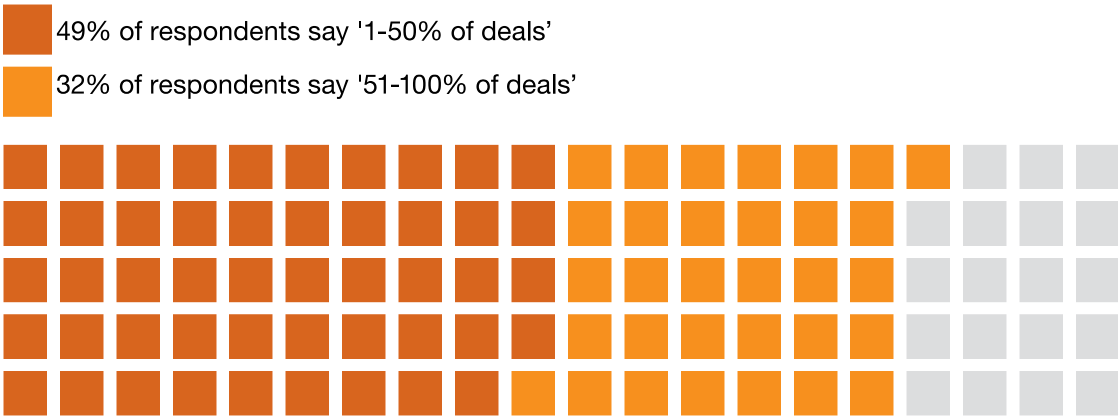
61 https://www.pwc.com/gr/en/advisory/risk-assurance/sustainability-climate-change/eu-sustainable-finance-and-the-increasing-importance-of-ESG-factors-in-accessing-finance.html

62 https://www.pwc.com/gr/en/advisory/risk-assurance/sustainability-climate-change/eu-sustainable-finance-and-the-increasing-importance-of-ESG-factors-in-accessing-finance.html

Figure 33: ESG as a primary driver of value creation in deals

One-third of PE respondents say that ESG was a primary driver of value creation in more than half of their organisation's recent deals.

Of the deals that your firm/fund completed during the last 12 months, what proportion included ESG as one of the primary drivers of value creation?



Source: PwC's Global Private Equity Responsible Investment Survey 2023

4.1.2. Role of financial institutions

The financial sector is innovating to facilitate the transition to a low-carbon economy. New financial instruments, such as green bonds and sustainability-linked loans (SLLs), are gaining significant traction. These products are designed to channel capital towards high-emission companies that are committed to genuine decarbonisation efforts. By linking financial terms to sustainability performance, these instruments create tangible incentives for companies to improve their environmental footprint.

Green bonds are defined by the International Capital Market Association's (ICMA) as 'any type of bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible green projects. Simply put, they are financial instruments that finance green projects and provide investors with regular or fixed income payments.[63] The transition to a low-carbon economy requires unprecedented levels of capital allocation towards green initiatives and green bonds are an important channel to do that. Green bonds are financial instruments that finance green projects and provide investors with regular or fixed income payments. The transition to a low-carbon economy requires unprecedented levels of capital allocation towards green initiatives and green bonds play a significant role in the same. 'Green' can include renewable energy, sustainable resource use, conservation, clean transportation and adaptation to climate change.

SLL is another product that is rapidly becoming a significant player in the sustainable finance landscape. It is similar to other revolving credit facilities – a type of corporate loan – but with a key difference: The interest paid by the borrower is linked to specific sustainability key performance indicators (KPIs) such as carbon emissions or other ESG targets.

> Any target that aligns with a company's sustainability objectives can be integrated into an SLL. This means the approach can be tailored specifically to the borrower's unique goals or linked to an existing sustainability rating.

Companies that meet their sustainability targets benefit from favourable interest rates, while those that fail to do so face higher rates. As a result, SLLs provide companies with a strong incentive to align their financing activities with their sustainability objectives.

Below are some of the other existing and emerging green finance products in the market:

- **Green equity funds:** Green equity funds are investment vehicles that pool capital from various investors to support environmentally focused investment strategies, managed by qualified investment managers.

63 https://www.worldbank.org/en/news/feature/2021/12/08/what-you-need-to-know-about-ifc-s-green-bonds

- **Green securitisation:** Green securitisation involves bundling green loans into securities to unlock additional capital for financing a decarbonised and climate-resilient economy. This process aggregates multiple small-scale loans, attracting a broader investor base.
- **Transition and sustainability bonds:** These bonds are utilised by companies in carbon-intensive sectors like oil and gas or heavy industry, where green bonds may not be accessible due to specific criteria.

While products like green bonds and SLLs are already making significant inroads, there is an urgent need to further enhance the financial system's ability to attract private capital for green and sustainable investments. This requires developing new financing instruments as well as improving and leveraging existing ones to gain traction with potential investors and mobilise the substantial capital required.

4.1.3. Green bonds and SLLs financing decarbonization in the chemical sector

Globally, decarbonising the chemical and petrochemical industry would require considerable investments for new chemical plants and energy supply. In Europe, the EU has allocated budgets for investments in sustainable technologies, such as lithium-ion batteries, biorefining, green hydrogen production and storage, among others. A portion of these funds will benefit the chemicals sector. At the corporate level, private companies are also dedicating capital to climate projects.

Green bonds: In recent years, chemical companies have started to adopt green finance frameworks to support projects that are environmentally and socially beneficial. In 2020, BASF issued a green bond worth EUR 1 billion with a term of seven years.[64] The proceeds from this bond were allocated to fund various sustainable products and projects. Arkema, a French chemical company, issued its first green bond to finance the construction of a new world-scale plant in Singapore dedicated to producing bio-based polyamide.[65]

Examples of green bonds in the chemical industry

Issuer	Country	Use of proceeds	Year	Amount
Arkema	France	To construct a plant that produces bioplastics from castor beans	2021	USD 333 million
BASF	Germany	For constructing a production facility for biobased polyamide	2021	USD 1,111 million
Lyondell-Basell	USA	To fund circular economy projects, increase their plastics recycling capacity and make progress on their goal to produce and market polymers from recycled or renewable-based sources	2023	USD 500 million

Source: https://cen.acs.org/business/finance/LyondellBasell-getting-green-bonds/101/i17; PwC analysis

In India, the green bond market is overseen by SEBI. SEBI's framework requires green bond issuers to disclose their environmental objectives, system or procedure to track the use of proceeds from the green bond and intended use of funds. It also specifies eligible categories for raising funds through green debt securities.

