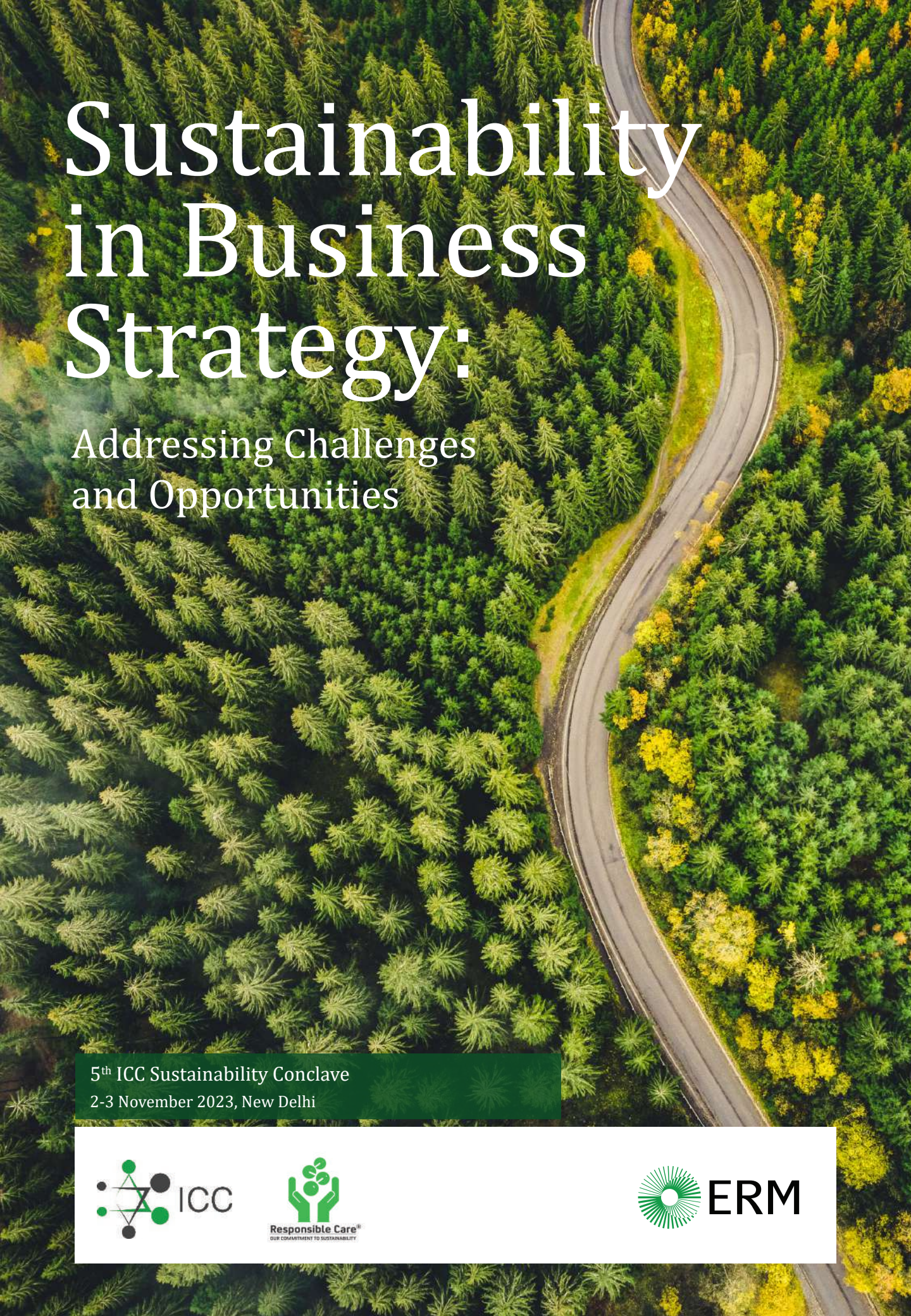

Sustainability in Business Strategy:

Addressing Challenges and Opportunities

5th ICC Sustainability Conclave

2-3 November 2023, New Delhi

ICC

Responsible Care®
OUR COMMITMENT TO SUSTAINABILITY

ERM

Words of Encouragement from the Hon'ble Minister

भगवंत खुबा
ಭಗವಂತ ಖೂಬಾ
BHAGWANTH KHUBA

सत्यमेव जयते

Azadi Ka Amrit Mahotsav

रसायन और उर्वरक एवं
नवीन एवं नवीकरणीय ऊर्जा राज्य मंत्री
भारत सरकार
Minister of State for
Chemicals & Fertilizers and
New & Renewable Energy
Government of India
01.11.2023.

MESSAGE

Indian Chemical industry is growing at a very rapid pace and playing a significant role in meeting the basic needs and enhancing quality of life of people and also contributing towards increase in exports from our country. Government of India has initiated several measures for development of this sector.

Government of India is also committed to achieve the ambitious goal of Net-Zero emissions by 2070. To achieve this goal, Chemical industry needs to transform itself from carbon intensive to carbon neutral industry.

It is heartening to note that Indian Chemical Council is organizing two days conclave dedicated to achieve sustainability in chemical sector. This conclave throws light on the important aspects of sustainability such as Environmental, Social and Governance (ESG), Carbon Neutrality, Safety, Green Chemistry, etc. There is a need for an all out efforts by all the stakeholders to achieve the noble goal of carbon neutrality and sustainable development.

I anticipate that this conclave will provide vital insight on achieving sustainability and will further help the efforts towards achieving the goal of carbon neutrality. I wish the conclave a great success.

Jai Hind!

(Bhagwanth Khuba)

Words of Encouragement from the Hon'ble Secretary

निवेदिता शुक्ला वर्मा
NIVEDITA SHUKLA VERMA

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

1st November 2023

Message

I am glad that the Indian Chemical Council is organizing its 5th Edition of ICC Sustainability Conclave on the theme 'Integrating Sustainability and Business Strategy for the Chemical Industry-Addressing Challenges and Opportunities'.

Indian Chemical industry plays a pivotal role in the economic development of the country and provides necessary input material for a wide range of allied sectors such as agro-chemicals, pharmaceuticals, dyes and paints, flavor and fragrances, construction chemicals, textiles, detergents and soaps, etc.

Among the 17 Sustainable Development Goals, Goal 9, "Industry, Innovation, and Infrastructure", and Goal 12, "Responsible Consumption and Production", directly require action by chemical industry for implementing environmentally sound management of chemicals and all waste throughout their life cycle and to significantly reduce their release to air, water and soil in order to minimize adverse impact of chemicals on human health and the environment.

This knowledge paper on 'Sustainability in Business Strategy – Addressing challenges and opportunities' throws light on various important aspects such as transition to low carbon economy, decarbonisation, safety management and sustainability in value chain etc.

I congratulate ICC in its endeavour to motivate the industry to actively strive towards a more sustainable future and I wish that this event will bring out necessary insights for the Department to work upon in this area.

(Nivedita Shukla Verma)

Acknowledgements

ERM would like to thank the India Chemical Council (for collaborating with us and inviting us as a knowledge partner for the 5th edition of ICC Sustainability Conclave, November 2023.

We are thankful to:

Mr. Kumaresh C Mishra,
IAS (Retd.) Director, ICC

Ms. Pallavi Thakur
Secretary - Northern Region Office, ICC

Mr. Dhrumil Soni
Officer - Sustainability, Environment & Regulatory, ICC

for their constant support and guidance.

We would also like to thank our team members from ERM:

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for their expertise and support on the knowledge paper.

Message from ICC Leadership

Mr. Rajen K. Mariwala

President, ICC & Managing Director,
Eternis Fine Chemicals Ltd.

The principle of sustainability has assumed a paramount position across various industries in modern times, but it found its roots in the chemical sector long before its widespread adoption. Owing to the fundamental characteristics of chemicals, their utilization has perennially been subject to stringent regulations. Furthermore, sustainability stands as a pivotal cornerstone in the realms of both their advancement and application.

As the 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 post COVID-19. This sustainability conclave exemplifies ICC's commitment to promote the cause of sustainability even while focusing on the growth potential for the industry.

I am happy that the foundation laid by ICC in Nov '19 with the first edition of the conclave is being successfully followed this year despite the unforeseen challenges that we are facing today. Growth shall not be on any ethical compromise and it shall and should on sustainable path by considering society as the focal point. The prosperity of business becomes closely interlinked with sustainability due to increased focus and awareness on the environment and people front. Sustainability for the Industries has become the pillar for growth and has been the key focus area for ICC with promotion of Responsible Care (RC) in the country. RC not only fosters safe production of chemicals but also nurtures environmental sustainability, security of chemicals and taking care of well-being of their employees and their surrounding communities.

I am confident that ICC will endeavor to follow up and support the implementation of outcomes emanating from deliberations 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. The visionary initiative taken by the esteemed Indian Chemical Council Team in conceptualizing this Conclave merits profound admiration and wholehearted support.
Best wishes for the success of the event.

Message from ICC Leadership

Mr. Kartik Bharat Ram

Vice President & Joint Managing Director,
SRF Limited

Economies world over are recovering from the impact of COVID-19 pandemic with industrial activities picking up to the pre-pandemic growth level. Normalcy is returning in all spheres of life. In the backdrop of recently concluded COP-26 in Glasgow, attention is now getting shifted towards the anthropogenic mediated effects of climate change and halting the temperature rise well within 1.50°C. India has set the tone for the climate action with the historic announcement of the "Panchamrit" by Shri Narendra Modi, Hon'ble PM of India in the recently concluded COP26 Summit.

The Indian Chemical industry, which is the third largest producer in Asia, with an estimated size of $178bn in FY20 that is expected to reach $300bn by FY25, employing 4.5mn people, is one of the key contributors to India's growing sustainability story.

Given the various climate and environmental related challenges the mankind is facing today, the chemical industry is playing a huge role in bringing out solutions to many problems such as shifting to greener sourcing, alternative energy solutions, evolving new circular business models, minimizing waste, reducing carbon footprints, sequestering the already emitted CO_2, and so on. This not only poses many new challenges to chemical industry but also opens up new business opportunities in areas unknown to date. All these are achievable through the use of innovations, cutting edge technologies and appropriate strategies.

I am proud and happy that ICC is at the fore-front in discussing the key issues facing mankind and role of chemical industry in working towards finding solutions to these challenges.

There could not have been a more appropriate time and theme for this 3rd edition of Sustainability Conclave of Indian Chemical Council, taking place on 2-3rd December 2021.

I am happy to note that within a short period of time this initiative of ICC has assumed a greater significance with the participation from Ministry of Chemicals & Fertilizers, Ministry of Environment, Forest & Climate Change, UNEP, ICCA, Cefic and ACC.

I wish the conclave a great success!

Message from ICC Leadership

Mr. Bimal Goculdas

Former President, ICC & Joint Managing Director,
Dharamsi Morarji Chemical Co. Ltd.

It is with great pleasure and an esteemed privilege that we welcome you to the Indian Chemical Councils 5th Edition of the Sustainability Conclave 2023.

Indeed, the chemical industry is currently undergoing a remarkable phase of expansion. Among the standout companies leading the way in today's market, a consistent and noteworthy theme emerges: an unwavering commitment to sustainability and responsible business practices. While the industry's growth trajectory is undeniable, it is of utmost importance that we steadfastly uphold the principles of Responsible Care, even as we ardently pursue rapid expansion.

The Indian Chemical Council's dedication to fostering the Chemical Industry in India is nothing short of remarkable. With unwavering commitment, ICC champions and nurtures all facets of the industry, employing a diverse array of initiatives. These include meticulously organized events, comprehensive training programs, prestigious awards and accolades, invaluable policy counsel, and an array of other impactful activities. ICC's tireless efforts underscore its pivotal role in the flourishing and advancement of the Chemical Industry across the nation.

Indian Chemical Council is glad to collaborate with Department of Chemical and Petrochemical ,GoI and ERM to Organized this event, which boasts a distinguished lineup of speakers hailing from government and industry, representing India and the world.

I hope that you will find this event not only valuable but also transformative. I extend my heartfelt gratitude for your participation and unwavering support for the noble cause of sustainable practices, a pivotal driver of the development and prosperity of the chemical industry in India.

Message from ICC Leadership

Mr. Ravi Kapoor

Conclave Chairman, and Managing Director,
Heubach Colour Pvt. Ltd

It is once again my pleasure and privilege to welcome you and introduce the fifth edition of ICC's Sustainability Conclave 2023 themed “Integrating Sustainability and Business Strategy for the Chemical Industry – Addressing Challenges and Opportunities” where we aim to navigate the challenges and explore the opportunities that lie ahead.

The G-20 Summit in 2023 marked a significant year, culminating in the New Delhi Declaration, which underscores the importance of a green pact to forge a sustainable path for the well-being and prosperity of present and future generations. This declaration carries a resolute commitment to achieve global net zero greenhouse gas emissions and carbon neutrality by approximately mid-century. The chemical industry of the world and India has a significant role in contributing to this task. Companies are seen to have a new and intense focus on ESG with stakeholders demanding that our industry 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 equally 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 2023 **"Integrating Sustainability and Business Strategy for the Chemical Industry"** is of paramount importance for necessity for long-term success and the well-being of our planet. It enables the industry to address its challenges and seize opportunities for growth, innovation, and positive societal impact while minimizing harm to the environment and communities.

Once again ICC is glad to collaborate with Department of Chemical & Petrochemical, GoI , UNEP and ERM, to bring about this event where we have a list of illustrious speakers both from Government and industry, India and abroad. We hope you find this a useful and value adding 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 which is a statement for life itself.

Message from ICC Leadership

Sothi Selvam D.

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 remarkable diversity, serving as a wellspring of essential raw materials for a multitude of crucial industries. With a workforce exceeding two million individuals, 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 catalyzing 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, reaching an impressive USD 300 billion by the year 2025.
The Indian Chemical Council (ICC) is committed to advancing the chemical industry's interests through a comprehensive approach. 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 organization 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 announce that the 5th edition of the ICC Sustainability Conclave 2023 is being organized by the Department of Chemicals and Petrochemicals, Government of India, in collaboration with ICC. I have no doubt that this momentous occasion promises to serve as a catalyst, propelling further investments and expediting the forward march of our nation's chemical and petrochemical industry.

