

Paving the Path to a VIKSIT BHARAT:

Transforming India's Chemical and
Petrochemical Industry through
Sustainability and Innovation



September 2024

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Shri Bhupendra Patel

Hon'ble Chief Minister of Gujarat



Bhupendra Patel

Chief Minister, Gujarat State

Dt. 11-09-2024

Message

The chemical industry in India is a cornerstone of our national economy, influencing a broad spectrum of sectors. Gujarat, as a pioneering state in this domain, remains a leader in chemical production, refining and petrochemical processing. Our robust infrastructure, coupled with our proactive, investor-friendly policies, has significantly attracted both domestic and international firms to establish and expand their operations here. The Gujarat PCPIR (Petroleum, Chemicals and Petrochemicals Investment Region) has been pivotal particularly in drawing investments and promoting sustainable industrial growth with the region. The rapid industrialization of Gujarat, especially within the chemical and petrochemical sectors, has yielded numerous benefits, including substantial economic growth and job creation, enhancing our state's socioeconomic fabric.

I am enthused by **ASSOCHAM Gujarat Council's** initiative to organize the '**Gujarat Chemical and Petrochemical Conclave-2024**' scheduled for **26th September, 2024** with an aim to bring together industry leaders, policymakers, academicians, and other stakeholders to address the sector's challenges and devise strategies for sustainable industry development in alignment with the vision for a '**Viksit Bharat**'. I am delighted to learn that the conclave will feature the unveiling of a Knowledge Paper jointly prepared by ASSOCHAM and ChemAnalyst as Knowledge Partner. I, hereby, extend my heartiest best wishes to for the success of the conclave and for their bright future ahead.


(Bhupendra Patel)

To,

Shri Chintan Thaker
Chairman, ASSOCHAM Gujarat Council
Sakar-3, Opp. Old High Court
Nr. Income Tax, Ahmedabad-14
Nr. Ir

Apro/ab/2024/09/11/rs

Shri Balwantsinh Rajput

Hon'ble Minister for Industries, MSMEs
Government of Gujarat



બલવંતસિંહ રાજપુત



ક્રમાંક: મંત્રી/ઉ.કુ.ઉ.,ના.ઉ.,શ્ર.અને રો./ /૨૦૨૩
શુભ-૨૬૦૧-૨૪૦
મંત્રી,
ઉદ્યોગ, લઘુ, સૂક્ષ્મ અને મધ્યમ ઉદ્યોગ, કુટિર, ખાદી
અને ગ્રામોદ્યોગ, નાગરિક ઉદ્યોગ, શ્રમ, કૌશલ્ય
વિકાસ અને રોજગાર,
ગુજરાત સરકાર
સ્વર્ણિમ સંકુલ-૧, બીજો માળ,
સચિવાલય, ગાંધીનગર-૩૮૨૦૧૦
ફોન નં. ૦૭૯-૨૩૨૫૦૨૩૬
ફેક્સ નં. ૦૭૯-૨૩૨૫૦૨૬૪
તારીખ : ૨૩/૦૯/૨૦૨૪

શુભેચ્છા સંદેશ

સ્નેહીત્રી,

એસોસિએમ દ્વારા તા.૨૬ સપ્ટેમ્બર, ૨૦૨૪ ના રોજ "ગુજરાત કેમિકલ એન્ડ પેટ્રોકેમિકલ કોન્કલેવ" નું આયોજન ઉત્સાહપર્ણક છે.

ભારતના યશસ્વી વડાપ્રધાનશ્રી નરેન્દ્રભાઈ મોદીના વડપણ હેઠળની ભારત સરકાર દેશમાં ઔદ્યોગિક, આર્થિક, માળખાગત અને સામાજિક ક્ષેત્રે ઐતિહાસિક સુધારણા સહ "નવા ભારત" ના નિર્માણની સર્વોત્તમ કામગીરી કરી રહી છે અને તેમના માર્ગદર્શન તળે રાજ્યમાં માન.મુખ્યમંત્રીશ્રી ભૂપેન્દ્રભાઈ પટેલના નેતૃત્વવાળી ગુજરાત સરકાર "સર્વાંગી વિકાસ" તેમજ "વિકસિત ગુજરાત થી વિકસિત ભારત" ની દિશામાં મજબૂત પગલાં ભરી રહી છે.

ગુજરાત કેમિકલ અને પેટ્રોકેમિકલના ક્ષેત્રે અગ્રણી રાજ્ય છે અને આ ક્ષેત્ર રાજ્યના ઔદ્યોગિક ઉત્પાદન અને રોજગાર નિર્માણમાં નોંધપાત્ર યોગદાન આપે છે. આ કોન્કલેવ રસાયણ ઉદ્યોગના અગ્રણીઓ, નીતિ ઘડવૈયાઓ, સ્ટાર્ટ-અપ અને નિકાસકારોને આ ક્ષેત્ર સામેના પડકારો, તકો અને તકનીકી ચર્ચા કરવા માટે એકસાથે લાવશે અને નવોદિત ઉદ્યોગકારોને ઉપયોગી બીવડશે તેવી આકાંક્ષા સહ કોન્કલેવની સફળતા માટે એસોસિએમ ગુજરાત કાઉન્સિલને શુભેચ્છાઓ અને સૌ આયોજક ઉદ્યોગકાર મિત્રોને આ આયોજન માટે અભિનંદન પાઠવું છું.

આપનો સ્નેહાદીન,


(બલવંતસિંહ રાજપુત)

પ્રતિ,

શ્રી વિપુલ બી. ગર્જીંગવાર,

સ્ટેટ હેડ-રીજીયોનલ ગુજરાત કાઉન્સિલ,
એસોસિએમ, ગુજરાત.

Shri Kanubhai Desai

Hon'ble Minister for Finance, Energy & Petrochemicals
Government of Gujarat



KANUBHAI DESAI



No. FEP/ *MESSAKE/27/2024*
/202
Minister,
Finance, Energy & Petrochemicals,
Government of Gujarat,
Swarnim Sankul-1, Gandhinagar.
Telephone : (079) 232 38152, 232 43506
232 50211 to 50214
Fax No. : (079) 232 50215
Date :- *18/09/2024*

Message

Gujarat's economy has become one of the most dynamic in the nation, drawing attention from both domestic and international sources. Our state has constantly been at the forefront of economic development.

With the help of Gujarat's advantageous location, highly qualified labour force, and strong infrastructure, we hope to establish an environment that will support industry growth. Our policies are designed to facilitate commercial operation, improve infrastructure and promote sustainable growth.

Gujarat has positioned itself as a pioneer in the energy and petrochemicals sectors, with major investments and improvements in both traditional and renewable energy. We are committed to convert Gujarat into a green energy power house that meets global environmental requirements while also increasing industrial capacity.

We are optimistic that Gujarat will continue to reach new benchmarks in its industrial development with sustained cooperation of institutions like ASSOCHAM. I send my warm regards to the ASSOCHAM Gujarat Council for their Annual report 2024.

Kanubhai Desai
(Kanubhai Desai)

E-mail : min-fin@gujarat.gov.in / min-ener@gujarat.gov.in

Shri Harsh Sanghvi

Hon'ble Minister of State for Home and Industries
Government of Gujarat



Harsh Sanghvi



Minister of State

४५६

Sports, Youth Service, Co-ordination of voluntary organization, Non-resident Gujaratis' Division, Transport, Gruh Rakshak Dal and Gram Rakshak Dal, Civil Defence, Jail, Border Security (All Independent Charge), Home and Police Housing, Industries, Cultural Activities (State Minister)

Government of Gujarat

Date:

17 SEP 2024

Gujarat has long been a key player in India's industrial sector, with prominence in the chemical and petrochemical industries. Our state's success in these areas is driven by a culture of innovation, strategic investments, and a comprehensive infrastructure that supports a wide variety of sectors. The chemical industry has been a central force behind Gujarat's economic growth, significantly contributing to industrial output and employment.

I am deeply impressed by Gujarat's achievements in chemical production and processing. Initiatives such as the Gujarat PCPIR have played a crucial role in attracting major investments from both domestic and international players. These efforts have not only strengthened the chemical sector but also set the stage for a more sustainable industrial future.

The upcoming **ASSOCHAM Gujarat's "Chemical and Petrochemical Conclave 2024"** is a testament to our state's ongoing commitment to this vital industry. As this event will bring together leaders, policymakers, and academics to examine the sector's current challenges and future opportunities. I am sure the conclave will address key areas in this sector such as fostering innovation, enhancing sustainability, and promoting collaboration—essential for maintaining Gujarat's position at the forefront of the industry.

I extend my gratitude to **ASSOCHAM Gujarat Council** for their dedication to organizing this important Conclave. I am confident that the dialogue and collaborations fostered at this conclave will pave the way for a prosperous and forward-thinking future for Gujarat's chemical & Petrochemical industry.

I wish ASSOCHAM Gujarat Chemical & Petrochemical Conclave - 2024 a Great success.

(Harsh Sanghvi)

To,
Shri Vipul B Ganjingwar (ASSOCHAM)
608, 6th Floor, Sakar-3,
Opp. Old High Court,
Income Tax, Crossroads, Ashram Road,
Ahmedabad- 380014 M. 8010472950

Swarnim Sankul - 2, 1st Floor, Sardar Bhavan, New Sachivalaya, Gandhinagar-382 010

Phone No.: (0) 079-23251958/59/60/61/63 | Fax No.: 079-23251962

Website: www.harshsanghvi.in | E-mail: min-home@gujarat.gov.in

Shri Jagdish Vishwakarma

Hon'ble Minister of State for Micro Small and Medium Enterprises
Government of Gujarat



JAGDISH VISHWAKARMA



No.: MoS/Co.SI.P&S.P/MSMI.CKRI.GA/ 1804-1 /202 4

**Minister of State,
Co-operation, Salt Industries,
Printing and Stationery, Protocol
(Independent Charge),
Micro, Small and Medium Industries,
Cottage, Khadi and Rural Industries,
Civil Aviation, (State Minister),
Government of Gujarat**

Swarnim Sankul-2, 1st Floor, Sardar Bhavan,
Sachivalaya, Gandhinagar-382010

Date: 13/09/2024

MESSAGE

Gujarat, a state renowned for its entrepreneurial spirit and industrial prowess, stands at the forefront of India's chemical and petrochemical landscape. In FY 2023-24, the State exported petroleum products, organic and inorganic chemicals worth USD 72 Billion, contributing to around 64% in India's exports of these sectors. With refining complexes, LNG terminals, Oil terminals, manufacturing clusters as well as future-ready ports, the State offers a complete and comprehensive ecosystem for the investors.

I appreciate ASSOCHAM Gujarat Council for organizing this timely conclave on chemical & petrochemical with an objective to focus on leveraging emerging technologies, adopting green practices, ensuring safety and promoting responsible waste management.

I look forward to the outcomes of this conclave and the continued growth and development of Gujarat's chemical and petrochemical industries, fueled by the innovation and resilience of our MSMEs."

I wish the Conclave a great Success.


[Jagdish]

To.
Chairman,
ASSOCHAM Gujarat Council,
608, SAKAR-III, Opp. Old Highcourt,
Income Tax Cross Road,
Ashram Road, Ahmedabad.

880

Smt. Mamta Verma, IAS

Principal Secretary

Department of Industries and Mines, Government of Gujarat



Mamta Verma, IAS
Principal Secretary



Message

MIS/PS-IMD/2024/37
Industries & Mines Department
Government of Gujarat
Block No. 5, 3rd Floor,
Sachivalaya, Sardar Bhavan,
Gandhinagar-382010.