Milestone issuances of green bonds in India

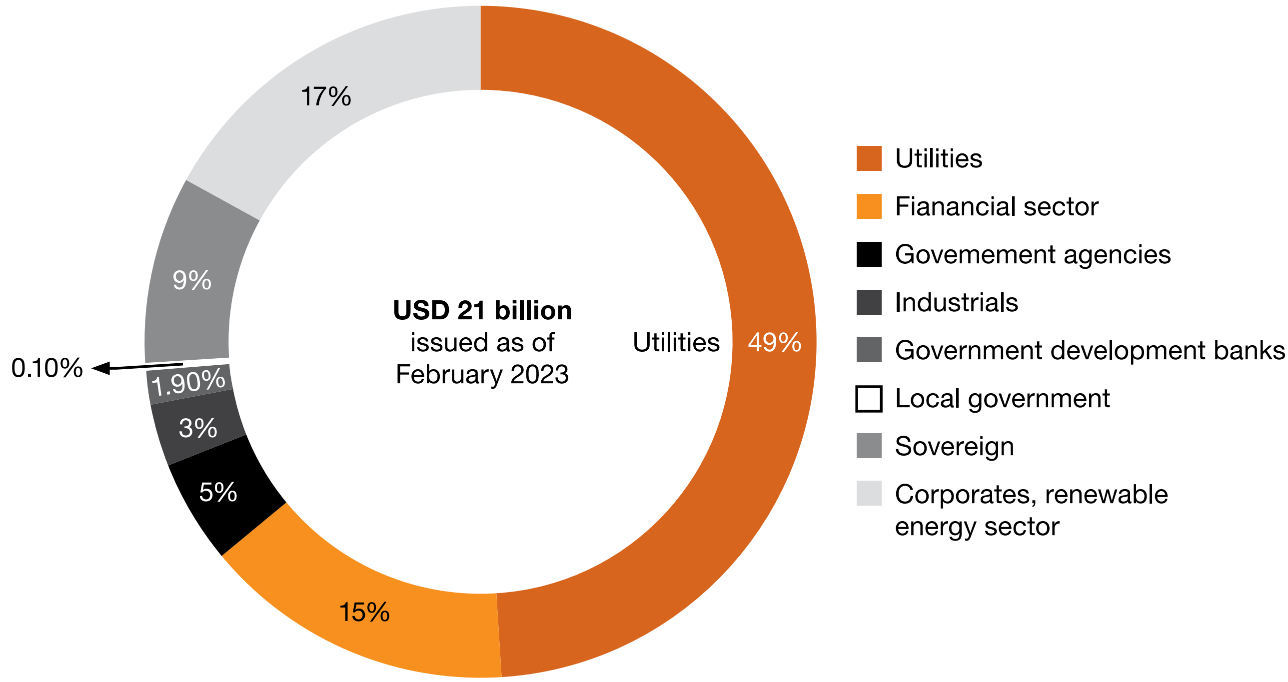
Issuer	Milestone	Year	Amount
YES Bank	First green bond issuance in India	2015	USD 260 million
Greenko	First high-yield green bond issuance in India	2016	USD 500 million
NTPC	Issuance of a corporate green 'Masala' bond	2016	USD 300 million
Ghaziabad Municipal Corporation	First local civic body in the country to issue a green bond	2021	USD 20 million
Indore Municipal Corporation	First city to enlist municipal green bonds on the National Stock Exchange's (NSE) debt securities platform	2023	USD 87 million
Government of India	First sovereign bond in two tranches of 5 and 10-year tenors	2023	USD 1 billion

Source: https://teriin.org/sites/default/files/files/Accelerating_the_Growth_of_Green_Bonds_Policy_Brief.pdf

64 https://www.borderless.net/news/energy-and-chemical-value-chain/basf-places-chemical-industrys-first-green-bond/

65 https://www.coatingsworld.com/contents/view_breaking-news/2021-04-22/arkema-starting-up-new-bio-based-polyamide-11-plant-in-singapore/

Figure 34: Green bond issuances in India by type of issuer



Source: https://cwas.org.in/resources/file_manager/Review%20of%20Green%20Bonds.pdf

SLLs: According to Bloomberg, the chemical industry has issued nearly USD 14 billion in loans between 2018 and 2020, with a primary focus on achieving carbon reduction targets.[66]

- Belgian chemical company Solvay's EUR 2 billion SLL was among the first to tie the loan to a major GHG reduction goal – i.e. cutting 1 MT of CO_2 emissions by 2025.[67]
- In 2019, a world leader in gases amended its EUR 2 billion syndicated credit line. This amendment linked the company's financial costs to three specific sustainability targets – reducing carbon intensity, promoting gender diversity and enhancing safety measures.

Within the chemical industry, SLLs make up the largest share in sustainable debt.[68] These loans are more flexible because they can be used for general corporate purposes, whereas green bonds are tied to specific investments aimed at environmental benefits.

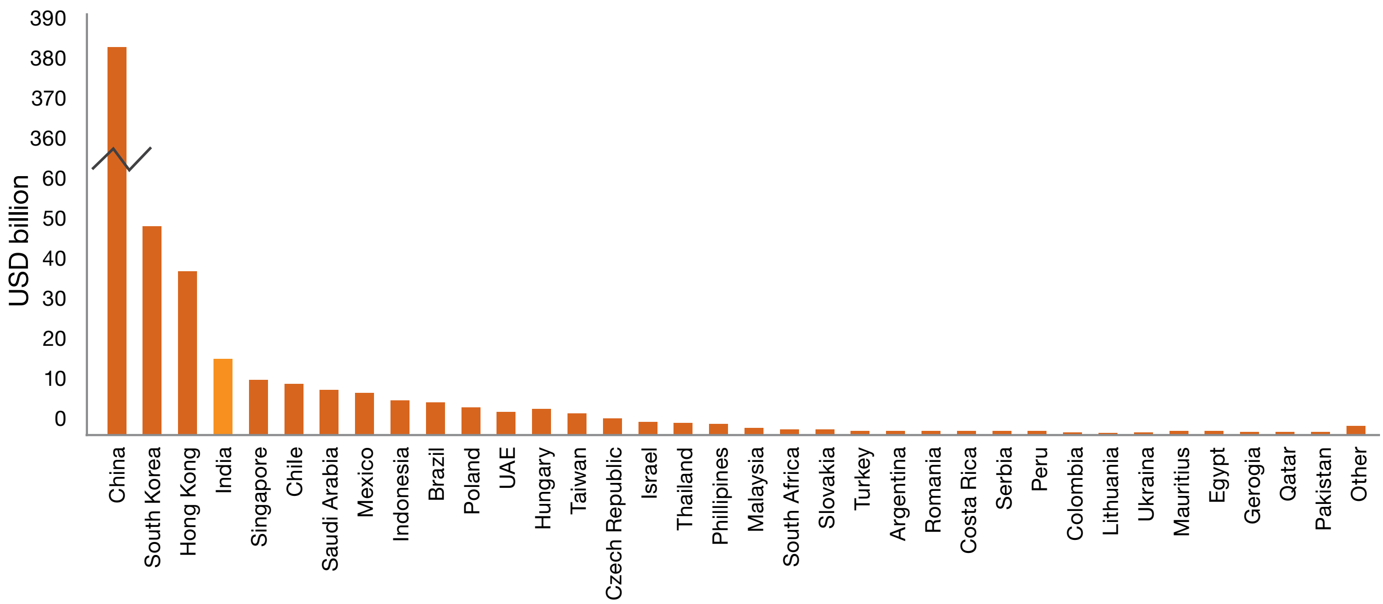
66 https://www.bloomberg.com/professional/insights/sustainable-finance/many-global-chemicals-companies-trail-on-carbon-transition-goals/
67 https://www.investing.com/news/stock-market-news/solvay-raises-fy-cash-flow-outlook-after-q3-beat-2658523
68 https://www.bloomberg.com/professional/insights/sustainable-finance/many-global-chemicals-companies-trail-on-carbon-transition-goals/

Green finance momentum in India

In India, there has been an uptake in these products in the past few years. Especially as sustainability corporate sustainability efforts have matured in the country, the importance of green finance in the country's transition to a net-zero economy is increasingly recognised. Over the past decade, Indian commercial banks have been supporting green finance programmes across various sectors, including sustainable agriculture, energy efficiency and renewable energy.