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

Message from ERM Leadership

Mr. Jaydeep Sathaye

Lead Partner, ERM

We are delighted once again, to help plan and create ICC's 5th Sustainability Conclave.

Chemical companies are navigating multifaceted internal and external challenges:

1. **Low carbon economy transition**
2. **Sustainability as a competitive advantage**
3. **Product circularity**
4. **Human capital focus**
5. **Sustainable supply chains**
6. **Social license to operate**

Each of the above areas is multifaceted. Thus, collaboration between companies, regulators, policy advisors, R&D and scientific organizations, civil society and others are vital, so that sustainable solutions are implemented. **'Let the best not be the enemy of the good',** it is said. We must apply that principle here and now, since the urgency and scale of the climate crisis- and its related issues- demand solutions that are quick and implementable at scale.

We try several approaches and the ones that are not sustainable- environmentally, socially and financially- fall away. New ideas, experiments, research insights relevant to the chemical sector are published almost daily. And thus, the pace of change for the sustainability of the sector accelerates.

Our endeavor in this 5th edition of the conclave and knowledge paper is to ignite debate, discussion, sharing of best practices and varied perspectives, and ultimately, actions that each of us take back to our daily lives, wherever we work. The chemical sector is foundational to life as we know it, and changes that occur here have impacts far beyond the balance sheets of the sector- it will not be an exaggeration to say the sector will grow in its influence and impact on Earth's balance sheet.

Contents

Getting Started

Introduction

According to the Department of Chemicals Petrochemicals (Ministry of Chemicals and Fertilizers, India), the Indian chemical industry is a knowledge intensive as well as capital-intensive industry. It is an integral constituent of the growing Indian industry. The diversification within the chemical industry is large and covers more than eighty thousand commercial products. This industry occupies a pivotal position in meeting basic needs and improving quality of life. It is also the mainstay of industrial and agricultural development of the country and provides building blocks for several downstream industries.

In a world characterized by rapid industrialization as well as decarbonization, the role of the chemical sector in guiding the transition towards a low-carbon economy is more crucial than ever.

The chemical sector's impact on supporting India's low-carbon transition is a cornerstone of this paper's agenda. As the Indian economy strives for sustainability, chemical products play a vital role in enabling decarbonization across various sectors. Emission reduction technologies, driven by chemical products, are poised to be the driving force behind meeting decarbonization goals. This paper aims to identify and capitalize on emerging market opportunities, such as climate risk and resilience, sustainable finance, and energy transition. By proactively managing sustainability-related risks from climate change and resource scarcity, businesses can not only survive but thrive in the transition to a low-carbon economy.

The paper will spotlight the necessity of ongoing innovation in the chemical sector to develop cleaner processes, materials, and technologies, thereby reducing carbon emissions. It will delve into the key challenges faced by the industry in its quest to decarbonize, with a special focus on the regulatory framework that incentivizes carbon footprint reduction. Collaboration is key in this journey, and this paper emphasizes the advantages of partnering with other industries, research institutions, and governments to accelerate decarbonization efforts.

In the era of carbon neutrality, the discussions will explore new markets and opportunities driven by the growing global demand for carbon-neutral products and services. Discussions will include business potential in carbon offset markets and trading, the role of nature-based solutions, and implications of potential bans on the term 'carbon neutral' to combat 'greenwashing.' These topics are at the forefront of sustainable transitions and understanding them is essential for the chemical industry's growth.

Digitalization is a catalyst for sustainable transformation. This paper will explore how cutting-edge technologies, from Artificial Intelligence and Big Data Analytics to IoT and Machine Learning, can help build a sustainable chemical industry. Readers will be able to evaluate India's current digital standing and what support is needed from the government and digital industry to adopt large-scale digital transformation successfully.

Sustainability goes beyond the industry itself; it's about creating a sustainable ecosystem. This paper will discuss the pivotal role of governments in offering sustainable investment opportunities for the chemical industry. Collaborations with governments, a supportive policy framework, incentives, and the importance of renewable energy projects will be explored, highlighting the role of public-private partnerships in fostering collaboration.

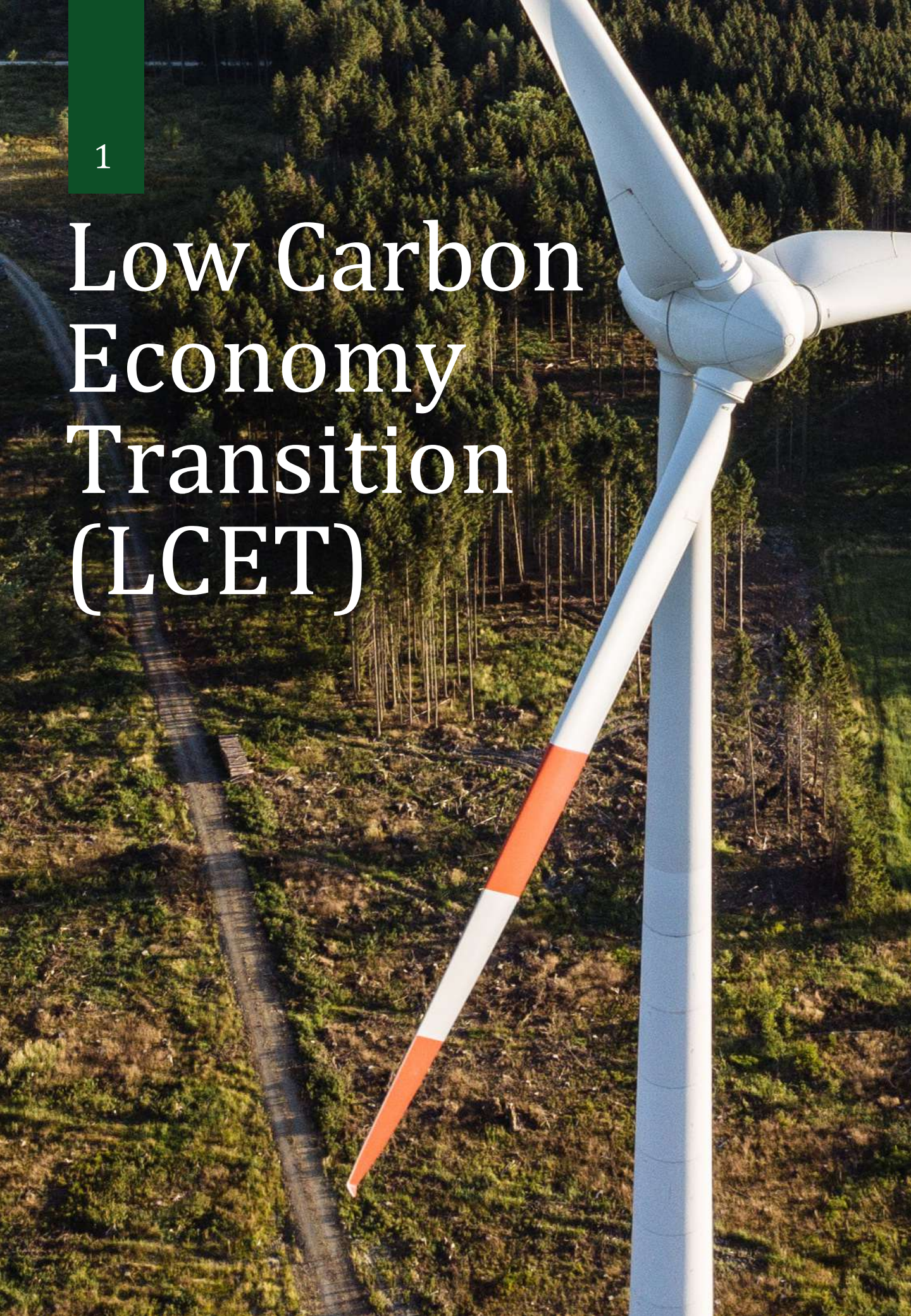
ESG regulations are reshaping the global trade landscape. This paper will also delve into the evolving global regulatory framework and its impact on international trade, including environmental and sustainability mandates integrated into trade agreements. It will address the challenges businesses face in complying with these regulations while remaining globally competitive.

Sustainability isn't a single point in the process; it's a thread woven throughout the entire value chain. This paper will explore the importance of sustainable product design, supplier management programs, transportation, and the need for enhanced recycling infrastructure and technologies.

The responsible stewardship of water resources is a pressing concern. The chemical industry's role in water management will be examined, including innovative wastewater treatment technologies, policies on water management, and corporate water stewardship. Opportunities to contribute to sustainable water management and achieving net-zero water through nature-based solutions are also discussed.

1

Low Carbon Economy Transition (LCET)



LCET Opportunities

Today's chemical industry possesses profound expertise in transforming innovations into solutions and products that meet market needs. Chemistry-based products cover a vast and highly diverse array of applications, both in mature and developing markets, with great relevance for the low-carbon economy transformation.

Although climate change is a global problem, there is no one-size-fits-all solution for every region in the world. Differences in economic systems, geographical circumstances, infrastructures, market needs and the level of societal and political acceptance—even among adjacent countries and economies—make it necessary for tailored development trajectories to be designed. Not only must these trajectories include factors such as technological feasibility but also environmental, societal, and financial options, and be compatible with the SDGs. Mindset changes and political and societal consensus are fundamental prerequisites.

The window of opportunity is closing rapidly when it comes to long-term strategic decisions toward achieving a low-carbon society by 2050. Financial restraints, both in public spending and the chemical industry, limit research and development—which means a clear focus is needed. To commercialize large-scale low-carbon production technologies in mature markets and to make capacities for developing applications and markets financially resilient and economically viable — with each solution having a favorable risk-reward balance — highly reliable political frameworks are indispensable. Those frameworks provide security to committed companies and support the unfolding of the chemical industry's potential toward a low-carbon society.

As per the report **"Enabling the Future"** by International Council of Chemical Associations (ICCA), following are some of the most crucial areas where chemical sector can play a significant role in helping achieve the low carbon transition.[1]

1. Facilitating the generation and storage of renewable energy

Power generation and storage technologies are vital for the successful transition to a new energy mix and low-carbon economy. The chemical industry has a major role to play when it comes to enabling energy storage solutions—from ammonia utilization and hydrogen storage to the production of hydrogen from biogas, steam reforming and water-splitting technologies. In addition, the chemical industry can contribute to alternative energy generation through perovskite solar cells, advanced mooring materials and superhydrophobic coatings for wind turbines as well as building-integrated photovoltaics and many other solutions.

2. Optimizing the chemical industry's processes

The Industry and production sector is responsible for 36% of global final energy consumption and 24% of total carbon emissions among other relevant emissions and impacts.[2] With a proactive move, this sector can clearly expect to bring about considerable improvement in resource efficiency as well as energy management systems and practices through technological innovation and better process design. As part of this development, the chemical industry has an important role to play as a solution provider and enabler. It has the innovative power to contribute to solving a wide range of technical problems along the value chain. These solutions include supporting recycling carbon emissions into chemical feedstock, deriving fuels and plastics from biological materials etc.

3. Shrinking the mobility and transport carbon footprint

With 23% of all energy-related carbon emissions caused by global transport, this area has great potential when it comes to low-carbon solutions.[3] Attempts to reduce the harmful impact of mobility and transport by road, rail, air and sea are already underway and the chemical industry plays a key role in this effort. It can contribute to reducing transport related energy consumption and GHG emissions by, for instance, developing lighter materials for fuel efficiency and better solutions for e-mobility batteries and fuel cells. Technical challenges are inherent to all these areas. With its research and development expertise, the chemical industry is ideally placed to contribute to the revolutionizing of global mobility and transport.

4. Helping to rise to the nutrition challenge of a growing world population

The agriculture, forestry and other land use sector (AFOLU) is responsible for almost 25% of anthropogenic GHG emissions (reference year 2010).[4] The majority of these stem from deforestation as well as livestock, soil and nutrient management.

With the global nutrition challenge of feeding a growing world population, this sector has come into the spotlight of the target to limit global warming. The chemical industry is instrumental to meeting the nutritional needs of humans and animals and making nutrition and agriculture more sustainable.

Chemical technologies in this area include those affecting the nitrogen cycle, e.g. through lower carbon-emitting fertilizers, animal feed additives as well as enabling carbon storage in ecosystems through ecosystem restoration and enhancement approaches.

5. Energy efficiency and alternative energy for building and housing

As the global population and economy expand, energy-efficient building and housing will have to contribute substantial GHG emissions savings to enable the transition to a low-carbon future.

Globally, buildings consume over one-third of all energy and carbon emissions. Insulation can play a significant role in reducing heat and cooling requirements. To this end, the chemical industry is developing new materials and researching new generations of thermal control and lighting systems. Another important aspect of building and housing is the need for alternative energy generation. Technological advances in solar photovoltaics, tidal energy and wind power offer great opportunities for the chemical industry to overcome technological challenges in this field.

The table below signifies the volume of opportunity for the chemical industry in not only serving the domestic market but potentially expanding the products to the export market as well in line with the transition in the global economy.

These opportunities will be available if all the countries globally strive to achieve the Nationally Determined Contributions that they have committed to at the Conference of Parties (CoP) to limit greenhouse gas emissions and limit temperature rise in alignment with Paris Agreement.