Date : 23 SEP 2024

Gujarat has long been at the forefront of India's industrial landscape, particularly in the chemical and petrochemical sectors. Our state's industrial prowess is built on a foundation of innovation, strategic investments, and a robust infrastructure that supports a wide array of industries. The chemical industry has been a cornerstone of Gujarat's economic growth, contributing significantly to our state's industrial output and employment generation.

Our state's proactive initiatives, such as the establishment of the Gujarat PCPIR (Petroleum Chemicals and Petrochemicals Investment Region), have been instrumental in attracting both domestic and international investments. These initiatives have not only bolstered the growth of the chemical sector but have also set the stage for sustainable industrial development in Gujarat.

The **ASSOCHAM's Gujarat Chemical and Petrochemical Conclave - 2024, scheduled on 26th September 2024**, is a testament to our continued commitment towards advancing the chemical industry. This conclave will bring together industry leaders, policymakers, academicians and other key stakeholders to discuss the challenges and opportunities in the sector.

I am also happy to know that a KNOWLEDGE PAPER Jointly Prepared by **ASSOCHAM & ChemAnalyst** will be released during the Conclave. I am sure that the Knowledge Paper will provide valuable insights and a strategic roadmap for the future of the chemical industry, emphasizing the importance of sustainable practices and innovation in achieving long-term growth.

I commend ASSOCHAM Gujarat for their unwavering dedication in organizing this significant event and for their efforts in crafting such an insightful document. I am confident that the discussions and collaborations from this Conclave will enable the participants to explore more sustainable and innovative industrial practices and will contribute to a brighter and prosperous future for Gujarat's chemical industry.

My best wishes to ASSOCHAM Gujarat Council for the great success of the Conclave.


(Mamta Verma)

Shri Sandip J. Sagale, IAS

Industries Commissioner
Government of Gujarat



Sandip Sagale, IAS
Industries Commissioner



Date – 23/09/2024

Message

Gujarat has emerged as a leading state in India for the chemical and petrochemical industry with its strategic location, excellent infrastructure and a conducive business environment. State's commitment to fostering industrial growth and innovation has created a fertile ground for businesses to grow.

The chemical and petrochemical sector plays a very important role in Gujarat's economy, driving job creation, technological advancements and contributing significantly to our exports. The state's abundance of natural resources, coupled with a skilled workforce and supportive policies has made it an attractive destination for both domestic and international investors.

The Government of Gujarat has been consistently working towards creating a conducive ecosystem for the chemical and petrochemical industry. We have implemented various initiatives to streamline regulatory processes, enhance infrastructure and promote research and development. These efforts have resulted in a significant expansion of the sector and have attracted investments from leading global players.

I am pleased to note that the ASSOCHAM Gujarat Council has taken the initiative to organize this important conclave. Such platforms provide valuable opportunities for industry stakeholders to come together, exchange ideas, and explore new avenues for growth. I am confident that the discussions and deliberations during this conclave will contribute to the further development and strengthening of the chemical and petrochemical industry in Gujarat.

As we look ahead, Gujarat remains committed to its vision of becoming a global chemical and petrochemical hub. We will continue to focus on infrastructure, promote innovation and create a favourable business environment to attract investments and drive sustainable growth.

I extend my sincere gratitude to the ASSOCHAM Gujarat Council and team for organizing this prestigious event. I wish the conference great success and hope that it will be a fruitful platform for knowledge sharing, networking and driving the industry forward.


(Sandip. J. Sagale)

Shri Deepak Sood

Secretary General
ASSOCHAM



The Chemicals and Petrochemicals (C&P) industry has long been a cornerstone of the global economy, contributing significantly to the growth of various sectors such as agriculture, healthcare, textiles, construction, packaging, and automotive. As an integral part of our daily lives, the industry's importance continues to grow.

Today, with the world shifting toward a greener future, the C&P industry is experiencing a transformative shift towards sustainable processes and innovation. This focus aligns with the ambitious goal of reducing emissions to meet the 2030 targets for sustainable development, as outlined by the UN's Sustainable Development Goals (SDGs). Industry is actively pursuing this agenda to ensure lasting protection of the planet and its resources. Striking a balance between socio-economic growth and environmental protection remains paramount. A skilled workforce equipped with relevant training is essential to achieve this balance. Such training fosters a culture of safety, health, and environmental responsibility, ultimately leading to enhanced organizational productivity.

India, with its vast industrial capabilities, stands poised to harness these emerging opportunities. Gujarat has established itself as a major hub for the C&P sector. The state's strategic location, robust infrastructure, and favourable policies have attracted significant investments, with the Gujarat Petroleum, Chemicals and Petrochemicals Investment Region (PCPIR) playing a vital role in fostering sustainable industrial growth. Despite the rapid expansion, the industry faces pressing challenges such as environmental concerns, regulatory compliance, the scarcity of skilled resources, and the pace of innovation. The global chemical industry dynamics favoured India and encouraged chemical companies in Gujarat to turn their insights towards future opportunities in this sector.

However, these challenges also present opportunities for innovation and growth. Further to fuel the growth of Chemical & Petrochemicals industry, need to focus on eco-friendly sustainable products, waste management technological advancements, green chemistry, R&D, infrastructure investments and renewable energy sources to enhance the industry's sustainability and global competitiveness.

On this occasion ASSOCHAM Gujarat Council jointly with ChemAnalyst has come out with this report on the subject highlighting various aspects of the Chemical & Petrochemical Industry. We hope that the contents of the report will provide valuable insights to policymakers, investors and industry stakeholders and the deliberations at the conclave will further help in laying the roadmap for building a sustainable industry for Viksit Gujarat to Viksit Bharat.

Deepak Sood

Shri Chintan Thaker

Chairman

ASSOCHAM Gujarat Council



The Chemical industry is critical for the economic development of any country, providing products and enabling technical solutions in virtually all sectors of the economy. Specialty Chemical is the fastest growing segment in the chemical industry. These are high value, low volume chemicals known for their end-use applications and/or have performance enhancing properties. There is immense potential for increasing consumption within the country as also for India to become a reliable supplier of such quality chemicals to the world. Compared to United States, Europe and even China, there is comparatively very low usage of such chemicals in India. Increasing judicious usage of such chemicals will not only help in the growth of this important segment of the chemical industry but also facilitate overall economic growth.

Gujarat has been the leading state in terms of attracting investment for chemicals industry and today known as the 'Petro Capital' of India. It contributes significantly to the country's petrochemicals production (62 %), chemicals production (51 %) and pharmaceuticals production (35 %). Its business friendly policies have made it the first choice for investors.

The upcoming ASSOCHAM's Gujarat Chemical and Petrochemical Conclave - 2024," scheduled for 26th September 2024, is a testament to our continued commitment to advancing the chemical industry. As this conclave will bring together industry leaders, policymakers, academicians, and other key stakeholders to discuss the challenges and opportunities facing the sector.

I am also happy to know that a KNOWLEDGE PAPER Jointly Prepared by ASSOCHAM & ChemAnalyst will be played an instrumental role to all stakeholder, It can also serve as a foundation for new evidence-based policymaking or incentives in the future. In this regard, the report provides an overview of India's CPC industry in the international and national scenario, highlighting the drivers of growth for the industry. A major focus is laid on bringing out pivotal and relevant information to comprehend the investment potential that lies within the state.

I wish my ASSOCHAM team for success of the event and best of luck.

Chintan Thaker

Shri Jaimin Shah

Co-Chairman

ASSOCHAM Gujarat Council



Gujarat has long been recognized as a leader in the chemical and petrochemical sector. Our state's strategic location, abundant resources and supportive government policies have created a favourable environment for businesses to thrive. However, we must also acknowledge the evolving global landscape and the need to adapt to new challenges.

The future of the chemical and petrochemical industry is marked by a growing emphasis on sustainability, innovation and digital transformation. To remain competitive, we must invest in research and development, adopt advanced technologies & prioritize environmental stewardship.

The ASSOCHAM Gujarat Council is committed to supporting the industry's growth and development. We believe that through collaboration, knowledge sharing and advocacy, we can create a more sustainable, resilient, and innovative future for the chemical and petrochemical sector.

On behalf of the ASSOCHAM Gujarat Council and the organizing committee of the Chemical & Petrochemical Conclave 2024, I would like to express our sincere gratitude to the Government of Gujarat, the Industries Commissionerate, INDEXTb and all other stakeholders for their invaluable support in making this event a success.

We are also deeply indebted to our Knowledge Partner, ChemAnalyst and Strategic Partner, Grant Thornton, for their dedicated contributions and insights. Their expertise has been instrumental in enriching the content and discussions of this conclave.

I appreciate the guidance & support provided by the Chairman of the Chemical & Petrochemical Committee to ASSOCHAM Gujarat Council secretariat in curating & organizing such an impactful event. Together, we can make sure that Gujarat remains at the forefront of promoting environmentally responsible industrial practices.

Thank you.

(Jaimin Shah)

Shri Manish Kiri

Chairman, Chemical & Petrochemical Committee
ASSOCHAM Gujarat Council



It gives me immense pleasure to be part of organizing committee of ASSOCHAM's Gujarat Chemical & Petrochemical Conclave 2024. As this conclave presents a wonderful opportunity to engage with industry leaders and experts under one roof.

The Chemical and Petrochemical industry is the backbone of country's industrial landscape, contributing immensely to various other sectors such as agriculture, pharmaceuticals, textiles, consumer durables, automotive and food processing. With its extensive forward and backward linkages, the industry is a key enabler of India's overall industrial growth, providing essential raw materials and intermediates for numerous downstream industries. As one of the fastest-growing sectors of the Indian economy, the chemical industry is critical to achieving the country's vision of becoming a \$5 trillion economy.

Gujarat, as a leading state in this domain, has always been at the forefront of chemical production, refining and petrochemical processing. The state's chemical industry has larger share in India's total chemical production and an even larger share in the production of petrochemicals. With an extensive network of ports, well-developed industrial estates, and special economic zones, Gujarat provides unparalleled logistical advantages for both domestic and international companies. The state's investor-friendly policies, ease of doing business, and proactive government support have further reinforced Gujarat as a preferred destination for chemical and petrochemical investments.

I would like to take this opportunity to appreciate the visionary leadership of the Hon'ble Chief Minister of Gujarat Shri. Bhupendrabhai Patel ji, whose dynamic approach and relentless pursuit of excellence have been instrumental in transforming Gujarat into a hub for chemicals and petrochemicals. His commitment to fostering innovation and sustainable practices continues to pave the way for the state's industrial growth.

At this occasion, I would also like to express my deep admiration for the Hon'ble Prime Minister of India Shri. Narendra Modi ji, whose global vision and special importance on 'Make in India' and sustainable development have significantly strengthened India's industrial perspective. His leadership has been a driving force in positioning India as a key player in the global economy.

Last but not the least, I extend my heartfelt gratitude to the leadership & secretariat team of ASSOCHAM Gujarat Council for all the efforts to add value in curating & executing this important conclave for Chemical & Petrochemical industry.

I look forward to insightful discussions and strategic recommendations that will further strengthen Gujarat's position as a leader in the chemicals and petrochemical industry, while promoting sustainable industrial practices. I wish the event great success and anticipate valuable contributions from all stakeholders.

(Manish Kiri)

Shri Karan Chechi

CEO & Founder

TechSci Research | ChemAnalyst



As India strives towards its ambitious goal of becoming a developed nation by 2047, the chemical and petrochemical industry plays a pivotal role. This sector is not only crucial for economic growth but also for addressing pressing environmental challenges. By prioritizing sustainability and innovation, the industry can align itself with national objectives and global standards.