To further promote the same, the RBI introduced the Framework for Acceptance of Green Deposits on 11 April 2023, effective from 1 June 2023. This framework encourages banks and non-banking financial companies (NBFCs) to offer green deposits, thereby enabling the financing of environmentally sustainable projects.

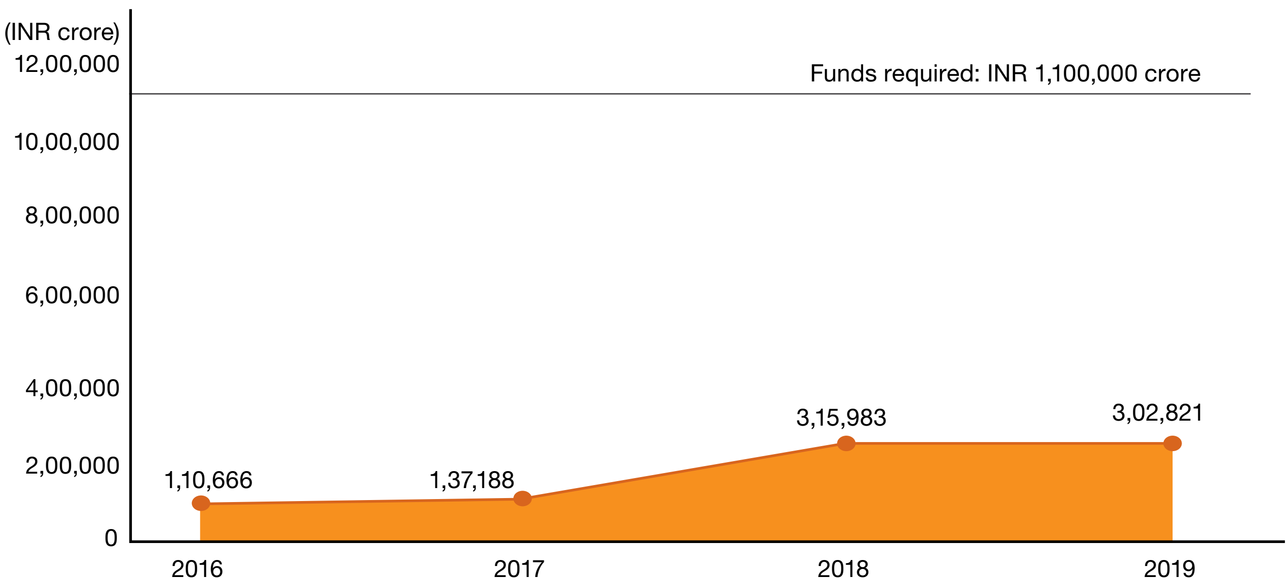
Figure 35: India's total green bond issuance in comparison to the global market



Source: https://www.energypolicy.columbia.edu/india-integrates-green-bonds-into-its-decarbonization-strategy/

According to RBI's Report of the Survey on Climate Risk and Sustainable Finance, 85% of the 34 scheduled commercial banks in India agreed to modify their lending and investing approaches to support green finance. Additionally, 56% of them plan to reduce their exposure to high carbon-emitting companies in the coming years. Banks possess the ability to catalyse a transition towards a more environmentally sustainable future by adopting sustainable finance products, strengthening risk management techniques and engaging stakeholders.[69]

Figure 36: Tracked green finance investments and the estimated funds required to meet current Nationally Determined Contributions (NDCs)



Source: https://www.climatepolicyinitiative.org/wp-content/uploads/2022/08/Landscape-of-Green-Finance-in-India-2022-Full-Report.pdf

69 https://www.rbi.org.in/Scripts/PublicationReportDetails.aspx?UrlPage=&ID=1215

Despite this progress, green finance flows in India are falling significantly short of the country's current needs. Currently, financing flows towards climate change mitigation comprise only about a quarter of what is required. A major hurdle is investor scepticism regarding the effective use of funds raised through green bonds, which is heavily influenced by the credibility of the bond issuer. Although regulatory frameworks are in place to support the green bond market, its success largely depends on how investors perceive the risks associated with these financial instruments.

Creating a strong policy environment is crucial for scaling green finance in India. To maximise impact, several key policy considerations need to be emphasised:

- **green taxonomy –** establishing a clear and standardised classification system for green investments
- **integrated measurement, reporting and verification (MRV) system –** implementing a uniform framework and methodology to track finances, identify constraints, pinpoint areas needing additional finance and enhance transparency
- **coordinated policy interventions –** focusing on improving technology and mainstreaming supply chains to accelerate investment and adoption in priority sectors that are currently lagging.