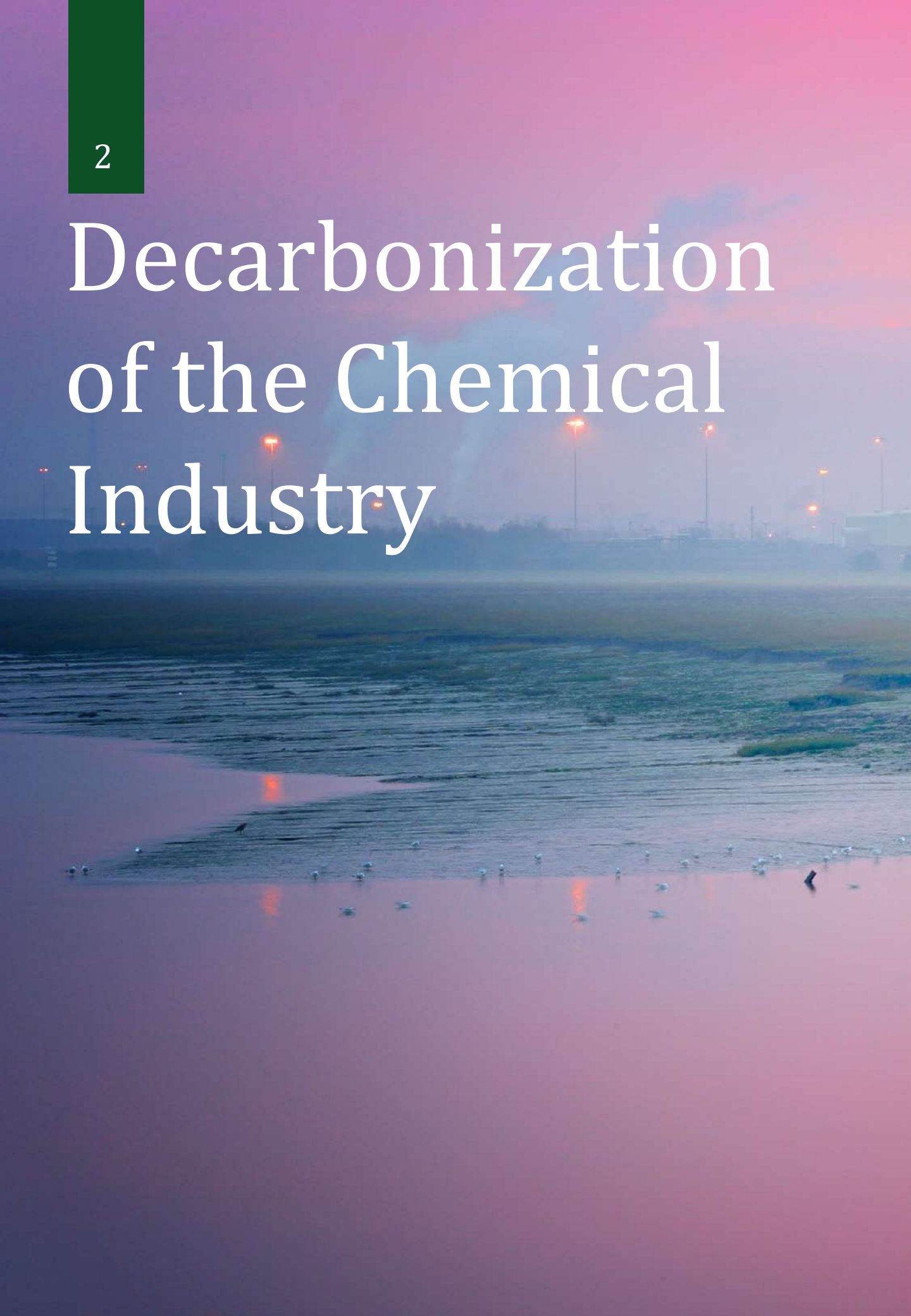
Table 1:
CHEMICAL SECTOR OPPORTUNITIES IN DOMESTIC AND EXPORT MARKETS

Particulars	Unit	India (2021)	India 2030	India 2050	Global (2021)	Global 2030	Global 2050
Renewable energy and hydrogen	TWh	337	990	5,818	8,060	17,654	49,440
Utilization of CCUS to support electricity generation	TWh	0	0.3	125.3	0.8	75.3	1,338.5
Modern bioenergy	PJ	4,391	7,400	12,593	41,166	68,690	112,365
Electrification of transport	PJ	73	442	2,890	1,586	5,665	28,419
Buildings CO2 emissions	MtCO2	164	161	64	3,045	2,267	1,029

Source: IEA (2022), World Energy Outlook 2022, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2022, License: CC BY 4.0 (report); CC BY NC SA 4.0 (Annex A)

2

Decarbonization of the Chemical Industry



Decarbonization of the Chemical Industry

2.1 DRIVERS FOR DECARBONIZATION

1. Changing stakeholder's expectations

Chemical sector players globally have set ambitious CO_2 emissions reduction targets ranging from 25% to 60% by 2030[5] and to achieve these targets, companies in the chemical sector would have to focus on mitigating their emissions. The drivers behind these targets, include national level policies for the decarbonization of the chemicals sector such as the one in France who have put in place a roadmap for decarbonizing the chemicals sector (2021).[6] Similarly, stakeholders, especially investors, have also started pushing pressure on companies to come out with the decarbonization pathways. As a result of this, it has become increasingly pertinent for chemical producers to produce green and low-carbon products. This will not only help in achieving their emissions reduction targets but would also bring forth the opportunities for generating additional revenues through these decarbonized chemical products either in the form of new market or green price premiums. An example of this would be the creation of new businesses that would look at providing waste heat from chemical production processes to local district heating systems, recycling of chemicals and utilization of waste – potentially to other producers in clusters or chemical parks or for gasification etc.

Further, with greater foreign investments flowing into the Indian chemical sector, the pressure is only increasing as most of these foreign investors have taken strict stance on emissions reduction and they will keep on pushing for more initiatives by the chemical sector companies in India to decarbonize as well. Chemicals is in sixth position in terms of total FDI in India amounting to ~3% of total FDI equity inflows in India. The fiscal year (FY) 2022-23 witnessed the highest recorded growth i.e., 91% over FY 2021-22 among all the sectors on FDI inflows.

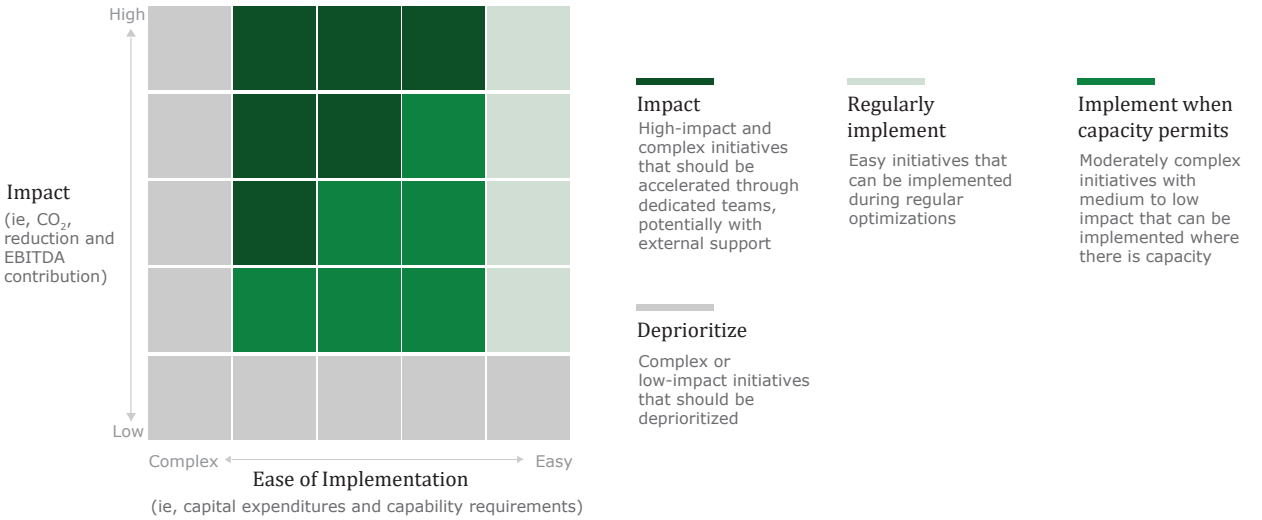
The trends of Foreign Direct Investment in chemical and petrochemical is summarized here

Year	FDI (in Rs. Cr.)
2018-19	13, 685
2019-20	7,492
2020-21	6300
2021-22	7202
2022-23	14,662

2. Decarbonization as a driver for transformation

With customer demands shifting towards products with a lower climate and environmental impact, companies in the chemical industry need to address this shift through integrating decarbonization efforts in their product portfolios, commercial models, and governance structure. This adaptation would require a transformation akin to corporate transformation and is underpinned by a clear implementation plan that is supported by detailed analyses on emissions reduction opportunities. These emissions reduction opportunities need to be identified and prioritized considering variables such as the potential impact, required capital and operational expenditure, ease of deployment / implementation, timeframes, and availability of resources / technologies to realize these

opportunities. The matrix below highlights these initiatives and variables based on their impact and ease of implementation[7]:



3. **Commercial model adaptation**

As per McKinsey and Company[8], the value creation potential of decarbonized chemical products can be realized through commercial models such as

- Green premiums: The cost of procuring carbon credits is reduced with an uptick of decarbonized products and services and these low carbon products and services can also fetch a higher price from end customers. Chemical sector players can benefit highly from these "green premiums" on decarbonized products and services, for example – as per a few industry sources, a green premium between 10 – 30% can be achieved for plastics that have been produced from chemical recycling processes.[9]

- Dynamic Value Offerings: Chemical sector operators can leverage their services in chemical clusters based on bespoke and flexible value offerings – in terms of waste heat and gas supply – as opposed to a bulk sale approach taking a more competitive approach for their independent value drivers.

2.2 CHEMICAL SECTOR EMISSIONS AND DECARBONIZATION LEVERS

Globally chemical industry emissions reached 935Mt in 2022,[10] third largest industry subsector contributor towards CO_2 emissions. International Energy Agency (IEA) estimates that chemical sectors CO_2 intensity needs to peak in coming years and decline towards 2030 (from 1.3 tCO_2/ton in 2022 to 0.92 tCO_2/ton in 2030) to get on track with the Net Zero Scenario by 2050.[11] The carbon intensiveness of this sector is due to chemical processes using fossil fuel feedstock like hydrocarbons combined with energy intensive processes like for chlor alkali. Further scope 3 emissions from the value chain also adds complexity to the decarbonization.

Exhibit 1 shows a typical chemical value chain which reflects 15-30 percent GHG emissions from scope 1 and 2. Hence, the scope 3 emissions add to chemical sector complexity and requires addressable solutions.

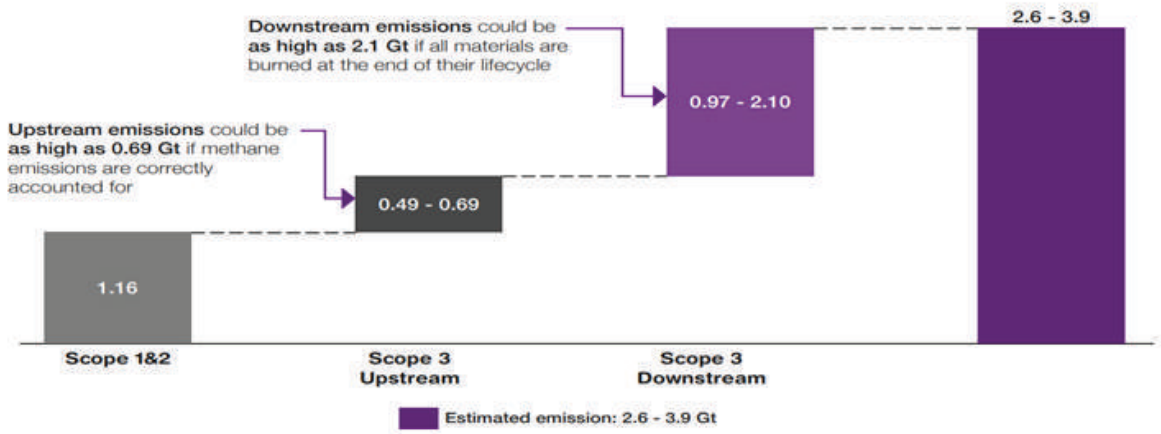
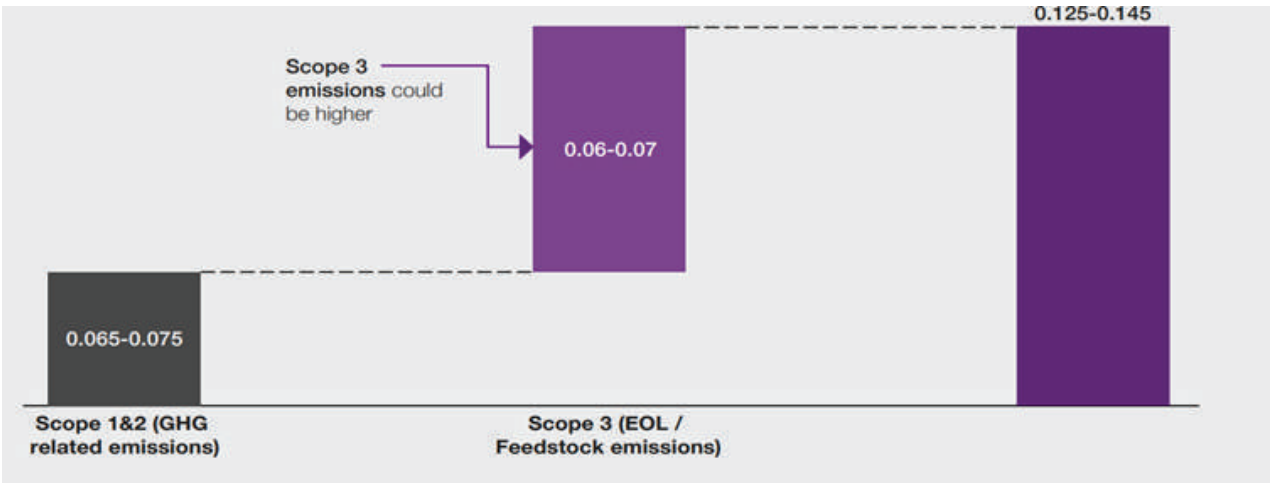
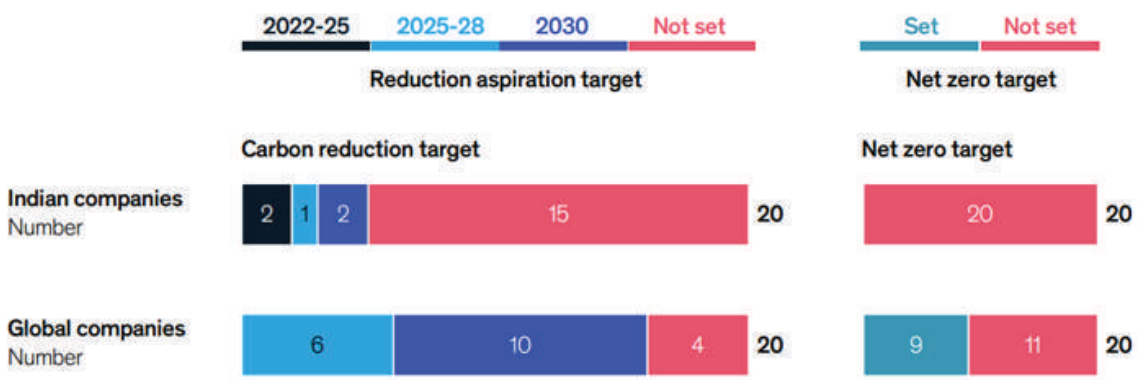


Exhibit 2 below: Indian chemical sector 2030 emissions outlook (Scope 1, 2 and 3 in Gt) (CII & AT Kearney)



A McKinsey report on "Accelerating India's sustainability journey in Chemicals", shows that the chemical industry in India requires to gear up their decarbonization strategies to future proof itself against adverse impacts of climate change in the sub-continent. Exhibit 3 draws a comparison on account of climate and decarbonization related efforts for chemical industry players in India versus foreign players.[12]

Exhibit 3 below: Decarbonization action plan setting between Indian & Foreign Chemical players*



Some potential non-exhaustive decarbonization levers for chemical industry players are shared below:

- **Process innovations through energy efficiency:** This includes adoption of circular economy model, thermal modelling for loss mitigation and energy conservation measures for process efficiencies.