The chemical sector significantly contributes to India's GDP and employment across various sectors. As demand for chemical products continues to rise, it's imperative that this growth is sustainable. The industry must adopt eco-friendly practices, reduce emissions, and enhance resource efficiency. Sustainability is no longer a choice but a necessity. The global community increasingly prioritizes Environmental, Social, and Governance (ESG) criteria, urging industries to embrace responsible practices.

Resource efficiency is paramount. Implementing practices that minimize waste and optimize resource use can significantly reduce the environmental footprint of chemical production. The adoption of green chemistry principles is equally important, as it leads to the development of safer and more sustainable chemical processes. Transitioning to renewable energy sources is vital for lowering carbon emissions.

Gujarat has emerged as a leader in transforming India's chemical landscape. The state's proactive policies, robust infrastructure, and collaborative ecosystem have positioned it as a leader in sustainable practices within the industry. The Gujarat government has implemented progressive policies that incentivize sustainability and innovation. Research and development in Gujarat are also noteworthy, with significant investments in educational institutions and innovation hubs.

Achieving sustainability and innovation requires united efforts. Collaborations among industry stakeholders, government agencies, and research organizations are vital for driving systemic change. Public-private partnerships can leverage resources, expertise, and technology to accelerate the adoption of sustainable practices. Forming alliances among companies within the sector facilitates knowledge sharing and collective action towards sustainability goals.

A sustainable and innovative chemical sector can contribute to economic growth, job creation, and environmental protection, ultimately enhancing the quality of life for all citizens. A commitment to sustainability and innovation also enhances the global competitiveness of India's chemical sector, positioning it as a preferred partner in international markets.

Karan Chechi

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Executive Summary

India's chemical and petrochemical industry is on the cusp of a transformative journey, crucial to achieving the nation's goal of becoming a developed country by 2047 under the "Viksit Bharat" initiative. The industry, a vital pillar of the economy, has an unprecedented opportunity to lead in sustainability and innovation, driven by global shifts toward greener practices and circular economy principles.

As one of the world's largest producers of chemicals, India must balance its growth ambitions with environmental responsibilities. The industry faces growing pressure to reduce its carbon footprint, manage resources efficiently, and minimize environmental impact. Aligning with the government's commitment to achieving net-zero carbon emissions by 2070, the sector must embrace sustainable production processes, including renewable energy integration, biotechnological innovations, and advanced carbon capture technologies.

Technological innovation will be critical in this transformation. Advanced technologies such as artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT) will drive efficiency improvements, reduce emissions, and optimize resource utilization. Digitalization, when combined with green technologies, will enable companies to monitor and manage their environmental footprint in real time. These advancements not only contribute to sustainability but also enhance operational compet-

itiveness, making the Indian chemical sector a global leader in sustainable manufacturing.

Gujarat plays a central role in this transformation. The state, which produces over 35% of India's chemical output and 62% of its petrochemical production, has established itself as the country's chemical hub. The Petroleum, Chemical, and Petrochemical Investment Region (PCPIR) in Dahej, Gujarat, is a prime example of how state-level infrastructure and policies can foster industrial growth. With major investments from industry giants like Reliance Industries, ONGC, and BASF, Gujarat is poised to lead India's transition to sustainable industrial practices. The state's chemical sector is already benefiting from its focus on circular economy models, renewable energy adoption, and sustainable infrastructure development. As Gujarat continues to attract global investment and promote green technologies, its leadership will be key in shaping the future of India's chemical and petrochemical industry.

Government policies, including Make in India and AtmaNirbhar Bharat, are paving the way for sustainable growth by promoting green chemistry, enhancing ease of business, and driving investments in cleaner technologies. The National Chemical Policy and Production Linked Incentive (PLI) schemes offer additional support, making India an attractive destination for both domestic and international investment in sustainable chemical production.



The shift toward a circular economy, which emphasizes resource efficiency, waste reduction, and recycling, presents a transformative opportunity for the industry. By adopting circular practices, India's chemical sector can unlock significant environmental and economic benefits, while ensuring resilience in global supply chains.

This shift will require significant investment in infrastructure, technology, and capacity-building, but it holds the potential to position India as a global leader in sustainable manufacturing. Collaboration across sectors will be crucial in realizing this vision. Public-private partnerships, combined with strong ties between government, industry, and academia, will drive research, innovation, and the adoption of green technologies. Gujarat's focus on integrating sustainable practices into its industrial ecosys-

tem offers a model for other regions in India to follow, ensuring that the country's broader economic and environmental goals are met.













In conclusion, India's chemical and petrochemical industry is at a crossroads, with a unique opportunity to lead the global shift toward sustainability. With Gujarat at the forefront of this transformation, and with the support of government policies and technological advancements, the sector can drive India's progress toward becoming a developed nation by 2047. By embracing innovation, fostering collaboration, and prioritizing sustainability, the industry will not only contribute to national economic growth but also ensure a prosperous and sustainable future for generations to come.





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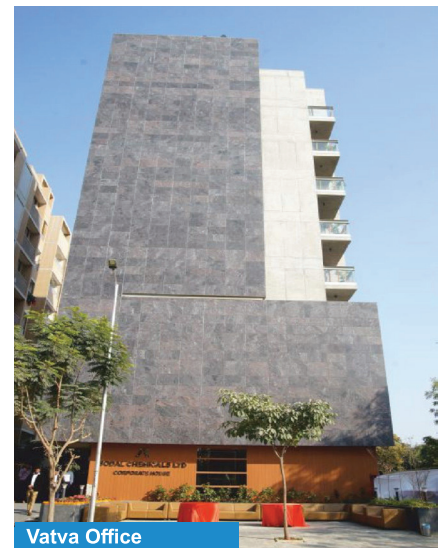
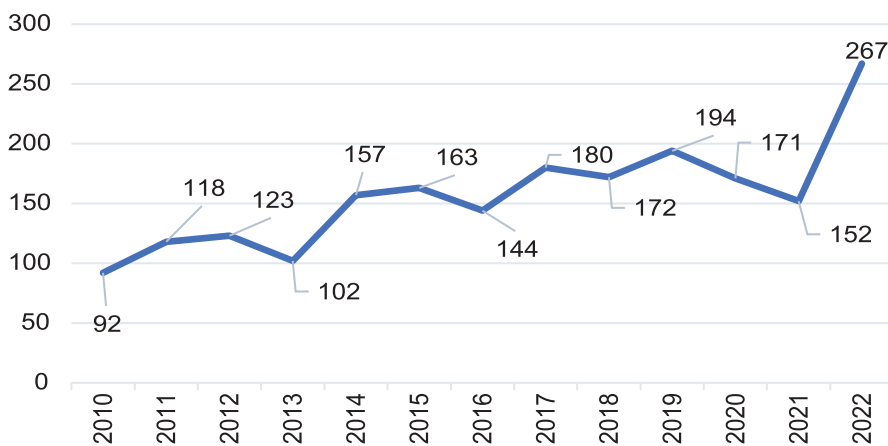
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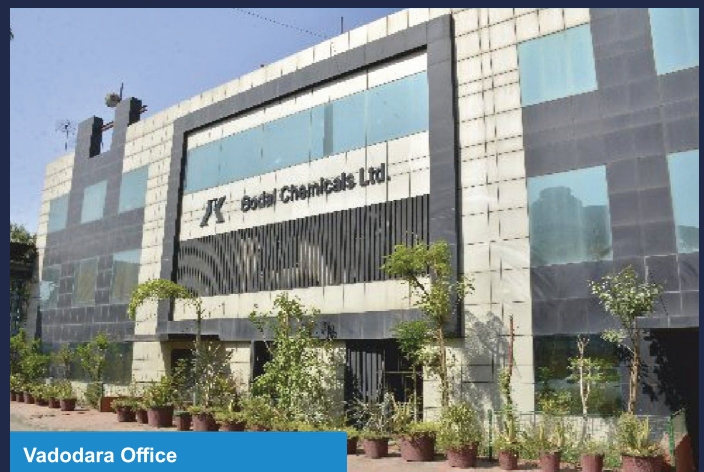
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Chapter - 1

Introduction

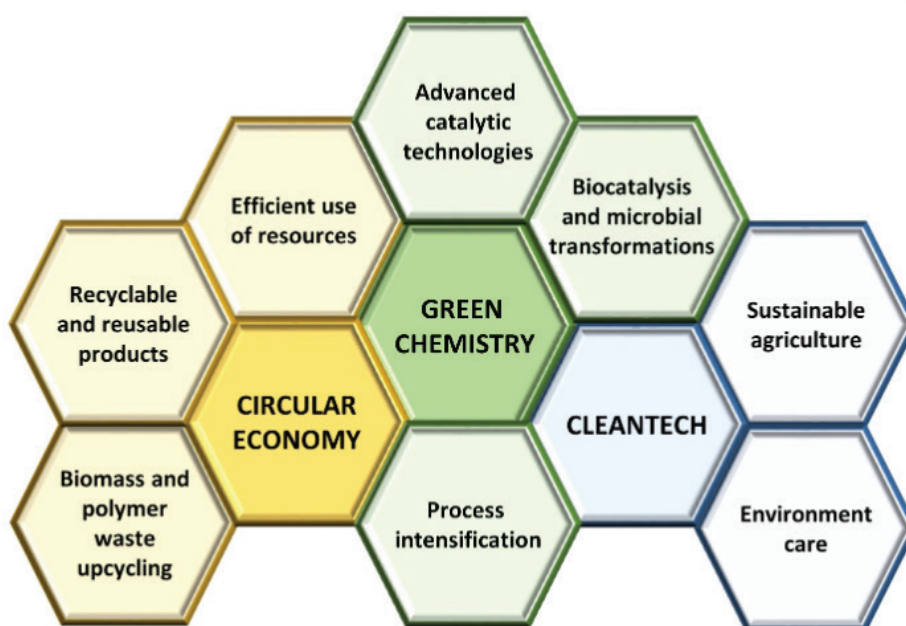
Overview of Sustainability in Industry

The global chemical and petrochemical industry are a cornerstone of modern economies, producing essential chemicals and materials for diverse applications. It plays a crucial role in sectors such as manufacturing, agriculture, and pharmaceuticals, contributing significantly to GDP worldwide. The industry is driven by technological advancements, including innovations in production processes and sustainable practices aimed at reducing environmental impact. As the chemical and petrochemical industry evolves, focus on sustainability and efficiency are becoming vital for maintaining growth and addressing environmental concerns.

Sustainability in the chemical and petrochemical industry is increasingly vital as the sector strives

to balance economic growth with environmental responsibility. The industry faces significant pressure to reduce its carbon footprint, manage resources efficiently, and mitigate environmental impacts. Additionally, the shift towards a circular economy—where waste is minimized, and resources are continuously recycled—plays a crucial role. There is a growing global awareness of the need for sustainable practices across all industries, including chemical manufacturing. However, conventional manufacturing methods have frequently resulted in environmental challenges, such as pollution, waste, and high energy use. In response, the industry is undergoing a major transformation, adopting sustainable practices and pioneering innovative solutions to mitigate these issues.