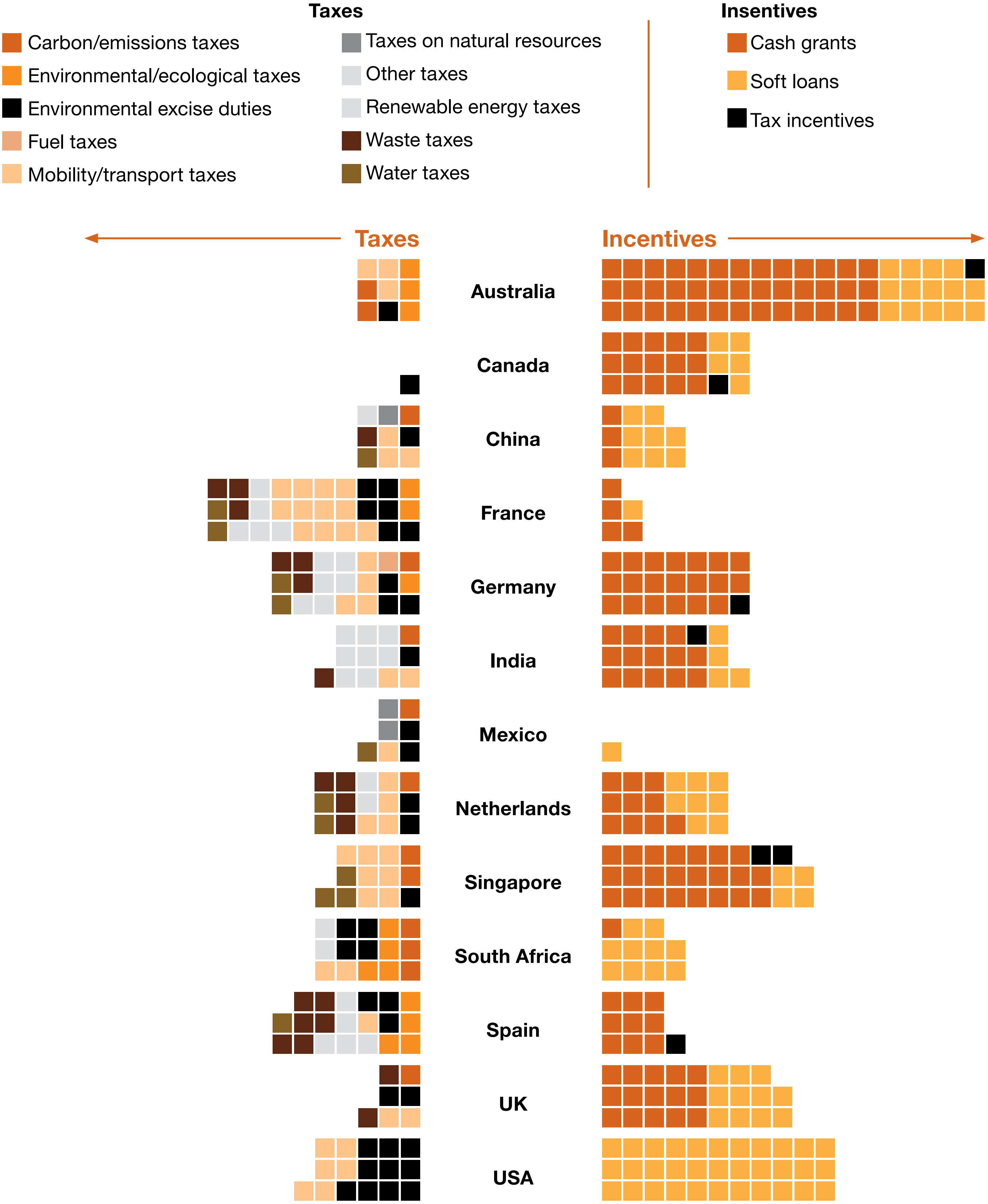
Unlike most of the world's largest markets, India has not yet formally announced the development of a green taxonomy. According to the Economic Survey of India for 2021-22, the Department of Economic Affairs under the Ministry of Finance established a Task Force on Sustainable Finance. This task force was mandated to propose a draft taxonomy for India, along with other sustainability-related objectives.[70] Recently, during the presentation of the Union Budget for 2024-25 on 23 July 2024, Finance Minister Nirmala Sitharaman announced that the government would develop a 'climate finance taxonomy'. This move aims to make more capital available for climate adaptation and mitigation, supporting India in meeting its climate commitments and facilitating a green transition. Although the formal announcement of a green taxonomy is still pending, the government's proactive measures show a strong commitment towards advancing sustainable finance. By addressing these critical policy areas, the government can create a more conducive environment for green finance, driving progress towards sustainability goals.

70 https://pib.gov.in/

4.1.4. Tax incentives and subsidies

The widespread adoption of environmental taxes and green incentives is crucial in helping countries and corporations reach their carbon-reduction goals. For example, the European Union Green Deal has introduced over 1,000 new or modified levies.[71] In addition to taxes, the increasing number of green incentives at the global, national and regional levels is influencing how companies allocate resources, develop new products and plan their strategies.

Figure 37: The green tax and incentive landscape in selected countries



Source: https://www.strategy-business.com/article/Green-taxes-and-incentives-can-help-businesses-achieve-ESG-goals

71 https://www.strategy-business.com/article/Green-taxes-and-incentives-can-help-businesses-achieve-ESG-goals

India has been implementing various environmental taxes for years now, mainly targeting goods that cause pollution, such as fossil fuels.[72] Examples include excise duties, green taxes, a forest development tax and a GST compensation cess. These taxes aim to reduce environmental impact in a cost-effective manner and encourage behavioural changes among companies. Currently, the focus is on offering incentives, grants, rebates and reliefs for green and clean technology and infrastructure. These measures will help accelerate the country's progress towards achieving net-zero carbon emissions by 2070.

The EU CBAM and its influence on Indian exports to the Union

The European Union's Carbon Border Adjustment Mechanism (CBAM), implemented in October 2023, represents an ambitious and first-of-its-kind approach to combating carbon emissions through targeted import tariffs. Although the initial mechanism focused on high-emission and hard-to-abate sectors – such as iron, steel, cement, fertiliser, hydrocarbons, electricity and aluminium – the European Parliament has signalled intentions to expand CBAM's scope to include plastics and chemicals by January 2026. Further extensions are anticipated by 2030 to cover all products that fall under the EU Emissions Trading System or are at risk of carbon leakage.[73]

For Indian chemical producers, this development carries significant implications. If polymers and organic chemicals are included within the CBAM's scope, export of products like ethylene dichloride and vinyl chloride monomer will be directly affected. CBAM's reporting requirements, which commenced on 1 October 2023, mandate quarterly disclosures of GHG emissions embedded in imported products, due within 30 days of each quarter's end. Although EU importers are formally responsible for reporting, the onus of data preparation falls heavily on exporters and producers, therefore requiring substantial compliance efforts. Moreover, CBAM is likely to reshape global supply chains, potentially shifting production towards regions with lower carbon footprints. This means that Indian chemical manufacturers face a critical imperative to accelerate decarbonisation efforts or risk eroding their competitive position in the European market due to increased import costs.

4.1.5. Case study for sustainable financing

DCM Shriram secures INR 200 crore SLL for major projects in Gujarat

In September 2023, DCM Shriram Ltd. secured an INR 200 crore SLL to support its capital expenditure programme in Bharuch, Gujarat.[74] The company, which has a major presence in sugar, fertiliser and chemical businesses, is undertaking projects worth approximately INR 3,500 crore, mainly in its chemical and sugar divisions.[75] While the sugar projects have been completed, the chemical projects are nearing completion. Although the specific sustainability-linked terms of the loan have not been disclosed publicly, DCM Shriram ranks among the top global chemical companies according to the S&P Global Corporate Sustainability Assessment 2023 and holds a 'B' rating in the CDP Climate Change Assessment for the same year.

4.1.6. Role of digitisation and AI in sustainable finance

The integration of AI into sustainable finance is set to revolutionise the sector by enhancing data analysis, mitigating risks, and identifying investment opportunities that generate both financial returns and positive environmental and social impacts.

The chemical industry will ultimately require a diverse set of measures, strategies and financing instruments to decarbonise and achieve a low-carbon future. Though the uptake has been gradual, particularly in India, green bonds and SLLs offer chemical companies a transformative opportunity to embed their environmental commitments into their financial strategies. By leveraging them, companies can accelerate their journey towards achieving ambitious sustainability goals. They also provide companies with a lower-cost alternative to deploying internal capital. Additionally, it enhances a company's reputation as a responsible and forward-thinking entity. This can attract investors, customers and partners who prioritise sustainability. In addition to this, effectively navigating fiscal measures is also going to be essential for businesses and policymakers aiming to support sustainability initiatives and achieve climate targets.

For Indian chemical manufacturers, accelerating decarbonisation will be crucial to maintaining competitive positions, particularly in mature sustainability markets like Europe. To move forward, companies must determine which green investments are the most effective and where to make them. Should they focus on developing eco-friendly chemical processes? Should they invest in renewable energy sources for their plants? Or should they upgrade their facilities to be more energy efficient? To answer these questions, companies need to perform detailed calculations that consider both the cost of carbon and the incentives for investing in new technologies or regions. Without this information, a company's leaders cannot make informed decisions about measures that could involve significant financial commitments.