- Carbon capture utilization and storage for emissions: These solutions can capture, store and use CO_2 to be converted to useful products. The CO_2 emissions released from production processes is collected at site specific location.

- **Industrial electrification through low-carbon energy sources:** Transport and chemical processes electrification by procurement of renewable energy for operational purposes.

- **Hydrogen as fuel:** Indian chemical players currently use enough hydrogen for ammonia production therefore green hydrogen blending and technology switching remains a potential decarbonization lever.

- **Bio-based feedstock:** Sustainable feedstocks like plant or animal fats, starch, or sugar, can help produce bio-based chemicals such as alcohols, polyesters, and other products.

It is worthwhile to add decarbonization action points and perspectives from chemical manufacturers directly to comprehend the overall disposition of the industry.

"Our company has committed itself to the path of net neutrality and aims to reduce SCOPE 1 and SCOPE 2 emissions in line with the SBTi norms. It is expected to happen in a phased manner and is the first milestone we are targeting," said Shivang Mahadeviya, Head of Corporate Strategy and Sustainability, Tata Chemicals[13]

It worth noting that, that all levers are not readily available at a scale for adoption. Therefore, CXOs must pursue levers which have positive net present values immediately and continually assess feasibility (technical and economic) for adoption of nascent technologies in local context.

The Indian Government is also taking initiatives to support companies collaborate on decarbonization efforts. The Department of Chemicals and Petrochemicals in collaboration with Confederation of Indian Industry (CII) organized the B20 International Conference on 'Chemicals and Petrochemicals: Sustainable transitions through Green Technologies and digitalization' on 24 May 2023 in New Delhi. The event marked the participation of the leading industry leader of chemical and petrochemical sector and about 520 delegates from G20 countries.

2.3 INDUSTRIAL DECARBONIZATION INITIATIVES IN CHEMICAL INDUSTRY: CASE STUDIES

This section brings together some leading industrial decarbonization projects in the chemical industry from national and international geographies. The case studies are either under development or ready for uptake by project developers. Some common examples of clean energy technology processes include Chemical and Physical absorption (Ammonia), Chemical depolymerization for polystyrene, Biomass and Waste gasification (methanol). These technologies can broadly be categorized into decarbonization themes like Carbon capture, Chemicals recycling and Biomass use.

To realize net-zero targets, companies must develop action plans considering combinations of such technologies to meet specific needs as well as which suit their operational context.

Case Study # 1

Project: Green Methanol Production in India
Stage: Planning and Designing

NTPC has signed a MoU with Tecnimont Private Limited, Indian Subsidiary of Maire Tecnimont Group, Italy to jointly evaluate and explore the possibility to develop commercial scale Green Methanol Production facility at NTPC project in India.

The Green Methanol Project involves capturing carbon from NTPC power plants and converting it into a green fuel. Green Methanol has a wide range of applications, including serving as a base material for the chemical industry, storing renewable electricity, and even as a transportation fuel. It is also considered as a substitute fuel for maritime fuel applications.

Source: PIB release dated 26 Dec 2022 available at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1886729

Case Study # 2

Project: ONGC signed MoU with Shell for cooperation in Carbon Capture, Utilization and Storage (CCUS) studies

Oil and Natural Gas Corporation Limited (ONGC) signed a MoU Shell for cooperation in (CCUS) studies. The collaboration shall focus on joint CO_2 storage study and EOR screening assessment for key basins in India including depleted oil and gas fields, saline aquifers.

It is aimed at developing CCUS/CCS as an emissions mitigation tool for combating climate change and injecting carbon dioxide (CO_2) for geological storage as well as enhanced oil production from mature fields of ONGC. approximately 350 people and leading to an additional 1,500 indirect jobs in recycling, energy and infrastructure.

Source: ONGC portal available at https://ongcindia.com/web/hi/w/ongc-%E0%A4%A8%E0%A5%87-%E0%A4%95%E0%A4%BE%E0%A4%B0%E0%A5%8D%E0%A4%AC%E0%A4%A8-%E0%A4%95%E0%A5%88%E0%A4%AA%E0%A5%8D%E0%A4%9A%E0%A4%B0-%E0%A4%AF%E0%A5%82%E0%A4%9F%E0%A4%BF%E0%A4%B2%E0%A4%BE%E0%A4%87%E0%A4%9C%E0%A5%87%E0%A4%B6%E0%A4%A8-%E0%A4%94%E0%A4%B0-

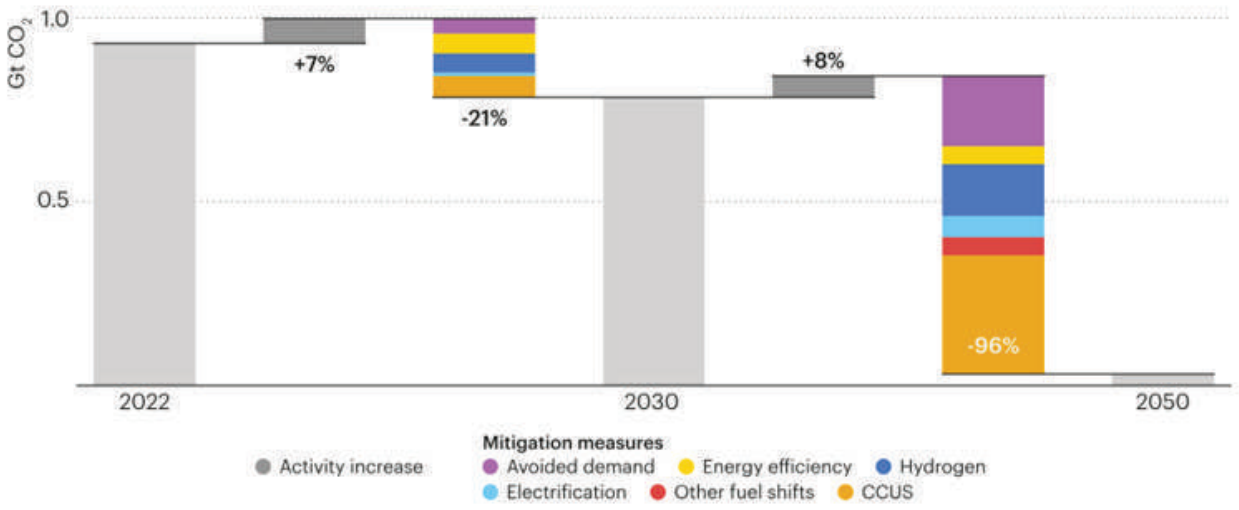
2.4 USE & DEPLOYMENT OF CCUS FOR DECARBONIZATION GOALS FOR CHEMICAL PLAYERS

1. Technical Perspective

According to Offshore Technology, (2023)[14] an oil and gas news and data website, as of 2021, the global chemical sector accounts for 14% of Industrial GHG emissions. However, chemical sector emissions are amongst the hardest to abate as the process emissions which occur from chemical reactions cannot be avoided through the utilization of alternative fuels. These process emissions make up close to 25% of the chemical industry emissions (IEA, 2019).

Further, the forecasted demand of chemicals to support the growing population in urban areas will reach 829 Mt per annum by 2030 (considering a compound annual growth rate (CAGR) of 1.9% between 2018 - 2030) which will subsequently increase the carbon footprint of the entire sector. However, the chemical industry is not on track with their net zero commitments and pathway[15] and hence, there is an imperative to decarbonize and improve the efficiency of the products and processes in the chemical industry. Therefore, there is an ever-increasing need for transforming industrial production to meet global targets on climate change and emissions reduction.

Carbon capture, utilization, and storage (CCUS) will be a crucial element in the industrial decarbonization efforts. The IEA Net Zero Emissions scenario (NZE) that is aligned with the Paris Agreement ambitions, emphasizes that by 2050 over 344 $MtCO_2$ shall be captured from industrial chemical sites.[16] For the chemical sector, CCUS will have a 56% share of CO_2 emissions reduction by 2050 (8% by 2030)[17] and is already one of the highly viable solutions for chemical production processes such as ammonia production.



Potential mitigation measures incl. CCUS in Chemicals sector. Source: IEA (2023)

The table below shows the chemical sectors' global emissions reduction through CCUS under IEA's NZE 2050 scenario

Milestones	2022	2030	2035	2050
Primary chemicals production (Mt)	719	861	905	878
Share of near zero emission primary chemicals production	2%	17%	39%	93%
CCUS-equipped	0.5%	8%	22%	56%
CO_2 captured (Mt)	4	52	143	344

Even for India, Niti Aayog feels CCUS will play a crucial role in India's need for energy, materials & food security and self-sufficiency and enabling the sunrise sectors of coal gasification and low-carbon hydrogen economy.[18] It can support hard to abate sectors like power, steel, cement, oil & gas, petrochemicals etc. that are critical to the continued growth of the Indian economy, and for ensuring energy, materials and food security for the country.

Indian government has started initiating work on identifying CO_2 capture hubs.[19] The work is at a conceptual stage to make CO_2 capture economically viable. Four inter-ministerial committees have been constituted by NITI Aayog to study the challenges and finalize recommendations in the area of safety and technical standard development, carbon capture projects, carbon utilization projects, and carbon transportation and storage. Department of Science and Technology (DST) has also been supporting various activities in area of CCUS which inter alia include:

- R&D projects through national and bilateral efforts to identify and prioritize breakthrough technologies.
- Two National Centres of Excellence to facilitate capturing and mapping of current R&D and innovation activities and develop a network of researchers, industries and other stakeholders.
- A multilateral research project to study the risk associated with permanent storage of CO_2 in basalts.
- 25 CCUS projects (capture:10, utilization:10 & storage:5)

2. Policy Perspective

Globally, many governments have started to aid via regulatory matters for the development and promotion of CCUS technologies for industrial decarbonization. Currently, the United States of America accounts for more than half the captured CO_2 emissions from a global perspective and has also made provisions to provide tax benefits and credits for CCUS development – with a credit of US$50 for each tonne of CO_2 emissions captured and sequestered.[20] Other regions and countries are also entering the fray on CCUS development. However, India needs to still match its efforts with foreign nations. Policies and incentives need to be established for developers in India to invest in CCUS projects.[21]

Country	Legal Regulatory Framework	Carbon Reduction Incentives	Carbon Price Incentives
US	Partial	No	Sufficient
UK	Partial	Insufficient	Insufficient
Norway	Comprehensive	Sufficient	Sufficient
EU	Comprehensive	Insufficient	Insufficient
China	Comprehensive	No	Insufficient
India	**Partial**	**No**	**None**

For key sectors such as the chemical sectors, the importance of technologies such as CCUS cannot be understated. The IEA (2019)[22] has made recommendations on the policies that can be used to support the uptake of CCUS to make the shift to a low-carbon economy:

- Provision of support for CCUS project development and operation for the chemical industry and include it in amongst the least-cost portfolio of technologies necessary to meet the industries emissions reduction targets and ambitions

- Low-cost and competitive CCUS investment opportunities for the chemicals industry should be

- identified and prioritised to establish knowledge on the CCUS impacts and provide a foundation for CCUS infrastructure development

Support the creation of CCUS hubs in industrial areas (for e.g., SEZs, industrial clusters, etc.) that have established logistics and storage facilities that will lead to reduced costs for enterprises that utilize and incorporate CCUS for their production processes.

- Policy frameworks that can facilitate significant emissions reduction in chemical sector facilities / sites should be implemented and the consequent potential impacts on competitiveness should be acknowledged and addressed.

Even Niti Aayog, in its study on Carbon Capture, Utilization and Storage (CCUS) - Policy Framework and its Deployment Mechanism in India,[23] has identified the crucial role that policies are expected to play in development of CCUS in India.

3. Infrastructure Perspective

As already established, CCUS is expected to play a vital role in decarbonization of the hardest to abate sectors. The issue of lock-in emissions for current industrial infrastructure remains one of the key challenges. According to IEA, CCUS contribution to chemical sector emissions cumulative reductions is 28 percent between 2030-2070 in sustainable development scenario.

Exhibit 4: Reflects global CO_2 emissions reductions due to different abatement levers and reduction due CCUS for different heavy industries under Sustainable Development Scenario in relative to State Policies Scenario.[24]

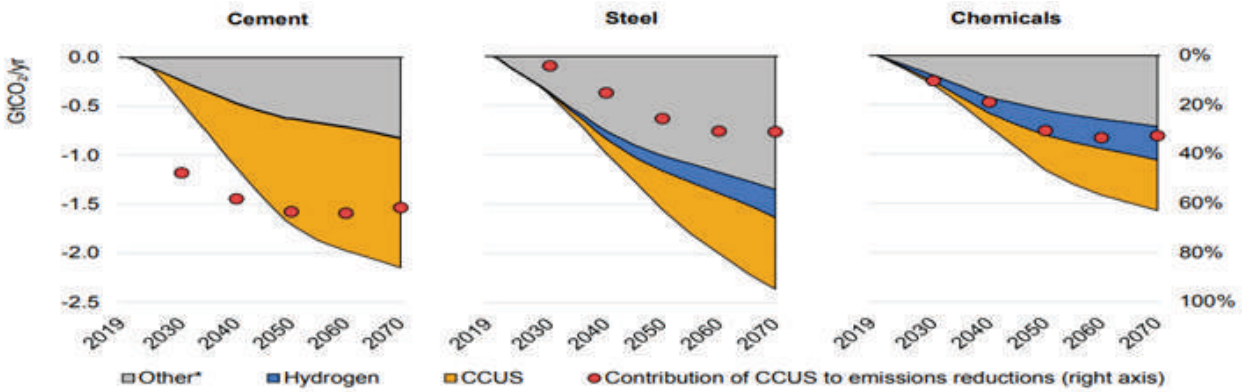


Exhibit 5: CO_2 emissions reductions potential for heavy industries under Sustainable Development Scenario relative to Stated Policies Scenario of IEA for net-zero 2070.