Figure 1: Green Chemistry and Sustainability



The petrochemical industry is a major driver of the global economy, providing essential materials for a broad range of products and sectors. However, it is also a significant source of greenhouse gas emissions. In response, the industry is adopting greener practices and pursuing sustainability through various strategies. One approach involves utilizing renewable energy sources like solar and wind power in production, which lowers both emissions and energy costs. Additionally, companies are incorporating energy-efficient technologies and optimizing operations to cut energy consumption and enhance efficiency. The industry is also focusing on developing sustainable feedstocks, including biobased and renewable alternatives, to decrease reliance on fossil fuels and explore carbon capture technologies. Investments in cleaner production processes, such as catalytic methods and biorefineries, aim to further mitigate emissions and minimize waste.¹

In India the chemical and petrochemical industry plays a crucial role in the social and economic development. As the nation progresses, supported by government policies that enhance business ease, promote self-sufficiency, and increase manufacturing output, the chemical and petrochemical sector is well-positioned to support and drive this growth. Sustainability in the chemical and petrochemical industry of India is becoming increasingly crucial as the sector supports the country's economic growth while facing environmental challenges. The industry is focusing on reducing its carbon footprint and enhancing energy efficiency to align with India's climate goals. The industry is investing in advanced technologies for better water management and exploring biotechnological alternatives to traditional processes. By embracing these sustainability measures, the Indian chem-

ical and petrochemical sector aims to contribute to the country's economic development while addressing environmental concerns and supporting India's broader sustainability objectives.

The Chemical and Petrochemical Industry of India occupies a crucial role in the economy, acting as a backbone for numerous sectors with a diverse range of over 80,000 commercial products. Although the government has made commendable efforts to reduce import dependency, enhance infrastructure, and improve the business environment, a strong emphasis on chemical sustainability needs to be integrated into this growth narrative. The chemical and petrochemical sector is vital for India's economic growth, supporting industries such as textiles, automobiles, and agriculture. Emphasizing sustainability, there is a call for adopting green chemistry principles, reducing carbon footprints, enhancing energy efficiency, implementing circular economy practices, improving water management, and exploring biotechnological alternatives.

In recent years, India has emerged as a competitive and high-quality manufacturing hub on the global stage, drawing significant foreign investment. According to ChemAnalyst, India's chemical and petrochemical (CPC) industry is projected to reach approximately \$304 billion by 2025. The pandemic has driven the global CPC sector to seek more diversified supply chains and invest in regions with favorable business ecosystems and investment policies. India stands out as a major potential investment destination, bolstered by Asia's expanding role in CPC production and sales.²

The Indian petrochemical industry has expe-

¹ <https://crimsonpublishers.com/pps/fulltext/PPS.000607.php>

² <https://chemicals.gov.in/latest-news/indias-booming-chemical-and-petrochemical-industry-understanding-industry-landscape>

rienced significant growth over the years. According to the Ministry of Chemicals and Fertilisers, Government of India, the proportion of chemicals and petrochemicals (excluding pharmaceuticals and fertilizers) in total national exports rose from 9.2% in 2012-13 to 12.4% in 2019-20. The sector is anticipated to expand rapidly, driven by the AatmaNirbhar Bharat and Make in India initiatives. Given that the industry is emissions-intensive, adopting technologies that reduce emissions is essential for ensuring sustainable growth.³

In recent years, global attention is focused on achieving net-zero emissions, with many countries setting timelines for carbon neutrality. At

Importance of a Viksit Bharat

The term ‘Viksit Bharat’ translates to ‘Developed India.’ Viksit Bharat 2047 embodies the government’s vision to elevate the country to a developed status by the centennial of its independence in 2047. The initiative is built on four key pillars: Yuva (Youth), Garib (Poor), Mahilayen (Women), and Annadata (Farmers).

Viksit Bharat 2047 is a vision to transform India into a developed nation by the centennial of its independence in 2047. This vision includes diverse aspects of development, such as economic growth, environmental sustainability, social progress, and good governance, with the goal of achieving a developed status by 2047. For environmental sustainability, the focus is to maintain a clean and green environment to protect its biodiversity and natural resources of the country.

The vision of “Viksit Bharat” (Developed India)

the COP26 Summit in Glasgow in 2021, Indian Prime Minister committed to reaching net zero by 2070. Achieving this goal requires a major shift in India’s energy mix, as fossil fuels remain a major part of its energy consumption. The Indian chemical sector, crucial to the nation’s economy and energy landscape, is now central to discussions on sustainability and green practices. While it contributes only about 4% of India’s greenhouse gas emissions, its role in essential supply chains—such as fertilizers, pharmaceuticals, and polymers—makes its environmental impact significant. The sector, known for its energy-intensive processes, is preparing to implement strategies that align with the national objective of net-zero emissions.

by 2047 has become a rallying call for national progress. As India seeks to establish itself as a global powerhouse by its 100th year of independence, every state has a vital role to play in achieving this goal. Gujarat, often referred to as the “Growth Engine of India,” stands at the forefront of this mission. With its rich history, entrepreneurial spirit, and progressive governance, Gujarat’s contribution is central to realizing the dream of a developed India. The state’s unique strengths in sectors like industry, agriculture, innovation, and infrastructure make it a critical player in driving the nation’s development journey.

Gujarat has long been recognized as one of India’s most industrialized states. The state’s industrial base, which spans textiles, petrochemicals, pharmaceuticals, and engineering, has been a key driver of India’s economic progress. Major cities like Ahmedabad, Surat, Vadodara,

³ <https://chemicals.gov.in/sites/default/files/Reports/Chemical%2520and%2520Petrochemical%2520Statistics%2520at%2520a%2520Glance-2019%2520%281%29%5B1%5D.pdf>

and Rajkot are home to large-scale industries that contribute significantly to India's GDP and exports.

The Vibrant Gujarat summit, initiated by the state government, has established Gujarat as a global business hub, attracting both domestic and foreign investment. The state's proactive policies, coupled with an entrepreneurial culture, have made it a magnet for industrial development. This aligns perfectly with the vision of Viksit Bharat, as Gujarat's thriving industrial base boosts India's manufacturing capabilities, job creation, and global competitiveness. In addition, Gujarat's success in the Special Economic Zones (SEZs) and its strategic position along the western coastline contribute to India's growing stature in global trade. Ports like Mundra and Kandla not only facilitate India's exports but also position Gujarat as a key logistics hub in India's broader trade network.

Despite being an industrial powerhouse, Gujarat has also made remarkable strides in agriculture. The state is a leader in the production of cotton, groundnut, and milk, thanks to innovations in agricultural practices, water management, and rural infrastructure. The success of the Gujarat Cooperative Milk Marketing Federation (Amul) is a prime example of how cooperative models can empower farmers and drive rural development. In the context of a "Viksit Bharat," Gujarat's agricultural achievements provide a blueprint for other states in terms of water conservation, use of modern technology, and creating robust supply chains. The state's ability to balance industrial growth with agricultural sustainability is essential for achieving inclusive development.

Innovation has always been at the heart of Gujarat's growth. The state is known for its vibrant startup ecosystem, which is fostering new-age entrepreneurs in technology, renewable energy, healthcare, and more. With the establishment of incubation centers, innovation hubs, and collaboration with premier institutions like the Indian Institute of Management Ahmedabad (IIM-A), Gujarat is nurturing the next generation of business leaders who will shape India's future. Moreover, Gujarat's focus on renewable energy, particularly solar and wind, aligns with India's commitment to sustainability and reducing carbon emissions. The state's innovative policies on clean energy transition are paving the way for a greener, more sustainable future, which is an integral aspect of Viksit Bharat.

Gujarat's infrastructure development is a testament to its forward-thinking governance. The state has made significant investments in roads, highways, ports, and airports, providing world-class infrastructure for industries and citizens alike. The development of the Delhi-Mumbai Industrial Corridor (DMIC), which passes through Gujarat, further cements the state's strategic importance in India's push for industrialization and connectivity. Urban centers like Ahmedabad have seen the development of modern transportation systems such as the metro rail and Bus Rapid Transit System (BRTS).

These projects enhance the quality of life for citizens and ensure that Gujarat remains a magnet for talent, investment, and innovation. Gujarat's robust infrastructure is crucial to making India a global investment destination, a key aspect of the Viksit Bharat vision.

OBJECTIVES & SCOPE OF THE WHITEPAPER

The primary objective of this whitepaper is to emphasize the critical role of sustainability in India's chemical and petrochemical industry. It seeks to highlight the need for adopting sustainable practices to align the sector with both national goals, such as achieving carbon neutrality by 2070, and global environmental standards. In addition, the whitepaper aims to promote innovation and technological advancement by underscoring the importance of integrating cutting-edge technologies like artificial intelligence, machine learning, and IoT. These technologies are essential for improving operational efficiency, reducing emissions, and optimizing the use of resources across the industry.

Another key objective is to demonstrate how policy alignment can support industry growth while promoting green chemistry and sustainable manufacturing. The whitepaper explores government initiatives such as Make in India and AtmaNirbhar Bharat, illustrating how these frameworks can drive progress within the sector. It also aims to facilitate the industry's transformation toward a circular economy, advocating for a shift away from traditional linear models. By focusing on waste reduction, recycling, and resource efficiency, the paper shows how the chemical and petrochemical industry can achieve long-term economic and environmental benefits.

Collaboration is also a theme of the whitepaper, which aims to encourage stronger ties between the government, industry, academia, and global stakeholders. Through these collaborations, India's chemical and petrochemical sector can enhance its global competitiveness and play a more significant role on the world stage.

The scope of this whitepaper covers a comprehensive analysis of the industry's current state and future potential with a key focus on the state of Gujarat and the developments happening in the state. The whitepaper also examines the technological advancements driving operational improvements and environmental efficiency while exploring the policy frameworks that support sustainable growth. The paper details the economic and environmental benefits of transitioning to a circular economy, supported by case studies that demonstrate successful implementation of sustainable practices. Furthermore, it highlights collaborative strategies among government, industry, and academia that foster innovation and the adoption of greener technologies. Lastly, the whitepaper provides a roadmap for the future growth of the industry, offering recommendations for achieving sustainability targets and positioning India as a leader in the global chemical and petrochemical sector by 2047.

Chapter - 2

Sustainability

Sustainable Practices and Regulations

Sustainability has become a crucial focus for businesses globally, with stakeholders increasingly demanding greater responsibility for the environmental, social, and economic impacts of industrial operations. According to ChemAnalyst, the global sustainable chemicals market was valued at USD 75.15 billion in 2023, is expected to experience significant growth over the forecast period, with a compound annual growth rate (CAGR) of 7.16% through 2029. The adoption of sustainable chemicals is anticipated to play a crucial role in driving overall sustainability. By shifting towards more eco-friendly chemical solutions, industries can significantly reduce their environmental impact, lower carbon emissions, and enhance resource efficiency. This transition not only supports the broader goals of sustainability but also fosters innovation and contributes to a more sustainable future for both the environment and society. The chemical industry is no exception, and Indian chemical companies are actively moving towards more sustainable practices.