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72 https://www.pwc.com/gx/en/services/tax/green-tax-and-incentives-tracker.html

73 https://www.pwc.com/m1/en/services/tax/me-tax-legal-news/2023/eu-carbon-border-adjustment-mechanism.html

74 https://www.financialexpress.com/business/industry-dcm-shriram-secures-rs-200-crore-sustainability-linked-loan-from-hsbc-bank-3257285/

75 https://www.financialexpress.com/business/industry-dcm-shriram-secures-rs-200-crore-sustainability-linked-loan-from-hsbc-bank-3257285/

4.2. Green/eco certification

In the last few years, there has been an increasing focus on mitigating the adverse impact of business activities on the environment. This has given rise to the need to assess business practices and products as per the relevant industry standards. Therefore, companies need to respond effectively and efficiently to environmental sustainability challenges through appropriate strategies and operations, such as green processes and product development.

> 'A green product is a product that is designed to have a positive impact on the environment and can be defined by several characteristics like energy efficiency, recycled, sustainably produced, non-toxic, biodegradable packed and having fewer negative environmental effects in general.' -UNEP

A green product has several key features that emphasise its sustainability and environmental stability, like **renewability, recyclability and being responsibly sourced, which help minimise its impact on the environment. In order to call a product authentically green is to have credible validations of a product's environmental claim called 'Green Certifications'**. These help customers to make informed choices by distinguishing genuinely sustainable products from those merely marketed as 'green'. Green product certifications are formal assessments that validate a product's environmental performance and sustainability practices. Generally, third-party organisations grant these certifications and indicate that a product meets specific environmental criteria or standards. Such certifications are a reliable way for consumers to identify eco-friendly products, helping them make informed purchasing decisions.

Given chemical products' intricate safety and environmental ramifications, green product certifications are especially important for the chemical industry. These certifications evaluate the effects of a product's lifecycle, considering elements including toxicity, waste management, emissions and resource efficiency. A chemical product must adhere to strict guidelines covering the whole supply chain – from the procurement of raw materials and production procedures to the safe handling, use, and disposal of the product – to be considered a green product. Certain third-party organisations and regulatory agencies, such as Cradle to Cradle, Green Seal and the EPA's Safer Choice Program, offer certifications to confirm that a chemical product is environmentally friendly and responsibly developed. These certificates promote the adoption of sustainable practices and increase consumer trust.

Evolution of green certifications

These certifications, which demonstrate a global commitment to environmental stewardship, have emerged as a crucial instrument in promoting sustainable production and consumption. In response to customer demand for ecologically friendly products, early eco-labelling projects were sparked by growing environmental awareness in the 1960s and 1970s. By the late 1980s, criteria for certifying products based on their environmental impact had been formalised with the establishment of groups like Green Seal. This movement was furthered by the 1992 Rio de Janeiro United Nations Conference on Environment and Development, which resulted in the approval of Agenda 21 and the Johannesburg Plan of Implementation (JPOI) in 2002. To promote sustainable choices, the JPOI underlined the necessity of efficient, transparent and reliable consumer information tools. This resulted in the proliferation of eco-labels and certifications across various industries, allowing consumers to make informed decisions while holding companies accountable for their environmental practices.

Importance of green certifications

Today, as sustainability continues to gain importance, these certifications play a vital role in fostering transparency, encouraging best practices and driving innovation towards a more sustainable future.

The certification of green products is essential for raising environmental consciousness and encouraging sustainable practices.[76]

The certification of green products is essential for raising environmental consciousness and encouraging sustainable practices.

- **Informing customers** about the effects on the environment, promoting eco-friendly and well-informed decision-making
- **Providing producers with incentives** to implement sustainable practices, like cutting back on waste, improving energy efficiency and using less resources
- **Encouraging manufacturers to raise environmental standards** and develop sustainable products by increasing consumer demand for eco-friendly goods
- **Increasing customer trust** by giving clear information about how products affect the environment
- **Creating best practices and sustainability benchmarks**, influencing both producers' and consumers' expectations
- **Helping to lessen the impact on the environment** by conserving natural resources and reducing carbon footprints
- **Playing a significant role in environmental conservation**, aiding the achievement of SDGs

4.2.1. International and regional standards

In recent years, the chemical sector has increasingly embraced sustainability, driven by growing environmental concerns and regulatory pressures. International and regional standards for green product certifications have emerged as crucial frameworks that guide companies in assessing and communicating the environmental impact of their products. These standards foster transparency and accountability, and also enhance consumer trust in a market that is increasingly favouring eco-friendly alternatives.

International green product certifications

These certifications are important for reasons other than compliance – in a crowded market, they act as competitive differentiators. Following accepted standards can help create new markets and ease international trade as governments and organisations around the world place a higher priority on sustainability. Furthermore, the development of these certificates is being influenced by the movement towards circular economy practices, which promote advances in end-of-life management, production methods and product design. As the chemical industry moves forward, manufacturers must keep up with the regional and global standards to satisfy regulatory obligations and stakeholder expectations.

This introduction sets the stage for a deeper exploration of the specific standards, their implications for the chemical sector and the emerging trends shaping the future of green product certifications.[77]

Type of certification	Regulatory compliance requirements	Description
Organic certification	USDA Organic (USA), EU Organic (Europe)	Certifies agricultural products grown without synthetic pesticides, fertilisers or genetically modified organisms (GMOs)
Energy efficiency certification	Energy Star (USA), EU Energy Label (Europe)	Indicates products that meet specific energy efficiency standards, promoting conservation and cost savings
Eco label certification	EU Ecolabel (Europe), Green Seal (USA)	Recognises products that meet strict environmental criteria across production processes and packaging
Sustainable forestry certification	Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI)	Certifies wood and paper products sourced from sustainably managed forests

76 PwC analysis, United Nations Environment Programme: Resource Efficiency Responsible industry Ecolabelling: https://www.unep.org/explore-topics/resource-efficiency/what-we-do/responsible-industry/eco-labelling

77 Green Business: Sources of Information Standards & Certifications: https://guides.loc.gov/green-business/businesses-going-green/standards-certifications , PwC analysis

Type of certification	Regulatory compliance requirements	Description
Cradle-to-cradle certification	Cradle to Cradle Certified™ (International)	Evaluates products based on lifecycle, focusing on material health, circularity and renewable energy use
Fair trade certification	Fair Trade Certified (USA), Fair Trade International	Ensures products are made under fair labour conditions, providing equitable compensation for producers
Carbon footprint certification	Carbon Trust Standard (UK), Publicly Available Specification 2050 (UK)	Measures and certifies carbon emissions throughout a product's lifecycle, encouraging emission reductions
Water stewardship certification	Alliance for Water Stewardship (AWS) Certification (International)	Assesses responsible water use and management practices, promoting sustainable water resource management
Waste management certification	Zero Waste Certification (International)	Recognises organisations that have implemented effective waste reduction and recycling practices

Aligning environmental certification with labelling

Environmental certifications and environmental labelling are interconnected tools that promote sustainable practices and inform consumers about the eco-friendliness of products and services. Certifications, such as ISO 14001, provide formal recognition of an organisation's commitment to environmental management and sustainability, often requiring rigorous assessments and compliance with specific standards. In contrast, environmental labelling serves as a more immediate means of communication, allowing consumers to quickly identify products that meet certain environmental criteria, such as energy efficiency or sustainable sourcing. Together, these mechanisms not only enhance transparency and accountability in production but also empower consumers to make informed choices, ultimately driving demand for greener products and practices across industries.