It must also be noted that the CCUS infrastructure will be coupled with the existing industrial infrastructure to curb process emissions which remains highest for chemical sector. Exhibit __ showcases Industrial process emissions CO_2 capture by 2070 under Sustainable Development Scenario for chemical sector in comparison to other hard to abate sectors.[25]

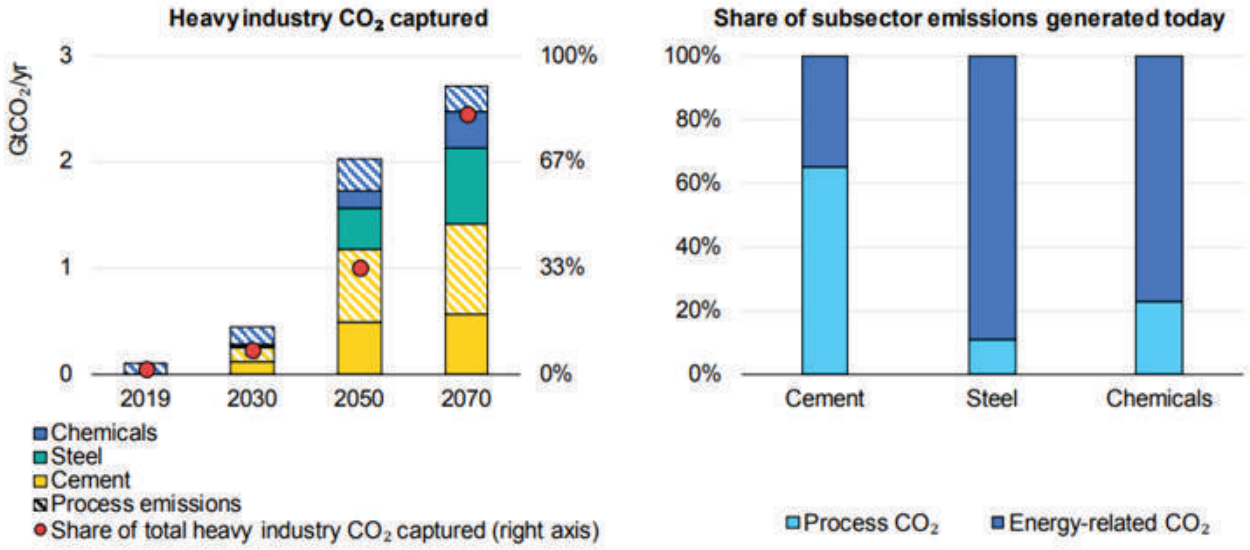


Exhibit: Industrial process emissions CO_2 capture by 2070 under Sustainable Development Scenario
In March 2020, the UK government has committed GBP 800 million in CCUS infrastructure. This includes establishing CCUS in two industrial locations and equipping gas fired plants with CCUS.

An additional of GBP 139 million was also announced by the UK government towards the same projects in July 2020.[26] CCUS deployment must also be accompanied by transport network for a 'hub-and-cluster' model in industrial regions. Finally, appropriate risk sharing arrangements and feasibility analysis for long-term viability will ensure bankability of CCUS projects.

3

Carbon Neutrality

Role of Carbon and Nature-based Climate Solutions

1. How the adoption of Carbon Offsets and Nature-Based Solutions can support the Indian Chemical Sector

India's commitment to achieving net-zero emissions by 2070 has set an ambitious yet essential target for the nation's environmental agenda. As the world grapples with the pressing issue of climate change, the Indian government's pledge demonstrates a firm determination to mitigate its carbon footprint significantly.

The Indian chemical sector is responsible for about 10% of the country's total industrial emissions. The sector is also a major consumer of energy, accounting for about 20% of the country's total industrial energy consumption. In this context, the Indian chemical sector emerges as a key player in the transition to a low-carbon future.

In recent years, the chemical sector has made significant progress in reducing its carbon footprint. Many companies have set ambitious targets to achieve carbon neutrality, and some have already achieved this goal. One example is the Indian Chemical Council (ICC), which has set a target for the Indian chemical industry to achieve carbon neutrality by 2050. The ICC is working with its members to develop and implement a roadmap to achieve this goal.

There are several ways that the chemical sector can reduce emissions, decarbonize, and use offsets to achieve net zero and carbon neutrality. Carbon offsets and nature-based offset solutions or Nature Climate Solutions (NCS) are two important ways to neutralize residual or hard-to-abate carbon emissions from the chemical sector.

2. The Carbon Offset and NCS Landscape

Carbon offsets are investments in projects that reduce greenhouse gas emissions or remove them from the atmosphere. Nature climate solutions are projects that protect or restore natural ecosystems, which can absorb and store carbon dioxide. Carbon offsets are mechanisms that allow entities to compensate for their GHG emissions by investing in projects that reduce or remove an equivalent amount of CO_2 from the atmosphere. These projects can range from afforestation and reforestation to renewable energy installations and methane capture initiatives. In recent years, there has been a growing interest in carbon offsets as a means to achieve carbon neutrality.

Carbon offsets designed around Nature-based Solutions (NbS) provide an approach that protects and enhances the natural capabilities of the ecosystem to sequester and offset carbon emissions. Tapping into nature and biodiversity conservation actions such as reforestation, afforestation, and protection of soil carbon can generate co-benefits such as socio-economic development and biodiversity conservation. In the context of India's chemical industry, nature-based offsets can support the sector in reducing its carbon emissions while simultaneously fostering economic growth and resilience.

3. Recent developments in carbon offsets and nature climate solutions

There have been a number of recent developments in carbon offsets and nature climate solutions in the Indian chemical sector. Some of the most notable developments include:

- G**overnment policies and regulations** play a crucial role in shaping the direction of the chemical sector's sustainability efforts. India's National Action Plan on Climate Change, the National Bio-Energy Mission, and various state-level policies are driving sustainable practices in the chemical industry. These policies provide financial incentives, regulatory support, and a clear roadmap for achieving carbon neutrality.

- The upcoming **Indian Carbon Market Exchange (ICME)** is a significant development in the country's efforts to reduce greenhouse gas emissions and achieve its net-zero goals. The exchange is expected to be launched in early 2024 and will provide a platform for businesses to trade carbon credits.

- Forests play a crucial role in absorbing CO_2 from the atmosphere. **Afforestation and reforestation initiatives**, such as the Green India Mission, aim to increase forest and tree cover, which can potentially yield carbon offsets besides preserving our rich biodiversity. By actively participating in such projects, the chemical sector can help restore and protect vital ecosystems while offsetting their emissions.

- Besides forest-based offsets, NCS with high offset potential include restoring biodiversity-rich **wetlands** which act as natural carbon sinks. Further, combining agriculture with tree planting can sequester carbon, improve soil health, and provide additional income sources for farmers. Contribution to **agroforestry** programs by providing expertise and resources for soil and crop management, can foster a win-win scenario for both the sector and local communities.

- The growing interest from Indian companies in **nature climate solutions.** A few Indian companies in the chemical sector are now investing in nature climate solutions, such as projects to protect and restore forests and mangroves. For example, companies such as Tata Chemicals, BASF, Pidilite, and others are investing in several projects to reduce its carbon emissions including investing in nature climate solutions including forest conservation, restoration of mangroves & wetlands, and addressing nature and biodiversity issues in their supply chain.

4. Potential considerations while investing in carbon offsets and NCS

Companies should only invest in high-impact natural climate solutions (NCS) projects that provide measurable benefits to nature and people, beyond the delivery of carbon credits.

NCS address multiple societal challenges, but only if they are designed and implemented to a high standard. High-quality NCS must effectively address key concerns such as permanence, additionality, leakage, double-counting, robust quantification, and verification associated with climate mitigation claims. Moreover, they should transcend the sole goal of delivering carbon credits by contributing to multiple Sustainable Development Goals (SDGs) specifically enhancing biodiversity and preserving ecosystem integrity and providing tangible social and economic benefits to local communities.

Co-benefits	Examples	Relevant SDGs
Climate adaptation benefits	• **Weather Resilience:** NbS such as reforestation, wetland restoration and others can boost resilience to extreme weather, reducing physical climate risks. • **Coastal Protection:** Coastal NCS (mangroves, seagrasses) can defend against sea-level rise and storms, shielding local communities and habitations. • **Water Management:** NbS can ensure sustainable water management by regulating flow, improving quality, and recharging aquifers, vital for ecosystems and communities, especially in water-scarce regions with climate changes.	 
Conservation of nature and biodiversity	• **Habitat Restoration:** Nature-based interventions can restore critical habitats (forests, wetlands, grasslands) for biodiversity. • **Species Preservation:** NbS can safeguard species, including endangered flora and fauna, dependent on intact ecosystems. Such interventions can further enhance ecosystem adaptability to environmental changes, supporting biodiversity. • **Pollination and Agriculture:** Interventions such as multi-cropping, agroforestry can help attract pollinators, maintaining plant diversity and food production.	 
Supporting resilience of local communities	• Improved Livelihoods: Nature-based offsets can create job opportunities and support local economies through activities like reforestation and Sustainable agriculture, benefiting communities ecnomically. • Enhanced Health and Well-being: Access to green spaces and cleaner air resulting from NbS initiatives can lead to improved physical and mental health for local residents. • Resilience to Climate Impacts: Eco-restoration projects, such as floodplain restoration and urban green infrastructure, can help communities better withstand climate-related events like floods and heatwaves, ensuring their safety and well-being.	 

Adapted from **"Natural Climate Solutions and the Voluntary Carbon Market:** A Guide for C-suite Executives[27]

Additionally, while the adoption of carbon offsets and nature climate solutions in the Indian chemical sector is promising, the following practical challenges and considerations must be addressed:

- **Regulatory Compliance:** Ensuring that carbon offset projects comply with national and international standards is essential to prevent potential backlash or controversy.

- **Monitoring and Verification:** Robust monitoring and verification mechanisms are needed to accurately measure emissions reductions and carbon sequestration, ensuring the integrity of carbon offset projects.

- **Investment Costs:** Some nature climate solutions, such as large-scale afforestation, can require substantial financial investments. The chemical sector must carefully assess the costs and benefits of these initiatives.

- **Adaptation to Changing Regulations:** The regulatory landscape for carbon offsets is continuously evolving. Companies in the chemical sector must remain adaptable and responsive to changing regulations and market dynamics.

The Indian chemical sector is undergoing a significant transformation towards carbon neutrality and sustainability. Recent developments in the industry include a shift towards green chemistry, the adoption of carbon offset initiatives, the exploration of nature-based solutions, collaboration with various stakeholders, and strong policy support.

These developments are positioning India's chemical industry as a global leader in sustainable practices, aligning it with India's goal of achieving carbon neutrality by 2070. As the sector continues to innovate and invest in sustainability, it can make a substantial contribution to the global fight against climate change. Additionally, adoption of nature-based solutions can further support the sector in exploring and understanding how biodiversity and nature-related risks are tied into their sustainability journeys – helping the sector align with global goals of Net Zero and Nature Positive.

4

Achieving Sustainability and ESG goals with Digital

Role of Digital Transformation in Achieving Sustainability and ESG Goals

Digital transformation continues to drive businesses towards their sustainability and ESG goals. The Indian chemical industry is a deeply integrated party to this effort.

4.1 DIGITAL TRANSFORMATION DRIVES SUSTAINABILITY AND ESG

1. To bring long term systemic change to this industry, digital transformation led by Big Data, AI/ML and Generative AI will prove to be the ultimate facilitators.
2. Big Data: Big Data analytics can help chemical companies optimize their processes, leading to reduced resource consumption, waste generation, and energy usage. By analyzing large datasets, companies can identify areas for improvement, predict maintenance needs, and enhance supply chain efficiency. Moreover, real-time monitoring of emissions and environmental impact can enable timely intervention to ensure compliance with environmental regulations and reduce the carbon footprint.
3. Artificial Intelligence: AI plays a crucial role in ESG reporting and monitoring. AI algorithms can sift through vast amounts of data to identify non-compliance with ESG standards and regulations. Moreover, it can help companies make informed decisions to align their strategies with environmental and social goals, such as reducing greenhouse gas emissions and improving working conditions. AI can also enhance risk assessment, making it easier to anticipate and mitigate potential ESG-related issues.
4. Machine Learning: Machine Learning can facilitate the development of more sustainable and eco-friendly products. By analyzing market trends and consumer preferences, ML algorithms can identify opportunities for creating environmentally friendly products. This can help chemical companies meet the growing demand for green and socially responsible products while reducing the environmental impact of their offerings.
5. Generative AI: Generative AI, which can create new content and solutions, can be used to optimize chemical processes. It can suggest alternative recipes or reaction pathways that are more efficient, cost-effective, and eco-friendly. By leveraging Generative AI, companies can develop innovative processes that reduce resource consumption and waste generation. efficient, cost-effective, and eco-friendly. By leveraging Generative AI, companies can develop innovative processes that reduce resource consumption and waste generation.

4.2 SOME PIONEERING STORIES FROM THE INDIAN CHEMICAL INDUSTRY

1. Asian Paints

Asian Paints, the largest paint manufacturer and the largest chemical company of India utilized Artificial Intelligence and Machine Learning to predict demand with pin-point accuracy!