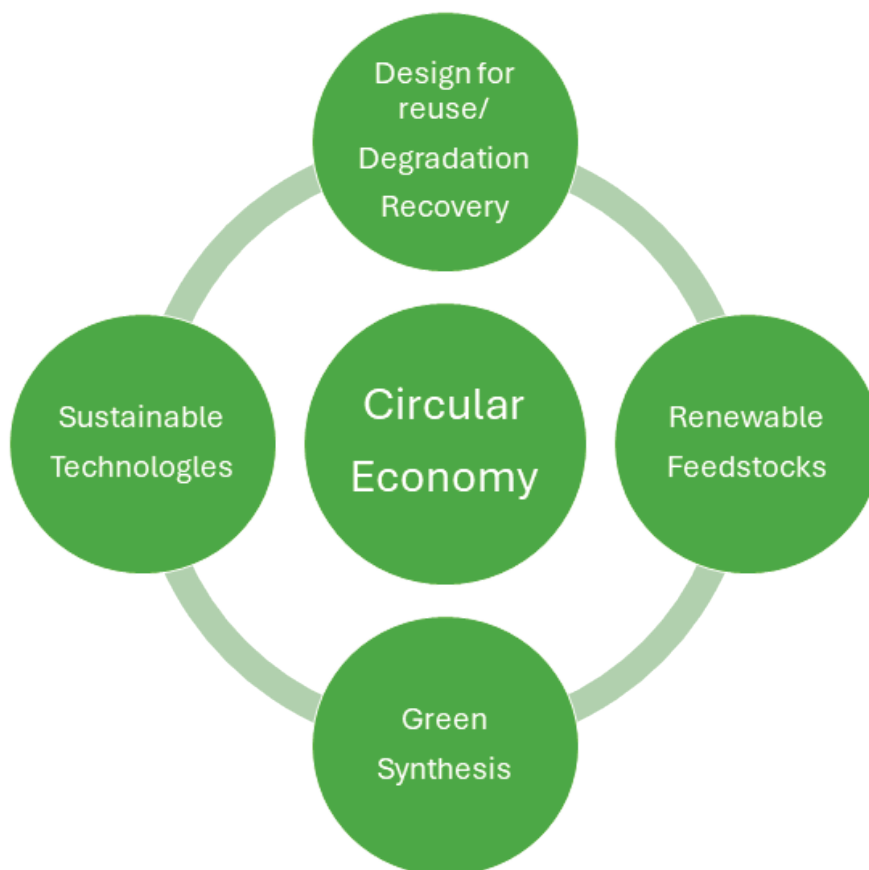
India's chemical industry is rapidly expanding, with a compound annual growth rate (CAGR) of around 8-10%, largely driven by the increasing demand for eco-friendly and sustainable products. The growth of the green chemicals market is bolstered by various government initiatives, such as the Green Chemistry Initiative launched by the Ministry of Chemicals and Fertilizers, which encourages the adoption of green technologies and processes. Supportive policies, including the National Chemical Policy, foster sustainable development and innovation, creating a favourable environment for international investment. Additionally, India benefits from

abundant and diverse feedstock sources—such as biomass, agricultural residues, and renewable energy—which ensure a stable supply chain for green chemical production. Growing environmental awareness among Indian consumers is further fuelling demand for sustainable products across sectors like agriculture, textiles, and packaging. This dynamic landscape presents lucrative investment opportunities, with a supportive regulatory framework and potential for joint ventures, strategic partnerships, and technology transfers to capitalize on the burgeoning green chemicals market in India.⁴

India has also made significant progress to become the sixth-largest global economy in chemical sales. Its key advantage lies in its demographic dividend and a rapidly expanding middle class with increasing purchasing power, positioning it as a consumption-driven economy. Despite the challenges of doing business in India, the government has implemented numerous structural reforms to create a more favourable environment for foreign investment. Initiatives such as 'Make in India' are aimed at enhancing the competitiveness of domestic manufacturing, attracting investment, and boosting exports, thereby supporting the industry's growth. On the other hand, petrochemical industry is also increasingly adopting greener practices and promoting sustainability through several strategies. One approach involves using renewable energy sources, such as solar and wind power, in production processes to cut greenhouse gas emissions and lower energy costs. Additionally, companies are incorporating energy-efficient technologies and optimizing operations to de-

⁴ <https://www.eai.in/blog/2024/03/why-is-the-indian-green-chemicals-market-an-attractive-destination-for-international-investment.html#:~:text=Government%20Initiatives%3A%20The%20Indian%20government,of%20green%20technologies%20and%20processes.>

Figure 2: Circular Economy & Sustainability



crease energy consumption and enhance overall efficiency.

The EU has recently led the charge in sustainability with its ‘Chemicals Strategy for Sustainability,’ outlining a long-term vision for its chemicals policy. This initiative, coupled with growing consumer environmental awareness, has driven key sectors to innovate and develop sustainable chemical solutions. The chemical industry, by interacting with other sectors, has the potential to influence them towards greener product portfolios and eco-friendly practices. Adopting nat-

ural ingredients, energy-efficient technologies, low-carbon products, and substantial R&D investments can enhance the competitiveness of Indian goods on the global stage. Additionally, businesses can refine their branding and marketing to emphasize sustainability, potentially commanding premium returns.⁵

Collective adoption of sustainable chemical manufacturing practices is crucial for achieving global environmental goals and aligns with major international agreements and initiatives:

⁵ <https://economictimes.indiatimes.com/small-biz/trade/exports/insights/why-specialty-chemicals-and-sustainable-solutions-will-be-the-way-forward-for-indian-exporters/articleshow/99508617.cms?from=mdr>

Importance of ESG & Circular Economy in Shaping the Future of the Chemical and Petrochemical (C&P) Industry

Sustainability is increasingly at the forefront of both societal and business priorities, driven by conscious consumer demand, heightened investor awareness, and more stringent regulations. This shift is intensifying the focus on environmental, social, and governance (ESG) factors within the chemical industry, which has traditionally faced scrutiny for its environmental impact due to energy-intensive processes, significant greenhouse gas emissions, and inadequate waste management.

The chemical and petrochemical industries play a crucial role in advancing sustainability efforts. Companies are increasingly prioritizing Environmental, Social, and Governance (ESG) criteria, responding to stakeholder demands for a clear and strategic focus on these standards. Success and value in the chemical sector are now judged not only by financial performance or innovative products but also by how sustainably these goals are achieved. This involves adopting the cleanest technologies with minimal emissions, ensuring safety, and fulfilling broader social responsibilities. Key issues such as greenhouse gas emissions, carbon footprint, and transparency in accounting and disclosure are becoming critical areas of compliance and scrutiny.⁶

According to the Global Carbon Atlas, India ranks as the third largest emitter of carbon dioxide (CO₂) worldwide, accounting for 7.2% of global emissions. The carbon emissions in India rose from 1,677 million metric tons in 2010 to 2,830 million metric tons in 2022. As India aims to become a major manufacturing hub and a

leading economic power, the demand for raw materials and associated emissions are projected to rise significantly. This positions India in a critical role to embrace sustainable practices and play a substantial part in mitigating climate change.

Sustainable regulations have evolved globally, with governments increasingly mandating ESG elements that were previously voluntary. ESG disclosures have become mandatory in major markets worldwide. In India, the Securities and Exchange Board of India (SEBI) has introduced new sustainability reporting requirements for the top 1000 listed companies. The new reporting requirements in India encourage transparent and standardized disclosures on ESG parameters and sustainability-related risks and opportunities for listed companies. This framework will enable companies to more effectively showcase their sustainability goals, positions, and performance to the market. As a result, it will foster long-term value creation and enhance investors' ability to make informed decisions regarding ESG factors.⁷

The circular economy is crucial for transforming the Chemical and Petrochemical (C&P) industry towards a more sustainable future. This approach focuses on closing the loop of product lifecycles through greater resource efficiency and waste minimization. For the C&P sector, it means redesigning processes to reduce material consumption, enhance recycling, and promote the use of renewable resources. Adopting circular economy principles enables companies

⁶ <https://www.indianchemicalcouncil.com/docs/ERM-ICC-Knowledge-papers-10-12-21.pdf>

⁷ <https://www.mayerbrown.com/en/insights/blogs/2021/06/india-imposes-new-esg-reporting-requirements-on-top-1000-listed-companies>

to lower production costs, reduce environmental impact, and comply with tightening regulations. It also drives innovation in product development and operational practices. By embracing these principles, the C&P industry can achieve long-term economic and environmental benefits, ensuring its growth and sustainability in a rapidly evolving market.

According to the Economic Advisory Council to the Prime Minister of India (EAC-PM), India's transition to a circular economy is projected to create an annual value of USD 218 billion (INR 14 lakh crores) by 2030 and USD 624 billion (INR 40 lakh crores) by 2050. These savings are anticipated to represent 11% of India's current GDP, increasing to 30% by 2050. However, successfully implementing a circular economy in India requires an effective ecosystem to foster the identification and adoption of sustainable and circular business models.

In India, the chemical industry, a major contributor to carbon emissions, has recognized the urgent need to address sustainability challenges. Leading companies in the sector are actively working to reduce their environmental impact and adopt sustainable practices. To combat climate change and reduce their carbon footprint, several major Indian chemical and petrochemical companies are setting ambitious net-zero goals and implementing various initiatives. These efforts underscore their commitment to sustainability and their proactive stance on reducing emissions. By setting net-zero targets, investing in renewable energy, and adopting carbon reduction strategies, these companies are contributing to the global sustainability agenda. Embracing sustainability not only enhances environmental performance but also boosts market competitiveness, attracts investment, and

builds a positive brand image.

Recognizing the urgency of sustainable practices, the Indian chemical industry is driving the transition toward a greener future through continued efforts and collaboration. Various companies in the country have taken certain initiatives strengthening their move towards sustainability. For instance,

- Reliance Industries Limited (RIL), one of India's largest conglomerates, has committed to achieving net-zero carbon emissions by 2035. The company plans to utilize renewable energy sources, enhance energy efficiency, and adopt carbon capture technologies. RIL is investing USD 10 billion in its 'Green Energy Plan' to reach its sustainability objectives.
- Tata Chemicals is focusing on reducing its absolute emissions by 30%. In the 2023 financial year, scope 1 emissions of Tata Chemicals Limited amounted to approximately 4,423.6 metric kilotons of carbon dioxide equivalent (CO₂e). The company has developed a comprehensive roadmap to address Scope 1, Scope 2, and Scope 3 emissions. It is actively investing in renewable energy projects, energy-efficient technologies, and exploring carbon offsetting solutions, all aimed at transitioning to a low-carbon economy.
- Aditya Birla Chemicals has set a goal to cut its carbon emissions intensity by 35% by 2030, compared to the 2018 baseline, and to achieve net-zero emissions by 2050. The company is investing in energy-efficient processes, exploring renewable energy options, and adopting circular economy principles to minimize its environmental impact.⁸

- Transitioning from a linear to a circular economy presents significant challenges, but the benefits are substantial. This shift promises to drive accelerated economic growth while enhancing environmental conservation for future generations. Embracing a circular economy can generate economic value and contribute to a sustainable world for those

to come. By establishing an integrated network of circular business models, companies can effectively foster a circular economy. With a system-wide approach and supportive economic conditions, India has the potential to emerge as a leading hub for sustainable manufacturing.

Reshaping and Fostering Sustainable Manufacturing

The chemical and petrochemical sectors are increasingly prioritizing sustainable manufacturing practices to tackle environmental and social issues. Companies are adopting advanced green technologies, such as bio-based chemicals and renewable energy sources, including green hydrogen. These efforts are complemented by cleaner production processes that reduce waste and lower energy consumption. Investment in energy-efficient technologies and optimized operations aims to cut greenhouse gas emissions and improve overall efficiency. Adhering to evolving regulations and standards drives further advancements, while cross-sector collaboration fosters innovation and enhances sustainability across the value chain. These initiatives not only align with global sustainability goals but also bolster the industry's competitive edge and resilience in the marketplace.

In an era where the future of the planet is at stake, sustainable manufacturing and production have become critical challenges. For India Inc., embracing sustainable practices is no longer an option but a necessary step to align national objectives with global environmental targets. India's commitment to sustainability is

clear through its ambitious targets under the Paris Agreement: a 50% reduction in carbon emissions by 2030 and achieving net-zero emissions by 2070. The nation has already made significant strides, surpassing its initial goal with a 24% reduction in emissions between 2005 and 2020. India's drive towards sustainable manufacturing is supported by strategic policies such as the National Action Plan on Climate Change (NAPCC), which outlines a path for sustainable industrial growth. Additionally, initiatives like the Zero Effect Zero Defect (ZED) certification enhance efficiency in smaller enterprises, while Renewable Energy Certificates (RECs) facilitate access to green energy.