Today, several types of environmental labelling exist – including those which are differentiated into groups and classified by the International Organization for Standardization.[78]

Figure 38: Types of environmental labelling standards as per ISO Standards

1 ISO type I I

Overall environmental preference

Type: Voluntary, multiple criteria based and third party

Description: These are labels that are often referred to as eco-llabels and identify overall environmental preference of a product (i.e. a good or service) within a product category based upon life cycle considerations.

2 ISO type II

Specific environmental impact

Type: Informative environmental self declaration referred to as certification schemes or sustainability labelling

Description: These labels share the same characteristics as type I but often are focused on specific impacts (i.e. energy consumption, agricultural practice) and applied only to a specific sector.

3 ISO type III

Product declaration

Type: Informational table

Description: It provides more detailed quantitative information of the products. It takes the form of a matrix and is similar to declarations of the nutritional characteristics of products.

Source: https://www.fao.org/4/y2789e/y2789e06.htm

There are also other types of environmental labelling, depending on who issues these labels to the products:

- **First-party labelling:** This is established by individual companies based on their own product standards, often influenced by environmental issues highlighted in media or advertising; also known as 'self-declaration'.
- **Second-party labelling:** This is created by industry associations for their members' products, using internal certification procedures; it also draws on external expertise at times for compliance verification.
- **Third-party labelling:** Initiated by an independent entity, this labelling certifies products as environmentally friendly, requiring producers to track the 'chain of custody' to ensure authenticity.

78 Ecolabeling: https://www.fao.org/4/y2789e/y2789e06.htm

Regional standards and certifications

In India, there are several regionally relevant green certifications that focus on environmental sustainability and safety of chemical products, addressing the unique regulatory landscape and sustainability goals of the Indian market. Key certifications include:

- **Ecomark:** Established by the Bureau of Indian Standards (BIS), Ecomark is India's official eco-label for environmentally friendly products, including chemicals. To earn Ecomark, products must meet the criteria for reduced pollution, biodegradability, non-toxicity and energy efficiency in production. This certification helps Indian consumers recognise safer, more sustainable products and encourages manufacturers to reduce the environmental impact of their chemicals.

- **GreenPro:** Administered by the Indian Green Building Council (IGBC), GreenPro certification focuses on products that promote sustainable construction, including chemical products used in building materials and coatings. This certification evaluates a product's life cycle impact and encourages the use of non-toxic, eco-friendly materials that support green building initiatives. GreenPro is increasingly important in India's building and construction sectors, where there is a growing demand for sustainable materials.

- **Indian standards for organic certification (NPOP):** While traditionally focused on agriculture, NPOP (National Programme for Organic Production) certification is relevant for chemicals used in organic farming, such as fertilisers and pesticides. This certification ensures that chemical products adhere to organic farming principles, including reduced toxicity, minimal ecological impact, and environmental sustainability.

- **ISO 14001 Certification:** Although ISO 14001 is an international standard, it is highly valued and widely used within Indian industries. This certification evaluates environmental management systems within companies and is particularly valued for demonstrating a commitment to sustainable manufacturing practices. ISO 14001-compliant chemical manufacturers in India can signal their commitment to minimising their ecological footprint.

- **Global Organic Textile Standard (GOTS):** GOTS certification is crucial for chemicals used in the textile industry, especially dyes, processing chemicals and auxiliaries that must meet strict environmental and social criteria. Given India's large textile sector, GOTS certification is widely sought after, ensuring that chemicals used in textile production meet global standards for organic integrity and environmental safety.

- **Green Seal India and Leadership in Energy and Environmental Design (LEED) India ratings:** While Green Seal certification was originally developed in the US, its principles are adapted in the Indian market through partnerships and localised standards, especially in the context of LEED India ratings. Chemicals used in building projects that seek LEED certification often must adhere to these standards for environmental safety, non-toxicity and low emissions.

- **International and export-oriented green certifications:** Indian chemical companies that aim to enter global markets frequently pursue internationally recognised green certifications. For instance, **Cradle to Cradle Certified**™ assesses products based on criteria like material health, recyclability, renewable energy use and water stewardship, aligning with circular economy principles essential for chemicals used in packaging, construction and personal care. Similarly, the **Blauer Engel (Blue Angel)** ecolabel, originating from Germany, is valued for its strict environmental and health standards, helping Indian exporters of paints, adhesives and detergents gain credibility in European markets. Additionally, the **Safer Choice certification by the US EPA** is pursued by companies exporting to North America, as it validates products for safer ingredients and low environmental impact, ideal for cleaning agents and surfactants. Together, these certifications allow Indian chemical companies to enhance their international competitiveness by meeting high sustainability benchmarks.

India's green product certification scheme: Ecomark[79]

The BIS is the primary authority which issues the Ecomark certification as a mark for products that are environmentally friendly. This government scheme was implemented in 1991. It's entirely voluntary and helps in identifying environmentally friendly products on the market. Many products such as food, medications, chemicals, electrical goods, paper, lubricating oils, packing materials and other items are all covered within the scope of the certification. The MoEFCC is the nodal ministry which leads the Ecomark scheme. The logo of the certification is found on Indian manufactured products which are complying with the environmental sustainability criteria.

The Ecomark is particularly vital for the Indian chemical sector, as it fosters the creation and promotion of environmentally friendly products, aligning them with the growing consumer preference for sustainable choices and regulatory requirements. By incentivising manufacturers to embrace sustainable practices, the Ecomark helps reduce environmental impacts and enhances product transparency, thereby improving competitiveness in the market. For industries utilising chemicals in production, the BIS has established specific standards that products must meet to qualify for the Ecomark certification.

Figure 39: Some important Indian Standards for obtaining EcoMark Certification from MoEF on Chemical Products

Household chemicals

IS 14724:2000: Biodegradability, safety for human health, and minimal environmental impact in formulation and use

Personal care products

IS 4011:1996: Non-toxicity, absence of harmful chemicals, and environmentally friendly packaging

Agricultural chemicals

IS 14040:2005: Safe and sustainable formulations, minimal environmental impact, and compliance with organic standards for fertilisers and pesticides

Construction chemicals

IS 15489:2004: Low volatile organic compounds (VOCs) emissions, use of sustainable materials, and minimal environmental impact throughout the product lifecycle

Packaging materials

IS 14021:1998 Recyclability, use of biodegradable materials, and minimal toxicity in production and disposal

Source: Indian Standard (IS) for ECO Mark: BIS https://www.services.bis.gov.in/php/BIS_2.0/bisconnect/knowyourstandards/ecomark

79 BIS Indian Standard on EcoMark: https://cpcb.nic.in/eco-scheme/ Ecomark: https://cpcb.nic.in/eco-scheme/

Green certification in the chemical industry

For the chemical industry, green certifications play a pivotal role in promoting sustainability and regulatory compliances. Such certifications are helping chemical companies to showcase their commitment to reducing environmental impact, improving safety and enhancing resource efficiency. By adhering to these sustainability related standards, companies can build consumer trustworthiness, market differentiation and competitiveness, and help achieve SDGs. As an ever-evolving industry, these certifications have become essential for meeting regulatory requirements and addressing stakeholder expectations in an increasingly eco-conscious landscape. As per TUV Audit/Certification Company, these certifications can be broadly categorised into **six buckets for the chemical industry**; a chemical company can choose to have a combination of these certifications on its products and processes as given below:

Figure 40: Types of certifications for the chemical industry

Corporate social responsibility
Labor
Health and safety
Ethics

Environment
Environment management corporation
Energy management

Hazardous substances
Hazardous substances content

Products climate resilience
Carbon emission evaluation
PCF evaluation method
Availability

Recycled material content
Products
Accessory
Packaging

End of life
Increasing product longevity
Take-back service
Dentification of materials and components
Biodegradable

Source: TUV Rheinland certification services: Type of certifications for the chemical industry

The Indian chemical industry, a vital sector of the national economy, is undergoing a significant transformation towards sustainability and environmental responsibility. In response to mounting pressures both globally and domestically to embrace green practices, companies in this sector are increasingly incorporating eco-friendly processes and products into their operations. This shift is supported by the acquisition of various green certifications and ecolabels, which not only bolster market competitiveness but also ensure adherence to stringent environmental regulations.