Operating for over 80 years, Asian Paints had large amounts of data on colour specifics sold in India at hype-local levels. Information such as colour, quantity, size and type. Combining this data with state-of-the-art Artificial Intelligence and Machine Learning based predictive algorithms, Asian Paints was able to forecast demand for a specific type of paint on a given day, in a given location, anywhere in India. They were able to make sure to supply the required paint products directly to the retail store, eliminating dependence on intermediate wholesale outlets. The company now delivers paints to 35,000 registered dealers nearly 3-4 times a day! Astonishingly, the paint stock delivered pre-emptively, even gets sold off 90% of times, within just 3 hours of delivery! Further, their distribution costs have been reduced to only 3% as compared to 30%-40% for their competitors.

2. Tata Chemicals

Tata Chemicals are turning to IIOT (Industrial Internet of Things) and analytics as the levers to their growth. They are looking to modernize their plants, monitor and optimize operations using IIOT.

- Tata Chemicals operate large plants and safety is core to everything the company does. The company has built a safety platform where it's employees log close to 2000 safety incidents, including near misses and unsafe practices. Their team uses analytics to identify top risks, providing predictability and proactive actioning.

- Their Mithapur plant with carbonating towers, batteries of boilers and power turbines have been equipped with IOT and analytics to drive better performance. These technologies provide real-time information and notifications on exact operating conditions. Leveraging cloud tech, these monitoring and maintenance activities can be done remotely as well.

- At the same site, Tata Chemicals have 36,000 acres of salt works with very few people. These salt works are run by a complex system of pumps that pump seawater from one part to another. While this was previously done manually, Tata Chemicals are now using remote sensing by satellite to identify salt compositions and remotely operate and manage their pumps.

The examples above showcase not just business value but also significant steps towards sustainability and ESG. Through reductions in distribution costs, timely maintenance and repair, business are able to reduce their carbon footprint across their supply chains, comply with local, national and international compliance requirements and most importantly, look after their safety of their people.

4.3 ESG REPORTING AND DIGITISATION

ESG reporting has become a mandate around the world and in India in the form of BRSR. However, most of the companies are finding it challenging to address ESG related disclosures in a meaningful and impactful manner. A Deloitte survey revealed that only 27% of Indian organizations feel adequately equipped to meet their ESG strategy and compliance requirements and even fewer, at 15% felt their suppliers can comply with their organization's mandates.

Here digital technologies can play a significant role in tracking compliance requirements and reporting standards globally. This includes providing best practices for reporting purposes, benchmarking with industry peers and gaps identification. Such technologies involve text processing, NLP, and have been further supported with adoption of XBRL for business information and financial data.

Chemical companies can benefit from transparency in their raw materials procurement methods, improving their global supply chain footprints and reinforcing investor sentiment in terms of long-term operational viability.

5

Evaluating Safety

Evaluating Safety Management

Safety management in the chemical sector is a critical component in ensuring the well-being of personnel, plant, and environment, as well as in the prevention of incidents across the organization. Every year, organizations invest largely in safety initiatives, assessments, and training but there are very limited means to assess the tangible as well as the intangible value that is derived from these safety management efforts. Measuring the value derived from safety management is a complex, multi-faceted problem that holds the potential to deliver well-managed, documented, effective outcomes that can in turn enhance the productivity of personnel and the overall effectiveness of the system as a whole. This knowledge paper explores the opportunities presented by safety management and examines how these technologies can enhance safety practices while mitigating risks. The findings of this research work will be of particular interest to safety personnel, managers, and researchers who are intrigued on enhancing their understanding of safety management.

5.1 INTRODUCTION

Over the last few decades, growth in the global chemical sector has witnessed a rather transformative journey. It has evolved from an isolated traditional setup to a more dynamic ecosystem. This ecosystem is triggered by and is integrated with different arms of research and development, patent and innovation, economic benefits, and technological breakthroughs. Out of this global landscape, India has emerged as a rather exciting success story with a consistent rise in revenue generation, increased expertise, and effective harnessing of research and development coupled with a strategic plan thereby aiming to become one of the leading chemical industry players of the world, The ability to adapt to new technology, integration with complex factors, and constantly deploy well-trained workforce has placed India as the 6th largest chemical producer with more than 2 million strong workforce and 80,000 commercial products.

The Government of India has launched Vision 2034 for the “Chemical and Petrochemical sector” to enhance domestic production, reduce the imports of materials, and attracting loft investments in the sector with a special focus on boosting domestic production. Safety management holds a significant value while accounting for overall safety in the chemical industry. Safety management involves the efforts being put in to ensure well-being of the personnel and mitigate/avoid/minimize the occurrence of incidents. Organizations spend resources to train personnel using cutting-edge technology with effective research integration to constantly adapt to a changing ecosystem. The chemical industry has moved from side-run operation to being a center player in the global economy and thus holds a significant value when it comes to safety. It is still unclear how industry and academia quantify the effectiveness of yearly contributions toward safety management.

The Department of Chemicals and Petrochemicals (DCPC) has also been actively looking at Safety in the chemicals industry. It organized a seminar on “Safe Use of Chemicals at Workplace” on 27.07.2022 under the chairmanship of Hon’ble Minister of Chemicals & Fertilizers & Health and family welfare. A Memorandum of Understanding (MoU) was signed in the presence of Union Minister Dr. Mansukh Mandaviya between DCPC and International Labor Organization (ILO) for adopting the International Chemical Safety Cards (ICSCs). The International Chemical Safety Cards (ICSCs) are data sheets intended to provide essential safety and health information on chemicals concisely. The primary aim of the Cards is to promote the safe use of chemicals in the workplace. The main users are workers and those responsible for occupational safety and health. The International Chemical Safety Cards (ICSCs) are used by the Department to disseminate the appropriate hazard information on chemicals at the

workplace in a comprehensible and easy manner. To date, 1784 Chemicals Safety Cards are available. These cards are helpful for dissemination of the appropriate hazard information on chemicals to industry associations to promote safe use of chemicals in the workplace.

5.2 BACKGROUND

Safety climate, rooted in the collective perceptions of employees, can be regarded as a temporal representation of an organization's "state of safety" or a snapshot of the existing safety conditions within the organization at a specific moment in time (Cheyne et al., 1998).[28] However, a universally accepted point among all scholars is that safety management practices play a crucial role in shaping the safety climate within an organization. Consequently, safety climate can be seen as a product of the interplay between factors like safety management practices, the behavioral and attitudinal aspects of both managers and workers, the work environment, general discipline within the organization, and the perception of risk in the workplace.he behavioral and attitudinal aspects of both managers and workers, the work environment, general discipline within the organization, and the perception of risk in the workplace.

5.3 SAFETY MANAGEMENT PRACTICES

Safety management pertains majorly on concrete actions, responsibilities, and associated functions with ensuring safety (Kirwan, 1998).[29] It is typically considered a subset of the overall organizational management and is executed through the organization's safety management system, which utilizes various safety management procedures. Safety management systems are integrated mechanisms within the organization (Labodova, 2004)[30] designed to oversee and mitigate the hazards that could impact the health and safety of workers. Safety management practices encompass the policies, strategies, processes, and measures implemented or followed by an organization's management with the aim of safeguarding their employees. These are crucial components that enable effective safety management in companies and are crafted to adhere to the pertinent regulations governing the organization. The degree to which these practices are put into action within an organization becomes evident through a range of management actions and programs, readily observable by insiders like employees. The safety management system (along with its practices) can be considered a precursor to the organization's safety climate.

When considering the elements within safety management, it is important to include those safety management practices that are readily observable by employees and have a significant role in shaping the safety culture. Many efforts have been made to identify specific safety management practices that can predict safety performance. Cohen (1977),[31] Cohen et al. (1975),[32] DePasquale and Geller (1999),[33] Griffiths (1985),[34] Harper et al. (1997),[35] found that organizations with lower accident rates exhibited some of the following characteristics: safety officers holding high-ranking positions, active involvement of management in safety initiatives, comprehensive training for new and existing employees, the presence of safety posters to identify hazards, well-defined procedures for promotions and job placements, regular communication between workers and supervisors regarding health and safety, frequent safety inspections, a higher priority given to safety in meetings and decision-making related to work practices, thorough accident investigations, and greater attendance of senior managers at health and safety meetings, along with empowering the workforce. decision-making related to work practices, thorough accident investigations, and greater attendance of senior managers at health and safety meetings, along with empowering the workforce.

5.4 TRAINING FOR IMPROVEMENT IN BEHAVIORAL SKILLS AND KNOWLEDGE

A pivotal component in any thriving organization, any successful accident prevention initiative, and any occupational safety and health program is the implementation of effective safety training. This This training serves to enhance behavioral skills, enhance related knowledge, and shape attitudes that contribute to safety. Moreover, safety training equips organizations with the means to make

accidents more foreseeable. To elevate the safety and well-being of all employees, organizations should establish a systematic, comprehensive safety and health training regimen for new hires. This should include the provision of mentors for these new employees and the incorporation of a buddy system to help familiarize them with safety, health, and quality systems, as advocated by Vredenburgh (2002).[36] discussions in training sessions, emergency response training, encouragement to participate in training programs, and instruction in hazard assessment.

Studies by Lee (1998),[37] Ostrom et al. (1993),[38] Tinmannsvik and Hovden (2003),[39] Cohen et al. (1975),[40] Smith et al. (1975),[41] and Zohar (1980)[42] have consistently revealed that companies with lower accident rates are characterized by robust safety training programs for their employees. Consequently, safety training is recognized as a management practice, and its effectiveness is gauged by criteria such as training provision for new hires, the inclusion of safety discussions in training sessions, emergency response training, encouragement to participate in training programs, and instruction in hazard assessment.

DCPC has also taken initiative with Indian Chemical Council to organize safety trainings for the chemical sector stakeholders in India.

5.5 WORK OWNERSHIP

Employee involvement is a behavior-centered approach that engages individuals or groups in the process of upward communication and decision-making within an organization. The degree of involvement can vary, ranging from no involvement, where decisions are solely made by supervisors, to full involvement, where all individuals connected to or impacted by the decision are included. Given that those closest to the work are often the most knowledgeable about suggesting improvements, they should be consulted before final decisions are made, particularly in cases that affect employees (Vredenburgh, 2002).[43] This empowerment of workers confers upon them the authority, responsibility, and accountability for crucial decisions, ensuring that both employees and management play a role in establishing goals and objectives. It motivates employees to perform at their best as individuals and as part of a team, thereby allowing managers to focus on planning, leading, and mentoring (Cohen and Cleveland, 1983).[44]

Worker involvement has been identified as a critical element in safety management by researchers like Lee (1998),[45] Rundmo (1994),[46] Dedobbeleer and Beland (1991),[47] Shannon et al. (1996),[48] and Cox and Cheyne (2000).[49] Consequently, workers' involvement in safety is recognized as a management practice and is assessed using criteria related to safety committees consisting of workers' representatives, worker participation in safety-related decision-making, involvement in identifying safety issues, and consultation with workers regarding safety-related matters.

5.6 TWO-WAY COMMUNICATION

Numerous forms of communication serve to augment the overall efficiency of any motivational endeavor. The impact and breadth of communication tend to be more significant in two-way communication, which can result in behavioral changes. Consistent communication concerning safety matters among management, supervisors, and the workforce is a sound management practice for enhancing workplace safety. Researchers such as Cohen (1977),[50] Vredenburgh (2002),[51] Cox and Cheyne (2000),[52] and Mearns et al. (2003)[53] have incorporated communication and feedback as a variable in their surveys, employing questionnaires administered to workers in diverse roles. Their findings underscore the correlation between safety performance and the level of communication within an organization.

5.7 PROMOTING SAFETY CULTURE

The utilization of incentives, awards, and recognition as motivational tools for encouraging safe

performance among employees is a well-established aspect in both organizational behavior management and total quality management models, as acknowledged by Hagan et al. (2001).[54] These mechanisms can boost enthusiasm into an organization's hazard control program and promote a sense of self-preservation among the workforce, as noted by Cohen et al. (1979).[55] An effectively designed reward system should stand out within the organization, offering visible recognition, which can be influential in modifying behavior, as emphasized by Vredenburgh (2002).[56]

This study also identifies safety promotion policies as one of the safety management practices, which is evaluated through criteria such as considering safe conduct as a positive factor for advancement, providing rewards and incentives for the reporting of hazards, fostering awareness among workers through programs during safety week celebrations, fostering healthy competition among workers to report unsafe conditions or acts, and encouraging supervisors to welcome and motivate workers to report safety concerns.

In many developed countries, the management of industrial plants often adheres to the practice of recruiting new personnel who inherently possess a safety-conscious attitude in their work. This approach can be viewed as a management practice that not only cultivates safety-conscious employees but also contributes to enhancing the overall motivation of the workforce. Turner (1991),57 Eckhardt (1996),[58] and Vredenburgh (2002)[59] have all identified that considering safety performance in the employee selection process significantly predicts injury rates. Conversations with senior executives in various industries have indicated that this practice is not commonly implemented in Indian industries due to factors such as a large population and a high unemployment rate. Consequently, this particular management practice is not addressed in this study.

5.8 SAFETY PERFORMANCE

While traditional metrics for assessing safety performance primarily rely on accident or injury data, it's worth noting that safety-related behaviors, such as safety compliance and safety participation, can also be regarded as integral facets of safety performance. Safety compliance reflects how employees behave to enhance their own safety and well-being, whereas safety participation encompasses the behaviors of employees that contribute to the safety and well-being of their colleagues, aligning with the organization's stated goals and objectives (Hagan et al., 2001).[60]

The model proposed by Neal and Griffin (1997),[61] which draws from job performance theories makes a distinction between antecedents of performance, determinants of performance, and components of performance. Neal et al. (2000)[62] identified safety climate as an antecedent of safety performance, with safety knowledge and safety motivation serving as determinants of safety performance. Safety compliance and safety participation are regarded as components of safety performance. In a different study, Pousette et al. (2008)[63] measured safety motivation and safety knowledge as two distinct safety-related attitudes. Self-reported safety behaviors were assessed through three safety behavior measures: structural safety behavior (related to participation in organized safety activities), interactional safety behavior (concerning safety activities in day-to-day work involving interactions with colleagues and management), and personal safety behavior (evaluating behaviors aimed at personal protection). In light of these studies, the authors of the present study integrated employee perceptions of the six identified safety management practices as antecedents of safety performance. The determinants of safety performance were measured by assessing safety motivation and safety knowledge, while safety compliance and safety participation were used to gauge the components of safety performance in this study.