Accounting for approximately 17% of the GDP and supporting a workforce of 27 million, India's manufacturing sector is a crucial component of its economic strategy. The government aims to increase the sector's contribution to 25% of GDP by 2025, highlighting its central role in the country's growth narrative. As India navigates this growth trajectory, balancing economic ambitions with environmental stewardship is essential. Sustainable manufacturing practices will play a key role in establishing India as a

leader in responsible global industrialization. Environmental, Social, and Governance (ESG) practices are transforming India's manufacturing sector by promoting cleaner energy use, resource efficiency, and waste reduction. Industry leaders are pioneering this shift with innovative approaches. For instance, Mahindra & Mahindra aims for carbon neutrality by 2040, a full three decades ahead of India's collective target. Similarly, Godrej & Boyce exemplifies successful ESG implementation with nearly complete waste diversion from landfills, demonstrating that circular economy principles can be effectively applied in practice.⁹

The chemical industry is pivotal in advancing sustainability through various measures. These include adopting green molecules (bio-based chemicals), utilizing renewable energy and green hydrogen, and developing cleaner, more efficient production processes that minimize waste and energy consumption via sustainable technologies. Although total carbon elimination is unattainable, significant reductions in

greenhouse gas (GHG) emissions are achievable through current industry practices. Examples include:

- **Agrochemicals:** Indian agrochemical firms are implementing eco-friendly practices, such as zero-discharge solutions, recovering over 80% of water, and significantly reducing total dissolved solids (TDS) and chemical oxygen demand (COD) levels.
- **Petrochemicals:** This sector is embracing circular economy principles, renewable energy use, and decarbonization efforts to support sustainable growth.
- **Chlor-Alkali Chemicals:** Indian chlor-alkali plants predominantly use green membrane technology. By-products like hydrogen are repurposed for flakes plants and boilers, while fly ash and brine sludge are utilized in coal-based power plants and construction materials. The industry is also advancing towards zero effluent discharge and recycling liquid effluents within plants.

Achieving New Heights: Opportunity to Boost Exports

India has consistently ranked third in chemical imports and fourth in exports over the past five years, demonstrating its significant role in global trade. The percentage share of India's chemical exports has steadily increased, driven by economic growth and rising domestic consumerism, which is expected to enhance per capita chemical usage. India has cemented its position as a reliable global supplier of dyes, dye intermediates, basic chemicals, agrochemicals, cosmetics, toiletries, and castor oils. The sector's growth is attributed to efforts by the

Department of Commerce & Industry, CHEM-EXCIL, and Indian exporters, despite challenges such as high freight rates and container shortages. Key states like Gujarat, Maharashtra, Karnataka, Tamil Nadu, and Andhra Pradesh have seen significant benefits. This growth is driven by increased exports of organic and inorganic chemicals, agrochemicals, dyes, and specialty chemicals.

India ranks among the world's top chemical exporters, dealing in inorganic and organic chem-

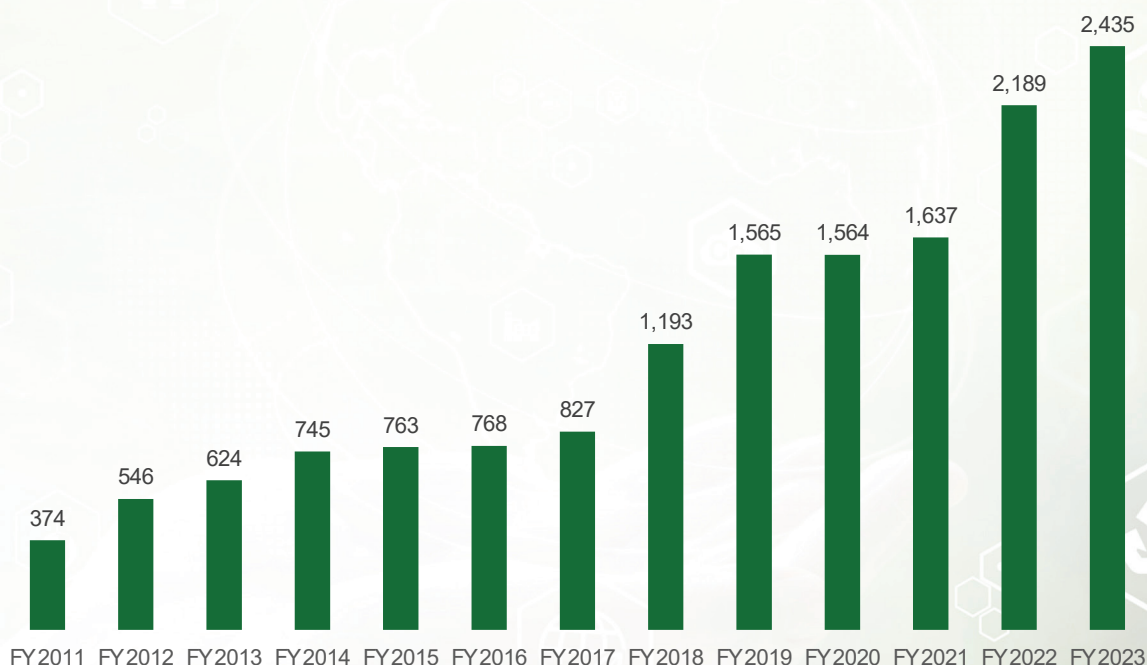
⁹ <https://etedge-insights.com/industry/manufacturing/driving-sustainable-manufacturing-practices-a-must-for-reinforcing-india-incs-commitment-to-environmental-responsibility/>

icals, dyes, agrochemicals, plastics, synthetic rubber, and filaments. In FY24 (up to December 2023), chemical and petrochemical exports totalled USD 15.1 billion. For FY23, these exports were valued at USD 23.8 billion, and in FY22, they reached USD 24.31 billion, reflecting a 38.67% year-over-year increase.

India exports chemicals and chemical products to over 175 countries, with major destinations including China, the USA, Brazil, the Nether-

lands, Saudi Arabia, Indonesia, the UAE, Japan, and Germany. The industry has also expanded its reach to markets such as Turkey, Russia, and Northeast Asia, including Hong Kong, Japan, South Korea, Taiwan, Macao, and Mongolia. In 2022-23, the USA was the top importer of Indian chemicals, with imports valued at USD 3.85 billion, followed by Brazil at USD 1.82 billion. Exports to China were valued at USD 1.74 billion during the same period.

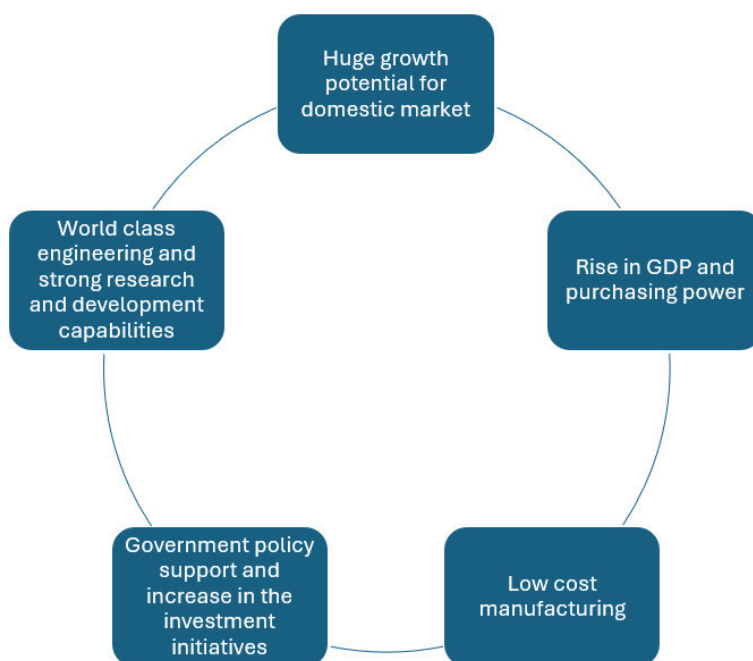
Figure 3: Value of Chemicals Exported from India from Financial Year 2011 to 2023(in billion Indian rupees)



The exports of chemicals from India is significantly increasing over the years due to supportive Government Policies such as:

- In the Union Budget for 2023-24, the central government allocated USD 20.93 million to the Department of Chemicals and Petrochemicals, highlighting its commitment to advancing the chemical sector.
- To boost domestic production, cut imports, and attract investments, the government has introduced a Vision 2034 for the chemicals and petrochemicals industry.
- The government plans to implement a Production Linked Incentive (PLI) scheme for agrochemicals, offering 10-20% output incentives to encourage production.
- A PLI scheme for the domestic manufacturing of critical Key Starting Materials (KSMs), drug intermediates, and APIs has been announced, with a financial outlay of ₹6,940 crore over the next eight years.
- Additionally, 100% Foreign Direct Investment (FDI) is permitted under the automatic route in the chemical manufacturing sector, attracting USD 20 billion in investments from 2000 to June 2022.

Figure 4: Opportunities in Chemical Manufacturing Industries



Disruptions in the supply chain in China have created significant opportunities for the Indian chemical manufacturing sector. China's anti-pollution measures are likely to benefit Indian chemical producers. The Petroleum, Chemicals, and Petrochemicals Investment Regions (PCPIR) policy is anticipated to draw investments totaling USD 280 billion by 2035. Special incentives provided through PCPIRs or Special Economic Zones (SEZs) are expected to stimulate the growth of downstream units, further advancing the chemical industry.¹⁰

Two key government initiatives, 'Make in India' and 'Atmanirbhar Bharat,' are designed to support the growth of the chemicals and petrochemicals sector. To leverage these initiatives, the industry must scale up through ecosystem development, including establishing Petroleum, Chemicals, and Petrochemicals Investment Regions (PCPIRs) nationwide, creating infrastructure linkages for a hub-and-spoke model, and integrating value chains. India's appeal as a manufacturing destination has grown due to competitive labor costs, cost-effective manufacturing, and recent corporate tax reforms. Indian specialty chemical companies have developed unique capabilities and established global supply relationships. Despite specific industry challenges, long-term prospects for the Indian chemical sector look promising. Rising domestic demand in key end-use sectors such as agriculture, consumer goods, infrastructure, automotive, electronics, and healthcare is expected to drive significant growth, with chemicals playing a vital role.

For 'Make in India' to succeed, structural changes are essential. While the 'China+1' strategy is still evolving, India's competitors are advanc-

ing rapidly. China, having been the dominant manufacturing hub, is now facing challenges. As industries like cosmetics, fashion, and FMCG experience growth, India can capitalize on its strengths in sectors such as perfumery, essential oils, and packaging-related chemicals.

The industry must focus on exploring and diversifying its value chain rather than concentrating on a single segment. Success in 'Atmanirbhar Bharat' hinges on developing comprehensive capabilities across the value chain to reduce import dependence, mitigate supply chain risks, and strengthen the economy. As the government prioritizes electronics, semiconductors, renewable energy, and pharmaceuticals, the chemicals and petrochemicals sector will evolve, positioning itself as a crucial element in India's global manufacturing strategy.

India's allowance of 100% FDI in chemicals and the introduction of Production Linked Incentive schemes are reinforcing its status as a preferred manufacturing hub. With increasing domestic consumption, sectors such as agrochemicals and specialty chemicals are poised for growth. Additionally, the trend towards distributed manufacturing systems—moving from single-country operations to multi-country setups—could help Indian specialty chemicals players navigate global supply chain risks and political uncertainties, positioning them for international success.¹¹

Recognizing the industry's potential, the Indian government has introduced Vision 2034 for the Chemicals and Petrochemicals sector to enhance domestic production, reduce imports, and attract investments. The plan includes a proposed production-linked incentive scheme to stimulate domestic manufacturing. Addition-

¹⁰ <https://www.solutionbuggy.com/blog/opportunities-in-chemical-manufacturing-industry-in-2023>

¹¹ <https://timesofindia.indiatimes.com/blogs/voices/indias-chemical-industry-unleashing-the-next-wave-of-growth/>

ally, India's 'Make in India' policy continues to support the sector by fostering growth and innovation.