4.2.2. Benefits for certification

In an era increasingly defined by environmental sustainability, obtaining green certification in the chemical industry offers a myriad of benefits that extend beyond mere compliance. This knowledge paper highlights key insights relevant to stakeholders, policymakers, and industry leaders attending the upcoming conference.

- **Enhancing environmental responsibility:**
  Green certification signifies a commitment to environmentally sustainable practices. By adhering to rigorous standards, companies can reduce their carbon footprint, minimise waste and promote the use of safer chemicals. This not only mitigates environmental impact but also fosters a culture of responsibility within organisations.
- **Creating market differentiation and competitive advantage:**
  In a crowded market, green certification serves as a powerful differentiator. Companies that achieve this certification can leverage it in marketing efforts, appealing to increasingly eco-conscious consumers. This not only enhances brand reputation but can also lead to increased market share as businesses position themselves as leaders in sustainability.
- **Ensuring regulatory compliance and risk management:**
  Obtaining green certification often aligns with existing regulations and anticipates future legislation. This proactive approach reduces the risk of non-compliance penalties and enhances operational resilience. By integrating sustainable practices, companies can better navigate the complexities of regulatory landscapes.
- **Increasing cost savings and efficiency improvements:** Many sustainable practices lead to cost savings through improved resource efficiency. By optimising processes and reducing waste, companies can lower operational costs. Moreover, green certification often encourages innovation in product development, resulting in more efficient and cost-effective solutions.

- **Access to opportunities:**
  As sustainability becomes a core value for investors and consumers alike, green certification can unlock new markets. Companies certified as environmentally friendly may find it easier to secure funding, partnerships and contracts, particularly in sectors where sustainability is a pre-requisite.

- **Employee satisfaction and attraction:**
  Sustainability initiatives can enhance employee morale and engagement. A commitment to green practices can attract top talent, particularly among younger generations who prioritise environmental responsibility. Companies recognised for their sustainability efforts often report higher employee satisfaction and retention rates.

- **Sustainability and resilience:**
  Ultimately, the pursuit of green certification is not just about immediate gains; it's about building long-term sustainability. By embedding sustainable practices into their core operations, companies position themselves to adapt to future challenges, ensuring longevity in a rapidly changing market.

4.2.3. Case studies of certified companies

Type of end-use industry	Company	Type of certification and ecolabel (category)	Impact
Bio-based chemicals (biofuels and biochemicals)	Godavari biorefineries (Biofuels, bio-based ethanol)	ISO 14001. Bonscuro certification for product standard and COC[80]	**For product and process:** Enhances sustainable sourcing and traceability of sugarcane products, enhances market differentiation, ensures compliance with sustainability standards and improves supply chain efficiency, ultimately positioning organisations as leaders in responsible production
Pharmaceuticals Intermediates and APIs	Aarti industries	ISO 14040:2006, Life cycle assessment zero waste to landfill certificate	**For process:** Enables a comprehensive evaluation of a product's life cycle impacts, leading to informed decision-making, enhanced sustainability, regulatory compliance, cost savings, and improved stakeholder trust
Coatings, adhesives, sealants and elastomers (case)	Pidilite industries (Adhesives, sealants)	Iso 14001:2015; cradle to cradle; green seal	**For product:** Differentiates its products in the market by demonstrating a commitment to sustainability, while also ensuring compliance with environmental regulations and reducing associated legal risks
Speciality chemicals plasticizers (plastics industry) and other chemicals	Tata chemicals	Responsible care certifications; FSSC 22000; ISO 14001; Ecomark; Ecolabel	**For process:** drives operational excellence through improved safety, compliance and resource efficiency, collectively fostering a culture of continuous improvement and consumer trust in eco-friendly products **For product:** enhances product sustainability by promoting environmentally friendly practices in design and manufacturing
Solvents (Chemical manufacturing)	Deepak nitrite (Ssolvents for industrial use, paint thinners)	Green chemistry certification: Ecologo	**For product and process:** promotes safer alternatives, reduces environmental footprint and enhances product appeal
Textile and synthetic fibres chemicals	Aditya birla group	Responsible care Green Pro certification; GOTS; Registration, Evaluation, Authorization and Restriction Of Chemicals (REACH); Global Recycled Standard (GRS)	**For products:** ensures sustainable practices and product quality, ensuring that our textiles are responsibly sourced, free from harmful substances, and aligned with global environmental standards, ultimately enhancing customer satisfaction and promoting eco-friendly initiatives

80 https://bonsucro.com/godavari-dreams-of-agricultural-based-resources-as-it-achieves-bonsucro-certification/

The adoption of green certifications in the Indian chemical industry is driving significant trends that collectively enhance market differentiation, regulatory compliance and sustainable practices. Companies are leveraging certifications to appeal to eco-conscious consumers, ensure adherence to environmental regulations and improve supply chain transparency through sustainable sourcing. Lifecycle assessment and zero waste initiatives enabled by certifications promote sustainable manufacturing, while best practices in resource efficiency and operational excellence lead to cost savings. These certifications also bolster consumer trust and brand loyalty by demonstrating a commitment to sustainability.

Moreover, these certifications promote innovation in green chemistry, incorporate circular economy principles and facilitate access to international markets by aligning with global standards. Ultimately, such certifications advocate for transparent practices and stakeholder engagement, fostering a culture of openness and accountability within the industry. Although the adoption of green certifications is steering positive changes in the Indian chemical industry, significant gaps persist compared to international competitors. Despite the progress made, Indian chemical firms often face challenges related to the high costs and complexities involved in obtaining and maintaining these certifications.

Furthermore, there exists a disparity in technological advancement and innovation levels between Indian companies and their global peers, which can impede the effective implementation of sustainable practices. The limited access to state-of-the-art research and development, coupled with inadequate collaboration with international stakeholders, intensifies these challenges. Additionally, the regulatory frameworks in India may lack the rigour and enforcement typically seen in more developed markets, resulting in inconsistencies in compliance and environmental performance. Addressing these gaps is essential for Indian chemical companies to fully harness the advantages of green certifications and enhance their competitiveness on a global stage.