5.9 DISCUSSION

In this section, we present the key underlying discussion questions that must be addressed to enhance the effectiveness of safety management systems. The questions are followed by possible solutions and various efforts being put in for safety management by an organization.

Question: Are there any specific KPIs related to analyzing the effectiveness of personnel after training and work related to various safety initiatives? If yes, then how do they influence the overall performance of personnel and the system as a whole?

Possible solution: There are different KPIs that can be used to measure various aspects of safety management. Incident rate reduction involves reducing safety incidents and safety initiatives. A lower incident rate represents a better safety performance. The compliance rate with the safety procedures and safety guidelines. The higher the compliance rate, better the safety management systems in place. Knowledge and retention related to retaining the information and skills developed during safety trainings. Another significant KPI is the safety culture assessment frameworks to verify the effectiveness of safety culture. With proper KPIs in place, there can be fewer disruptions, higher morale, increased productivity within the workforce.

Question: Are there financial metrics related to calculating the return on investment of the safety management efforts? If the safety incidents/accidents are reduced and there is a financial benefit, is it accounted for while spending on safety management initiatives?

Possible solution: While determining the return on investment related to safety management efforts, different organizations opt for different initiatives related to financial metrics. These metrics quantify the effectiveness of safety initiatives. Reduction in incidents results in financial benefits due to reduced medical expenses, worker compensation, legal and compliance costs, etc. Saving calculation cost, budget allocation, monitoring, and benchmarking help in enhancing the return on investment to allow making informed decisions related to safety management investments.

Question: How can an organization quantify the extent of resilience of the safety culture inside an organization and its management? How does benchmarking of safety value contribute to the data-driven decision-making related to safety management? Is there a need for industry-specific benchmarking that is accepted globally to make our systems more resilient during emergencies/catastrophic situations?

Possible solution: Organizations can quantify their resilience through various safety-related assessments, questionnaires, surveys, etc. Quantitative assessments can be done by deploying models like the Relative Importance Index (RII) that ais in providing insights into various strengths, and weaknesses of safety management across an organization. These assessments are also useful in identifying areas of improvement where an organization will excel. Benchmarking and data-driven decision-making helps in collecting valuable data sources to enhance safety performance. Industry-specific benchmarking, regulatory requirements, and sector-specific hazards help in making resilient systems during emergencies, natural disasters, pandemics and other catastrophic events.

Question: How can organizations use the various Information and Communication Technology (ICT) tools and methodologies to effectively collect, process, and act on safety data in the shortest amount of time?

Possible solution: The data collected from different systems must be visualized to aid in effective data-driven decision-making by management and information being pushed across internal/external stakeholders and communities around the organization.

Question: How can generative AI and Large Language Models aid in enhancing the safety management systems while parallelly making the personnel more equipped with the latest information?

Possible solution: Leveraging the generative AI and large language models can aid the training professionals in developing smart, automated use case-oriented training modules, and materials enhancing the use of safety protocols and providing real-time on-demand safety information to employees. These generative AI-based solutions help in creating realistic safety scenarios, enhancing the incident response via simulations, and ensuring up-to-date information delivery to personnel through on-demand trigger-based systems.
response via simulations, and ensuring up-to-date information delivery to personnel through on-demand trigger-based systems.

6

Policy and Regulatory Framework

Policy & Regulatory Framework for Indian Chemical Sector

With the emerging trend in ESG performance reporting, the chemical sector is also concerned about a few sustainability challenges triggered by the toxic chemicals usage, water consumption, and greenhouse gas emissions.

Indian Chemical sector's tryst with sustainability, however, could be dated back in 1980s with the sector's response to chemical disaster through regulatory regime.

The direct implication of historical safety issues in 1980s at country's judicial and policy level was adoption of Absolute Liability in environmental adjudication, as well as introduction and enforcement of Public Liability Insurance Act (PLI) and Manufacture, Storage, and Import of Hazardous Chemicals Rules (MSIHCR). The introduction of principle of Absolute Liability in Indian judicial system was a crucial step in compelling Indian Chemical sector for developing robust environment, health, safety and sustainability performance management systems and policies. The principle states that those enterprises or Industries which are involved in hazardous or inherently dangerous activities for their commercial gain and if that activity can cause catastrophic damage, then the enterprise is liable to pay compensation to the aggrieved parties. Whereas the PLI was introduced to provide public liability insurance for the purpose of providing immediate relief to the persons affected by accident occurring while handling any hazardous substance. On the other hand, MSIHCR provides comprehensive requirements on safe and environmentally sound handling, usage, and storage of 684 hazardous and toxic chemicals listed in the rules.

Between 1980 and early 90, Indian Chemical sector was equipped with norms and guidelines on environmentally safe management of chemicals produced and used in their own factories.
The focus then shifted to a new concern for the sector. The concern was for in-bound chemicals from developed countries. Imports across the sector have increased steadily in recent years, with petrochemical intermediates accounting for over 30 percent of total imports.

However, the much-needed import related National Policy and regulations started being into effect since 1992, when India became a member of the Basel Convention. The Basel Convention aims to protect the environment by bringing measures to control and regulate hazardous and other waste disposals. It applies Prior Consent Approval procedure to regulate the transboundary movement of the hazardous and other wastes. The member nations to the convention are required to have domestic legislation for both prevention and the punishment of the illegal trafficking of such hazardous wastes. The Convention regulates various range of chemical wastes including biomedical and healthcare wastes, used oils, used lead acid batteries, Persistent Organic Pollutant wastes (POPs wastes), chemicals and pesticides that persist for many years in the environment, Polychlorinated Biphenyls (PCBs), compounds used in industry as heat exchange fluids, in electric transformers and capacitors, and as additives in paint, carbonless copy paper, sealants and plastics and thousands of chemical wastes generated by industries and other consumers. Besides waste, the Basel Convention also handles some topical issues like electronic and electrical waste (e-waste) such as mobile phones and computers, ships destined for dismantling, mercury and asbestos wastes and Illegal dumping of hazardous wastes.

India responded to this International Convention with range of legislations such as Hazardous and Other Wastes (Management and Transboundary Movement) Rules of 2016, Bio-Medical Waste

Management Rules 2016, and E-waste Management Rules 2016. All these legislations, especially the Hazardous Waste regulations constitute a significant element of Indian chemical sector's sustainability performance with respect to waste management and handling.

By ratifying Basel Convention, India significantly restricts and regulates import of hazardous and toxic chemical wastes. But the most crucial chemical import related International Convention remains in dilemma. The Rotterdam Convention is the name for that Convention which was adopted by the Conference of Plenipotentiaries (COP) in 1998 in Rotterdam (Netherlands) that aims to promote shared responsibilities in relation to the international trade of hazardous chemicals. The parties of the Rotterdam Convention ensure shared responsibilities and cooperative efforts while trading certain hazardous chemicals internationally, through Prior Informed Consent (PIC) procedure.

Having a national level policy and regulation in line with this convention could have immensely contributed to the sustainability journey of Indian Chemical Sector. However, India has only acceded to Rotterdam Convention on 24th May 2005, but did not ratify it. Thus, no legislation is in place to further strengthen the country's chemical sector's sustainability goal. The main point of conflict from India's point of view is Chrysotile Asbestos, which is a well-debated mineral that is speculated to be added in Annex III of the Rotterdam convention. India's Fiber Cement Product Manufacturer's Association in the COP 9 to the Rotterdam Convention opposed the listing of Asbestos in Annex III of PIC procedure, saying there were no Indian studies showing negative health impacts from chrysotile exposures. India though has banned asbestos mining in India.

However, being the world's 6th largest importer of chemicals, Indian Chemical sector would have achieved some significant sustainability milestone, by having its own binding norms through establishing a prior informed consent ("PIC") procedure to ensure that restricted hazardous chemicals are not exported to them that they do not wish to receive.

One of the biggest success stories of Indian Chemical Sector's sustainability journey is of course its contribution in phasing out ozone depleting refrigerants. India, as Party to the Montreal Protocol since June 1992, has been successfully implementing the Montreal Protocol and projects and activities for phasing out of ozone depleting substances, in line with the phase out schedule of the Protocol. India phased out Chlorofluorocarbons, Carbon tetrachloride, Halons, Methyl Bromide and Methyl Chloroform for controlled uses as on 1st January 2010, in line with the Montreal Protocol schedule (the ratification enforces Ozone Depleting Substances Rules). Currently, Hydrochlorofluorocarbons (HFC) are being phased out as per the accelerated schedule (by end of 2040) of the Montreal Protocol. The study on reduction of Greenhouse Gas (GHG) emissions through phase-out of Ozone Depleting Substances (ODS) under the Montreal Protocol implementation in India, carried out by the Ministry of Environment, Forest and Climate Change estimates that the reduction of GHG emissions due to phase-out of ODS till 2022 is 465 million tonne $C0_2$ equivalent, while it is expected that the reduction of GHG emissions till 2030 is expected to be 778 million tonnes of $C0_2$ equivalent.

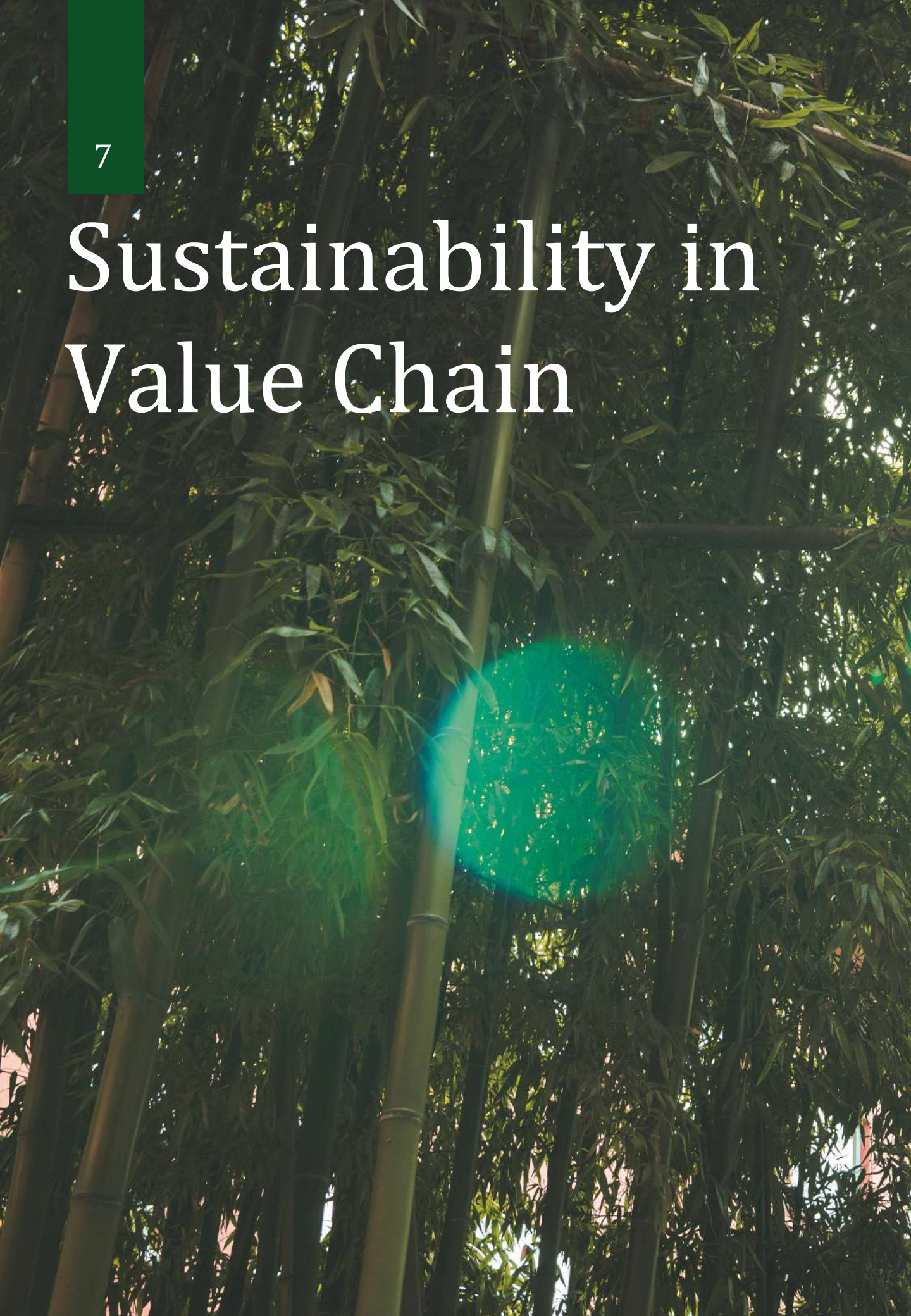
It is expected that the implementation of actions emerging from India Cooling Action Plan (ICAP) will supplement efforts in adopting climate-friendly alternatives and promotion of energy efficiency during the implementation of HFC phase-out under the Kigali Amendment. This will significantly contribute to India's climate action in achieving the net zero emissions by 2070, through the 'Panchamrits', committed by the Prime Minister of India, at the Climate Change Conference of Parties in 2021.

There are national policies and regulatory framework in place which provide foundation for Indian Chemical Sector in formulating an ESG vision and strategy. Also, there is no denial that there are gaps in terms of having appropriate sustainability policies/regulations for the sector. The sector should review their current business practices to understand where they stand and what could be changed.

There should be prioritization of sustainability drivers that matter most and then those can be used to formulate a clear ESG vision. The sector's efforts for improving decarbonization should be at the forefront. Emissions are a major consideration in the environmental impact of the chemical sector. In absence of robust chemical import-export regulatory framework and National policy, the sector should be actively exploring green growth opportunities and developing products with a focus on sustainability to meet the needs of today's environmentally conscious domestic and global customers.

7

Sustainability in Value Chain



Sustainability in Value Chain

Sustainability was initially conceptualized into supply chain management context mostly from the perspective of environmental performance, popularly known as Green Supply chain management (GSCM). Subsequently, social issues were also given equal importance and an approach based on broader perspective of sustainability including finance, environment and in social aspects, popularly known as Sustainable Supply Chain Management (SSCM) evolved.