To achieve net-zero emissions by 2070, Indian companies must align their strategies with the transition to a low-carbon economy, which requires significant investments in new technologies and skilled labour. The Indian government has introduced several measures to address environmental challenges and support growth in the chemical sector. Key actions include:

1. **Increasing Foreign Direct Investment (FDI):** The chemicals sector now allows 100% FDI under the automatic route, with a notable 91% increase in FDI in FY 2023. This influx of global expertise brings advanced technologies and sustainable practices, enhancing sector efficiency and aligning with environmental goals.
2. **Boosting Non-Hazardous Chemical Production:** The deregulation of non-hazardous chemical production and anti-dumping duties on substandard imports aim to support domestic producers and enhance industry scale and profitability.¹²
3. **Upcoming Initiatives:** The government plans to revise the 2007 Petroleum, Chemicals & Petrochemical Investment Regions (PCPIRs) policy to establish integrated chemical complexes with shared infrastructure. Additionally, it encourages the development of plastic parks and chemical manufacturing units in various regions, including SEZs and underdeveloped areas.

The Indian chemical sector is vigorously pursuing a strategic plan to achieve net-zero emis-

sions, driven by government initiatives such as increased foreign direct investment (FDI), enhanced skill development, and efforts to regulate substandard imports. Proposed reforms, including a revamp of the Petroleum, Chemicals, and Petrochemical Investment Regions (PCPIRs) and new incentives for chemical manufacturing units, highlight a commitment to sector growth. Gujarat, with its strategic geographic location, robust industrial base, and significant presence in the petrochemical sector, has emerged as a key state in the implementation of this policy. The Dahej PCPIR in Gujarat is one of the four PCPIRs approved by the Indian government, alongside those in Andhra Pradesh, Odisha, and Tamil Nadu. The Dahej PCPIR exemplifies the synergy between state and central governments in implementing the PCPIR policy and highlights Gujarat's strengths in the petroleum, chemicals, and petrochemical industries.

The PCPIR policy was formulated to attract large-scale investments by creating integrated and well-planned industrial regions. These regions focus on:

1. **Development of world-class infrastructure** like ports, roads, and utilities.
2. **Promotion of downstream industries** in petrochemicals, plastics, and chemicals.
3. **Boosting domestic production capacity** to reduce imports of chemicals and petrochemical products.
4. **Increasing exports** by establishing competitive and globally integrated production facilities.

Under this policy, the PCPIRs are envisioned as industrial hubs where core sectors such as refining, petrochemicals, and chemicals can attract

¹² <https://www.ibef.org/blogs/mission-net-zero-a-strategic-plan-for-the-indian-chemical-sector>

investments, leading to the development of downstream industries and enabling a holistic growth ecosystem.

Gujarat's Dahej PCPIR: A Key Component

Dahej PCPIR is one of India's most successful PCPIRs and stands out as an example of how a well-planned industrial region can boost the state's economy and industrial landscape.

Strategic Location and Connectivity

- Dahej PCPIR is located in the Bharuch district of Gujarat, strategically positioned along the Gujarat coastline, providing direct access to the Arabian Sea.
- It is well-connected through road, rail, and sea transport, facilitating easy access to raw materials and finished products, both domestically and for export markets. The Dahej port plays a critical role in international trade, particularly in liquid chemicals and petroleum products.

Industrial Base and Anchor Tenants

- The anchor industries in the Dahej PCPIR include prominent players such as ONGC Petro Additions Limited (OPaL), Indian Oil Corporation, Reliance Industries, and Gujarat Alkalies and Chemicals Limited (GACL). These companies provide the necessary foundation for the development of a robust petrochemical ecosystem.
- The presence of Petroleum, Oil, and Lubricants (POL) industries and specialty chemicals manufacturers adds significant value to the cluster, fostering backward and forward linkages.

Investment and Infrastructure Development

- The Dahej PCPIR has attracted significant foreign direct investment (FDI) and domestic investment in recent years, with the establishment of large petrochemical complexes, refining units, and supporting industries.
- Infrastructure development has been a key focus, with the government creating a multi-modal logistics hub, power supply networks, water desalination plants, and environmental management systems to support industrial growth.

Contribution to Gujarat and India's Economy

- The Dahej PCPIR plays a vital role in enhancing Gujarat's share in India's overall petroleum and chemical output. Gujarat already accounts for a significant portion of India's chemicals and petrochemicals production, contributing around 62% of India's petrochemical production and 30% of the country's refining capacity.
- The development of the PCPIR has also generated employment, both directly and indirectly, across the state. Thousands of jobs have been created in core industries, infrastructure development, and ancillary services.
- The region has emerged as a hub for downstream industries, which utilize the output of core industries for manufacturing products such as plastics, textiles, and fertilizers. This has led to value chain integration, enabling small and medium enterprises (SMEs) to thrive.

Challenges and Opportunities

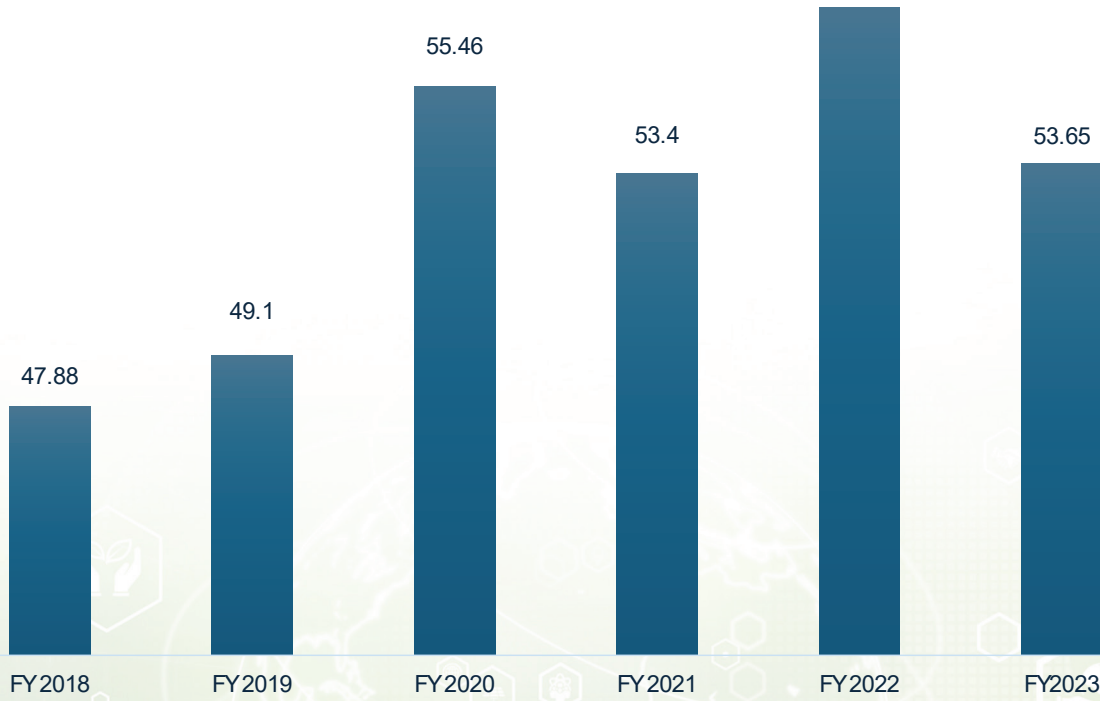
Despite its successes, the Dahej PCPIR faces several challenges that need to be addressed to fully realize its potential:


1. **Environmental Concerns:** The petrochemical industry is inherently resource-intensive and poses environmental risks such as pollution and habitat degradation. Gujarat's regulatory bodies need to enforce stricter environmental standards and implement sustainable practices to minimize the ecological impact of industrialization in the region.
2. **Sustainability and Innovation:** With the global shift towards greener and more sustainable industries, there is a need for greater investment in clean technologies within the PCPIR. Gujarat's government is actively working on introducing cleaner fuel sources, more efficient processes, and waste management systems to meet international standards.
3. **Skilled Workforce:** As the Dahej PCPIR continues to expand, the demand for a skilled workforce will grow. There is a need to enhance vocational training programs, foster public-private partnerships in education, and equip the local workforce with skills relevant to the petrochemical industry.
4. **Global Competitiveness:** As India seeks to become a global manufacturing hub, the Dahej PCPIR must continue to upgrade its infrastructure and policies to stay competitive. Attracting more foreign investors and strategic partnerships with global corporations will be critical for its sustained growth.

The Future of Gujarat's PCPIR in the Context of Viksit Bharat

1. The Dahej PCPIR aligns with the vision of Viksit Bharat (Developed India) by 2047. It represents a key initiative in promoting industrial development, attracting investment, and fostering innovation in the core sectors of petroleum, chemicals, and petrochemicals. The region's growth can serve as a catalyst for other states looking to replicate Gujarat's success in this field.
2. Moving forward, Gujarat's focus on sustainability, clean energy, and value addition in downstream industries will be crucial for ensuring that its industrial growth contributes meaningfully to the broader goal of making India a global economic power. The Dahej PCPIR, with its vast potential for growth and innovation, will play an essential role in driving India's petrochemical revolution and establishing the nation as a global leader in the chemical and petrochemical sectors.

Figure 5: India's Basic Chemicals and Petrochemical Productions (MMT)





Chapter - 3
Green Practices

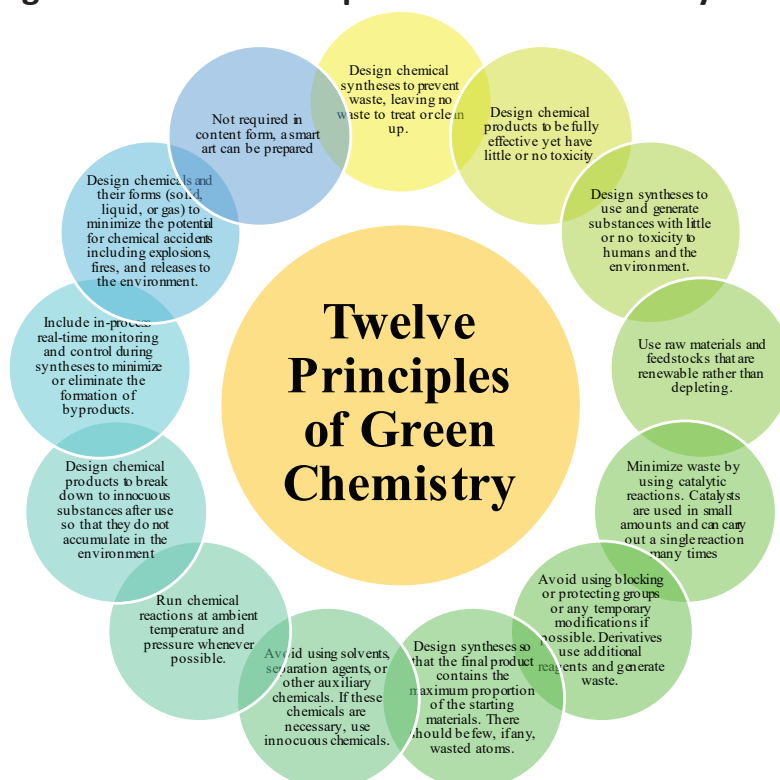
Government Policies to Enhance Chemical Manufacturing:

Green chemistry has become a crucial driver for sustainable development and environmental stewardship within the chemical industry. India is well-positioned to become a leading player in the global green chemistry arena, given the growing interest and alignment with sustainability goals.