Comparative analysis of Indian and international certifications

Aspect	Indian chemical industry	International companies
Awareness of certifications	Companies generally have low awareness, especially SMEs.	Companies have high awareness across all company sizes; widespread adoption of certifications.
Types of certifications	There is a marked focus on ISO 14001, USDA Bio Preferred and specific eco-labels.	There are diverse certifications including ISO 14001, LEED, Cradle to Cradle, and Product Environmental Footprint (PEF).
Implementation challenges	Implementation of standards generally have high costs, resource constraints and fragmented regulations.	International companies follow structured processes for certification, often backed by dedicated sustainability teams.
Product range	Limited range of certified sustainable products	Comprehensive product lines with numerous certified eco-friendly options
Consumer engagement	Growing focus on eco-labels but still in its nascent stage	Strong engagement with consumers regarding sustainability practices and transparency
Innovation in sustainability	Some innovation but often reactive rather than proactive	Leading-edge innovations in green chemistry, circular economy practices and alternative materials
Transparency and reporting	Limited reporting frameworks; inconsistent sustainability disclosures	Regular sustainability reports following GRI, SASB, and other global standards, promoting transparency
Government support	Limited incentives for certification and sustainable practices	Strong government policies and incentives that encourage sustainability (e.g. tax benefits, grants)

Future of green certifications for chemical companies

The trajectory of the chemical industry is increasingly linked to sustainability, with green certifications playing a pivotal role in fostering compliance with environmental regulations and encouraging eco-friendly practices. These certifications allow companies to demonstrate their dedication to minimise environmental impacts, enhance resource efficiency and ensure safety. This, in turn, helps to build consumer trust and set companies apart in a competitive marketplace. As the Indian chemical sector adopts these certifications, it responds to both international pressures and local demands for sustainable practices. This shift not only boosts market competitiveness but also ensures adherence to rigorous regulatory standards. Moreover, this presents an opportunity to new markets and investment opportunities while promoting innovation in green chemistry.

However, challenges such as the high costs associated with certification and gaps in technological advancement when compared to global counterparts continue to persist. Addressing these challenges will be essential for Indian companies to fully capitalise on the advantages of green certifications and succeed in an environmentally conscious market.

5. Conclusion and future outlook

The sustainable transformation of India's chemical manufacturing industry requires a holistic approach that includes feedstock diversification, decarbonisation and circular economy principles. By integrating fossil-based, bio-based, recycled/reused, and CO_2-X based materials, the industry can enhance supply chain resilience and economic stability. This balanced strategy is crucial not only for environmental sustainability but also for economic viability, ensuring a robust future for the industry.

A key aspect of this transformation is decarbonisation, which involves electrifying high-temperature processes, utilising green hydrogen, and adopting bio-based or low-carbon feedstocks. In addition to this, carbon capture, utilisation and storage (CCUS) play a crucial role in managing CO_2 emissions. Therefore, transitioning to renewable energy sources and enhancing energy efficiency through advanced technologies will substantially reduce the industry's carbon footprint, stabilise power grids and lower operational costs.

A sustainable supply chain forms the backbone of this transformation, driven by the need to address climate change, uphold human rights and embrace circularity. Responsible sourcing, supplier evaluations and adherence to ethical standards are becoming the industry norm. Initiatives such as TfS and Responsible Care underscore the importance of environmental stewardship and social responsibility. As consumer demand for eco-friendly products rises, the urgency for decarbonisation and resource efficiency intensifies. Collaboration and innovation are vital for the Indian chemical industry to meet global sustainability goals and remain competitive.

Transitioning towards circularity in the chemical sector is crucial for promoting resource efficiency, reducing waste and supporting sustainable economic growth. Embracing circular economy principles helps minimise the carbon footprint and conserve natural resources. India's regulatory framework enforces stringent regulations and provides incentives for sustainable practices, encouraging the industry's shift towards zero waste. Initiatives such as energy-efficient manufacturing, water recycling systems and waste-to-energy projects are gaining momentum – although stricter regulations and technological advancements are still needed for widespread implementation.

LCA emerges as an essential tool for chemical companies to develop sustainable products and meet evolving regulations. The SEBI's BRSR framework mandates LCA studies, pushing companies to evaluate their environmental impact. Industry-wide initiatives like the WBCSD and TfS promote LCA practices. Despite challenges such as

the higher cost of sustainable products and lack of financial incentives, LCA can optimise formulations and reduce product toxicity, leading to long-term environmental and health benefits.
Sustainable finance plays a pivotal role in driving the transformation of the chemical manufacturing industry. Financial institutions and investors are increasingly demanding detailed sustainability reports, transparency in governance and strong social responsibility commitments. Companies that achieve high ESG performance can access capital more easily, secure favourable financing terms and enhance their reputations.
Green bonds and SLLs offer companies a way to integrate environmental commitments into their financial strategies, thereby advancing their sustainability goals. To attract private capital for green investments, it is crucial to overcome investor scepticism and establish a robust policy environment. This includes developing a clear green taxonomy and an integrated MRV system. These steps are essential to build investor confidence and drive the flow of funds into sustainable projects.

Green certifications play a crucial role in the journey towards sustainability, helping to differentiate products in the market, ensure regulatory compliance and promote sustainable practices. These certifications appeal to eco-conscious consumers, ensure adherence to environmental regulations, and enhance supply chain transparency. They encourage LCAs, zero waste initiatives, resource efficiency and operational excellence, which can lead to cost savings and increased consumer trust.
However, Indian chemical firms continue to face challenges such as high costs, complexity and technological disparities compared to their international counterparts. Addressing these gaps is essential to fully leverage the benefits of green certifications and compete on a global scale. Overall, green certifications promote transparent practices and stakeholder engagement, fostering a culture of openness and accountability in the industry.
In conclusion, the future of sustainable chemical manufacturing in India depends on a comprehensive approach that integrates diverse feedstocks, advanced decarbonisation strategies and circular economy principles. By encouraging collaboration, fostering innovation, implementing stringent regulatory frameworks and leveraging green certifications, the industry can achieve its sustainability goals and maintain its competitive edge on the global stage.

About ICC

The Indian Chemical Council (ICC) is the apex national body representing all branches of the Chemical Industry in India such as Organic and Inorganic Chemicals, Plastics & Petrochemicals & Petroleum Refineries, Dyestuffs & Dye-intermediates, Fertilizers & Pesticides, Specialty Chemicals, Paints etc.

Indian Chemical Council (formerly Indian Chemical Manufacturers Association) was founded in the year 1938 by Acharya P. C. Ray & Rajmitra B. D. Amin, along with a group of Industrialists for promoting the interests of the nascent chemical industry.

What began as a vision, emerging from foresight and aspirations, became the Indian Chemical Manufacturers Association and was again rechristened the Indian Chemical Council (ICC). Over the years, the Indian Chemical Council went from strength to strength and has evolved into a movement embodying the goals, concern and achievements of the chemical industry in India.

The ICC is well represented by senior executives from a wide range of global and local chemical companies. The executive committee of the ICC includes veterans of the chemical industry with vast experience and keen insight into the workings of the chemical industry in India. Their guidance and vision steers ICC to further growth and service.

In keeping with the dramatically paced growth of the industry in the latter half of this century, the ICC has striven to give an impetus to the objectives of the industry. Realizing the power of information, ICC has consciously worked as a bridge for the many that forms the Indian Chemical Industry.

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