SSCM is defined as, "the management of material, information, and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements". (Ref: Sustainable supply chain management in the chemical industry: Evolution, opportunities, and challenges by Rajeev A, Rupesh K. Pati, Sidhartha S. Padhi, 2019) According to McKinsey research, the India's chemical industry has been a global outperformer in demand growth and shareholder wealth creation over the last decade. The country is set to be the fastest growing global demand center for chemicals on the back of rising disposable incomes, a favorable demographic dividend, increasing global preference for biofriendly alternatives, and growing diversification of global chemical supply chains.

The Indian Chemical industry is considered the sixth largest seller of chemicals in the world and the fourth largest in Asia. According to joint study by McKinsey and the Indian Chemical Council (ICC) notes that India's contribution to global sales is expected to triple by 2040 at this rate of growth, making the country a $850-1,000 billion market with a 10-12% share of global sales.

With the unprecedented growth expected in the chemical industry and considering worldwide spread supply chain, it is important for chemical industry to safeguard long-term business continuity as environmental regulations, such as mandatory zero liquid discharge, 'net-zero' emissions or carbon neutrality, grow increasingly stringent worldwide. In essence, a focus on sustainability in the supply chain is an essential prerequisite for the future viability of companies.

7.1 KEY CHALLENGES AND RISKS IN SUSTAINABLE SUPPLY CHAIN

Managing supply chain is a key challenge for many chemical companies considering its complexity, evolving regulations lack of integration of sustainability framework and monitoring. Some of the key risks/challenges are as follows:

- Evolving regulations: In most case the supply chain in is spread across multiple geographies and jurisdiction with the ever-evolving regulatory landscape, there is a long list of requirements that need to be complied and monitored to avoid supply chain disruption, legal scrutiny, and reputational risk. In other words, chemical companies must comply or face costly fines/closure

- Supply chain complexity monitoring: For chemical companies, the product manufactured is likely to have multiple material suppliers across the value chain, which adds to the layer of complexity Monitoring of such complex supply chain therefore poses a major hurdle especially when it comes to keeping track of sustainability measures being adopted and implemented.

Integrating and demonstrating environmental and social responsibility: Consumer expectations on integrating and demonstrating compliance to environmental and ethical standards by the suppliers

have grown in recent years, with global issues like climate change, environmental degradation etc. taking center stage This is also being complemented by pressure being put on by regulators to source in a sustainable manner This is a major challenge experienced by the smaller suppliers and or those based out of developing countries, where regulatory enforcement lacks clear mandate and execution.

7.2 ADDRESSING THE CHALLENGE IN SUSTAINABLE SUPPLY CHAIN

Many companies in the chemical industry have already begun to focus on sustainable supply chain management. For the supply chain, this means that in addition to economic criteria, environmental, health, safety, and social criteria must also be met by the chemical industry and its value chain – both upstream and downstream.

As on onset of this endeavor, it is imperative that the leadership team and board of the chemical manufacturing company acknowledges the importance of sustainable supply chain. Also, that it further transfers to the actionable measures impacting the supply chain management viz. supplier selection process and management. Studies show that chemical companies spearheading this movement have established targets, metrics, measures, and code of conduct for ensuring sustainability in supply chain management.

In the last decade, there have been important steps in this direction including initiation of "Together for Sustainability (TfS)" founded in 2011. The group companies in TfS are committed to ensure responsible procurement of goods and services, and to improve environmental, health and safety, and social standards in the industry. This is achieved by conducting standardized supplier assessments. Another such initiatives in this direction are initiative by Sustainability Initiative of the German Chemical Industry by publishing Guide to Sustainable Supply Chain Management, and Action Plan on the Circular Economy by the European Union, and many others across the World.

The challenge of sustainable supply chain for Chemical industries have also proved to be an opportunity for technological knowledge transfer from key manufacturers to their entire supply chain, bringing highest possible transparency in data exchange, and innovation in the chemical industry management of sustainability aspect.

One Step Forward: Circular Supply Chain Management (CSCM) in the Chemical Industry
Circular supply chain management is an extension of circular economy (CE). The consistent decade long attempt for achieving sustainability in the supply chain has opened the innovative suppliers' outlook to look for opportunities to step up and explore the inclusion of CSCM in the manufacturing process. Companies have initiated attempts to minimize the consumption of materials and resources by closing material and energy cycles. In other words, they aim to avoid waste and emission generation, material losses in the life cycle of production, and constantly aim to find alternatives for extraction of raw materials from environment.

The latter is majorly done through exploring the possibility of using recycled material in the process. As an impact of these efforts, it is evident that the pollution load is gradually reducing, and biodiversity is protected through efforts of such Chemical industry on the path of CSCM. Another important factor that is driving circular supply chain management is the recent environmental regulations such as ban on single use plastic, increased vigilance of pollution control boards and regulatory authorities on solid waste and wastewater management in the industries, and mounting pressure from communities, customers and stakeholders to operate in environmentally responsible manner. Collective efforts of internal and external stakeholders in the chemical industry have made achieving sustainable supply chain a plausible dream.

The seemingly different attempts of sustainable supply chain management, and circular supply chain management, are in fact integrated and interrelated into developing roadmap for chemical

manufacturing companies in meeting their sustainability targets. The challenges of past decade have led to enabling opportunities for a more responsible chemical manufacturing era for India.

8

Responsible Water Management

Responsible Water Management in the Chemical Industry

Water is in crisis – as it is both a victim and driver of climate change.[64]

The impacts of climate change manifest in exacerbated floods, rising sea levels, diminishing ice sheets, wildfires, and droughts. A disrupted global water cycle intensifies climate change on a global and systemic scale, transcending local boundaries. Nonetheless, water also possesses the potential to combat climate change. Sustainable water management plays a pivotal role in bolstering the resilience of societies and ecosystems while curbing carbon emissions.

Sustainable water management plays a pivotal role in bolstering the resilience of societies and ecosystems while curbing carbon emissions. Scientific research underscores the interconnectedness of communities and nations not only through rivers and surface water but also via atmospheric moisture flows. Actions taken in one region can influence rainfall patterns in others.[65]

Science also shows how communities and nations are hydrologically intertwined – not just by rivers and the surface water, but through atmospheric moisture flows. Practices in any one region impact rainfall in others.

Water's significance extends across all sectors, spanning industry, agriculture, housing, and energy. According to US non-profit CDP, which runs a global disclosure system on environmental impact, the chemical sector has a water watch impact rating of "critical". The chemical industry is one of the largest water consumers in India, with around 20% of the total industrial water consumption attributed to the sector. This high-water consumption puts pressure on scarce water resources, leading to water scarcity in some regions.[66] Chemical producers are acutely exposed to physical and reputational risks emerging in the vicinity of production sites.

For most chemical producers, water management remains a low priority. Although water serves as a critical input for chemical processing and plant cooling, most leading companies have low water recycling rates and few actionable goals related to water use.[67]

Without bold and concerted local, national and global actions, the problems of too little, too much and too dirty water – inextricably linked to climate change and the loss of biodiversity, with each reinforcing the other – will only get worse.[68]

8.1 WATER MANAGEMENT SOLUTIONS

The chemical industry over the years has been implementing water saving initiatives at the company level, from reducing consumption to lowering water pollution. However, there is a need to push innovation and drive the advancement of solutions – technologies such as IoT, AI, and advanced meters will be pivotal in monitoring water quality and enabling sustainable water use. The technological landscape may appear ripe with alternatives, but there are often challenges in spotting and assessing the right technologies that may have a significant impact. The water conservation journey often begins with the introduction of measurement technologies to track usage. Adding intelligent and interconnected capabilities to assets can prove advantageous. Beyond simply

monitoring water usage patterns and identifying issues, the true advantages for water management arise when data is integrated to form a comprehensive perspective of the entire system, leading to the generation of actionable insights. Optimizing controlled water losses through evaporation and bleeding is another area that could deliver positive returns.

Water quality is also an important area where improvements can be made. Closed-loop water reuse systems present an appealing option for industries. Numerous industrial processes demand water of exceptional purity, necessitating treatment or filtration between each cycle. The critical factor lies in creating sustainable and economically viable solutions for this purpose. The chemical processing sector will benefit enormously from any new developments in this space. Finding ways to reuse or recycle the large quantities of water used in heating, cooling, and distillation processes could enable significant reductions in plants' water footprints.[69]

Water management has traditionally focused primarily on operational efficiency and regulatory compliance but since water is a local and shared resource, it also important to consider regional effects of climate change, along with competing demands due to population growth and increased production. While the cross-sectoral approach to water management on a local level is gaining prominence, it needs to be enhanced further.

8.2 WATER STEWARDSHIP FOR A SUSTAINABLE TOMORROW

While decarbonization remains high on the industrial agenda throughout 2023, it's not the only sustainability issue demanding urgent attention. Water stewardship is another critical priority for industry leaders, and it requires extensive collaboration and innovation. (Sagentia Innovation) Corporate Water Stewardship emerges as a strategic approach for companies to become responsible water users while mitigating the water risks to their businesses. Many global corporations are publicly disclosing their water risk and responses through initiatives such as the CDP's Investor Water Program, Alliance for Water Stewardship, CEO Water Mandate and Global Reporting Initiative amongst others.

Water stewardship refers to the use of water that is socially equitable, environmentally sustainable, and economically beneficial. It allows chemical producers to derive value from their existing water management practices and continue enhancing them. Water stewardship in the chemical industry not only benefits the environment but also offers financial, regulatory, and reputational advantages while helping companies adapt to changing water-related challenges.

Collective action and community engagement is one of the key elements of the Water Stewardship concept, taking several forms like:

- Local Deals- identifying 'win-win' opportunities alongside external users such as agriculture, communities.
- Engagement with local authorities, government, public and private sectors, NGOs.
- Assessing suppliers based on transparency and reporting of water management performance.

By taking the steps towards Water Stewardship implementation, a site will mitigate all foreseeable risks relating to water. Integrating risk management regarding water quality can yield significant savings by reducing effluent treatment costs. Where the resources and capacities of local governments fall short of meeting demands, Water Stewardship plays a role in stimulating improvements to river basin management by guiding the appropriate actions needed to effect real change.

8.3 WATER POSITIVITY – LEADING THE WAY TO ABUNDANT FUTURE

Sustainable water supplies are not a given any more. Businesses working in areas of water scarcity don't want to be viewed as making the problem worse. Water-positive pledges aim to help companies align with UN goals for people to have adequate access to clean water while also securing their own water supply. What differentiates water positive from just saving water is the focus on areas where water security is a problem and overcompensating for consumption in those places.[70]

NITI Aayog, in August 2023, laid out a standard definition and approach of water neutrality/ positivity for Indian industries, which intends to save water, promote efficient water use and enable evaluation and validation of the water neutral/positive claims made by industries. It proposes standard definition of water neutrality/positivity as:

"Total of direct freshwater use as well as estimated indirect or virtual water use as a part of water critical supply chains, should either be less than or equal to all the quantifiable (and verifiable) water savings achieved as well as to be further (and futuristically) executed towards improving operational water use efficiencies, water conservation efforts (including rainwater harvesting, source diversification, rejuvenation, additional storages etc., both in plant's watershed as well as critical watersheds from where supply chains are derived giving priority on neutralizing impacts in same watersheds or aquifers where high criticality exists and impact occurs." [71]

The general equation (defining the general principle) is defined below:[72]

Water and Wastewater Management at Plant Level **(Within the fence)**	+	Water conservation/water use efficiency at Watershed scale **(Beyond the fence)**	+	Water conservation/water use efficiency and wastewater management of **Supply Chain**	≥	Total water extraction or consumption measured and/or estimated as sum total of freshwater - all of the sources - within the fence. Beyond the fence and as a part of supply chains

Attaining water neutral/water positive status is a journey that calls for collective accountability and responsible actions. The adoption of a water neutrality/positivity approach is expected to bring substantial advantages to the industry.

8.4 NATURE-BASED SOLUTIONS – EMBRACING NATURE'S WISDOM

Traditionally, governments and companies have taken a reactive, risk-based approach to water management, one that focuses on mitigating the economic consequences of floods and droughts but pays little consideration to environmental impacts. Now is the time to change this outdated approach to water management by investing more in the power of nature-based solutions (NbS), which protect and enhance ecosystem services, to help manage water with resilience and for the long term. Technological innovation, supportive water governance mechanisms and economic policies, more efficient water operations, and traditional infrastructure and nature-based solutions all have their roles to play in improving how societies manage water.[73]

Nature – based solutions (NbS) offer a vital means of moving beyond business – as – usual to address many of the worlds water challenges while simultaneously delivering additional benefits vital to all aspects of sustainable development. NbS use or mimic natural processes to enhance water availability (e.g., soil moisture retention, groundwater recharge), improve water quality (e.g., natural and constructed wetlands, riparian buffer strips), and reduce risks associated with water-related disasters and climate change (e.g., floodplain restoration, green roofs).[74]

NbS create very promising new opportunities to use water more effectively and efficiently, enable urban farming or mitigate energy consumption. A wide application of NBS needs a systemic change from wanting to do things separately with various technologies towards learning to let nature take

care of them in an integrated way that restores a close to natural local water balance and further important nature functions.

8.5 THE WAY FORWARD

The chemical industry is confronted with a pressing need for responsible water management due to the global water crisis and its interconnection with climate change. As the impacts of climate change intensify, action is needed to optimize water management, reducing industry's reliance on and exploitation of this precious resource. Ambitious goals need to be backed up with practical strategies and appropriate levels of funding. Intelligent use of technology is just one part of the solution. Innovative strategies that change how, where, and when water is used are also required.

Water Stewardship is an emerging paradigm that underscores the responsible and fair utilization of water, yielding advantages for both industry and the natural environment. It emphasizes actions at local level prioritizing the need to understand and engage in the broader catchment, since water users share risks and opportunities related to water resource management.[75]

Moving towards water positivity is another imperative, particularly in water-scarce regions. Companies are focusing on overcompensating for their water consumption, aligning with UN goals for adequate water access.

Additionally, nature-based solutions (NbS) are gaining prominence, shifting from reactive to proactive water management approaches. These solutions mimic natural processes to enhance water availability, quality, and resilience while delivering multiple benefits for sustainable development.

Annexures

Footnotes

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