The Indian government is actively supporting green chemistry through various initiatives.

Additionally, policies and regulations, including the National Chemical Policy, are designed to support the growth of the green chemicals market and attract international investment. India benefits from abundant and diverse feedstock for green chemical production, such as biomass, agricultural residues, and renewable energy sources, ensuring a stable supply chain for green chemical manufacturers.

Figure 6: Twelve Principles of Green Chemistry



Tata Chemicals, a key player in the Tata Group's diverse portfolio, is integrating green chemistry principles into all its new products. As the world's second-largest soda ash producer with operations spanning India, Europe, North America, and Africa, the company is prioritizing carbon reduction and sustainability, with 70% of its capacity sourced from natural origins. Tata

Chemicals is heavily investing in technological innovation, including transforming its 80-year-old Mithapur plant into a smart factory. The plant now employs advanced technologies like analytics, IoT, artificial intelligence, and digital twins to monitor emissions, enhance operational efficiency, and reduce environmental impact. Additionally, Tata Chemicals has launched the

UK's first carbon capture plant, utilizing amine-based technology to capture up to 40,000 tonnes of CO₂ annually—equivalent to removing 20,000 cars from the road—and convert it

into sodium bicarbonate. The company is also concentrating on decarbonization, redesign, circular design principles, and sustainable renewable solutions through its R&D efforts.¹³

Figure 7: Key Indian Players in Green Chemicals Market

	KEY INDIAN PLAYERS IN INDIAN GREEN CHEMICALS MARKET	

Green Chemistry Initiative:

The Ministry of Chemicals and Fertilizers has introduced the Green Chemistry Initiative to advance the use of green technologies and processes within the chemical industry. This initiative seeks to lessen the environmental footprint of chemical manufacturing by promoting the use of renewable feedstocks, reducing waste generation, and fostering the development of eco-friendly products and processes.¹⁴

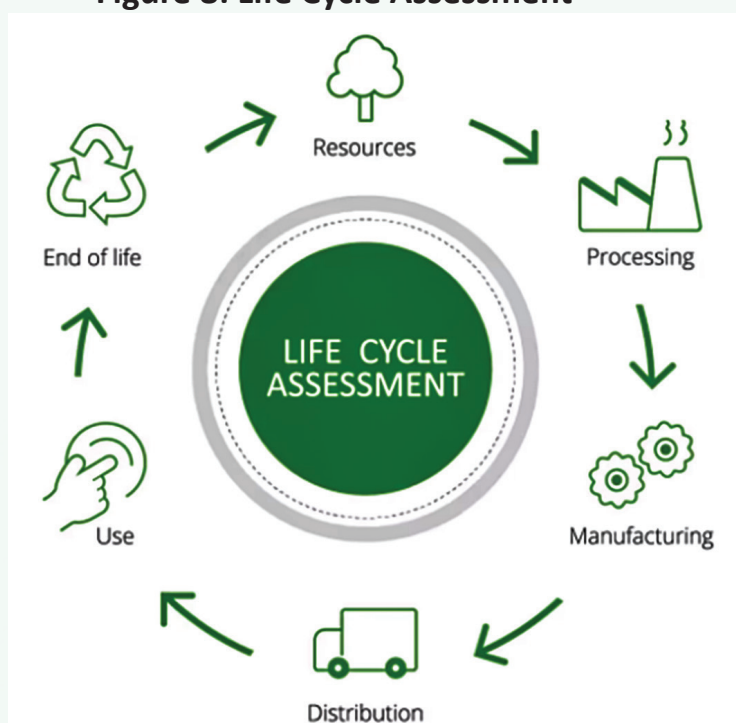
As sustainability becomes a central focus, designing chemical products, processes, and supply chains with environmental considerations is increasing. For over two decades, environmental assessment has been a key component of chemical process design. Various performance

indicators and metrics have been developed to evaluate environmental impacts during process design. These metrics often include assessments of acute toxicity, biodegradability, and ozone depletion potential as part of hazard evaluations related to environment, health, and safety. However, these metrics are frequently limited by data availability and regulatory scope, focusing primarily on the process in question. To fully address sustainability, it is necessary to extend the assessment beyond individual processes and consider potential trade-offs throughout the entire life cycle. This broader perspective is particularly relevant to advancing chemical and petrochemical sustainability in India.

¹³ <https://www.businesstoday.in/industry/story/new-products-are-focused-on-green-chemistry-principles-says-richard-lobo-of-tata-chemicals-384258-2023-06-05>

¹⁴ <https://www.eai.in/blog/2024/03/why-is-the-indian-green-chemicals-market-an-attractive-destination-for-international-investment.html#:~:text=Green%20Chemistry%20Initiative%3A&text=The%20Initiative%20aims%20to%20reduce,eco%20friendly%20products%20and%20processes.>

Figure 8: Life Cycle Assessment



Life Cycle Assessment

The integration of eco-friendly technologies for waste reduction and value enhancement requires a comprehensive understanding of the environmental impacts associated with various waste management options. Life Cycle Assessment (LCA) provides a systematic evaluation of the environmental benefits and drawbacks of processes involved in waste treatment and value enhancement. By applying LCA, chemical industries can identify the most sustainable waste management strategies, allowing them to make informed decisions that minimize environmental impacts across the entire life cycle of their products.

While life cycle assessment methods offer valuable insights for decision-making, they can be resource-intensive and may require data that

is difficult to obtain. LCAs also face challenges in evaluating chemical risks and assessing impacts on human health and the environment throughout a product's life cycle, as well as in determining material recyclability. The ISO 14000 standards offer widely accepted guidelines for conducting LCAs, but certain aspects, such as defining study boundaries, are open to interpretation. This variability can lead to different outcomes across LCA studies, making comparisons difficult.

Given these limitations, the concept of life cycle thinking has gained traction. For instance, the US National Research Council (2014) promotes this flexible approach in its guide on selecting chemical alternatives. Life cycle thinking involves qualitative analysis to identify potential

trade-offs, without the need for the quantitative assessments required by LCAs.

The life cycle assessment (LCA) of bioethanol and other products is increasingly gaining attention as industries and consumers seek more sustainable options. According to ChemAnalyst, India Bioethanol market is anticipated to grow at an impressive CAGR of 17.44% to reach at USD 10644.31 million by 2027. As demand for sustainable solutions rises, companies are focusing on LCAs to identify opportunities for improving environmental performance, optimizing resource use, and minimizing waste.

India Glycols Limited, a prominent publicly traded company based in India, exports chem-

ical products to over 40 countries globally. The company has benefited from the UNEP/SETAC Life Cycle Initiative program, receiving guidance and support from life cycle management (LCM) affiliated with the Federation of Indian Chambers of Commerce & Industry (FICCI). The life cycle assessment concluded that using renewable-based raw materials for manufacturing monoethylene glycol (MEG) is preferable to traditional petrochemical methods in India, the US, and Europe. India Glycols Limited also conducted life cycle assessments for various products including bio-ethanol, bio-ethylene oxide, bio-glycols, bio-glycol ethers, and bio-polyethylene glycols. These assessments revealed new business and growth opportunities

Renewable Feedstocks and Green Hydrogen

Numerous facets of the chemical manufacturing sector have embraced sustainable and eco-friendly practices. Specifically, incorporating renewable feedstock into chemical production aligns with one of the twelve principles of green chemistry. As the term suggests, a renewable resource can be utilized repeatedly without substantial depletion and can be rapidly replenished without intricate industrial procedures. Take, for instance, solar panel-generated electricity, which remains renewable as long as the sun endures, ensuring a continuous power supply. Similarly, in large-scale chemical manufacturing, a renewable feedstock refers to a substance that can be readily regenerated without significant depletion. Biomass serves as a noteworthy example of such a renewable feedstock, offering both cost-effectiveness and efficiency, particularly over the long term.

The challenge with many manufacturing feedstocks is their non-renewable nature, meaning they are used continuously without the possibility of replacement. In contrast, renewable feedstocks can be replenished quickly and do not experience significant depletion, allowing them to keep pace with consumption. For example, petroleum, which takes millions of years to form, differs from biomass feedstocks like manure from livestock farms, which are readily available. Moreover, biomass feedstocks do not require destructive extraction methods, such as mining. Compared to petroleum-based feedstocks, they also involve significantly lower costs for acquisition and processing.

A sustainable feedstock is one that can be replenished at a rate equal to or faster than its consumption, ensuring a steady or increasing

supply. It is crucial that replenishment does not reduce overall availability. For example, materials like cement, sourced from non-renewable resources such as rocks and minerals like lime-

stone, are not sustainable. Quarrying these resources results in permanent depletion, as new rocks cannot naturally replace the ones that are extracted.

Examples of Renewable Feedstocks

Water, as a universal solvent, is essential in the field of chemistry, serving as a key raw material in many chemical manufacturing processes. Without water, chemical reactions and conversions would be significantly slowed or even halted. While some products, like dried fruits, require rehydration, most beverages naturally contain water, and the majority of canned and preserved foods also have water content. Water is a renewable resource, as it is naturally recycled through atmospheric processes.

Hydrogen, the primary fuel for stars, is the most abundant element in the observable universe. However, on Earth, its presence in elemental gas form is rare, accounting for only 0.000055% of the atmosphere. There are several commercial methods for producing hydrogen, including extraction from natural gas, crude oil, or through electrolysis. When hydrogen and oxygen combine with a spark, water is produced, and hydrogen can be separated again via electrolysis. Oxygen, produced as a byproduct of photosynthesis by plants, algae, and other photosynthetic organisms, is vital for animal life and makes up 21% of Earth's atmosphere¹⁵. While oxygen can be extracted from water through electrolysis, its commercial production typically involves industrial purification and separation from air. The attached schematic provides a more detailed explanation of this industrial process.

Green Hydrogen

The green hydrogen market offers substantial growth potential, driven by the urgent need to decarbonize the global energy system. The continued reliance on fossil fuels has caused significant environmental damage, making the transition to cleaner energy sources critical. Hydrogen, as a clean and non-polluting gas, has gained widespread interest across industries such as transportation, petrochemicals, and heating. By 2050¹⁶, it is expected that at least two-thirds of global hydrogen production will come from green hydrogen, playing a pivotal role in achieving a net-zero emissions energy system.

Countries like India, with abundant renewable energy resources and favorable geographical conditions, are well-positioned to become leaders in the green hydrogen market. Europe, with its advanced technology and infrastructure, is also poised to lead the production and distribution of green hydrogen, making it central to the energy transition. Additionally, green hydrogen has the potential to decarbonize hard-to-abate sectors and improve energy security in regions like the Caribbean.

In January 2024, BASF Process Catalysts announced a partnership with Envision Energy, a leading provider of green technology solutions,

¹⁵ <https://education.nationalgeographic.org/resource/photosynthesis/>

¹⁶ <https://pib.gov.in/PressReleasePage.aspx?PRID=1937584#:~:text=Presenting%20key%20findings%20of%20the,125%20GW%20renewable%20energy%20capacity.>

to accelerate the conversion of green hydrogen and CO₂ into e-methanol through an advanced process design. BASF will contribute its innovative SYNSPIRET catalyst technology, while Envision Energy will integrate this with its cutting-edge energy management system. The collaboration aims to demonstrate the efficiency of this process at Envision Energy’s site in Inner Mongolia, China, showcasing the potential of green hydrogen in sustainable energy.

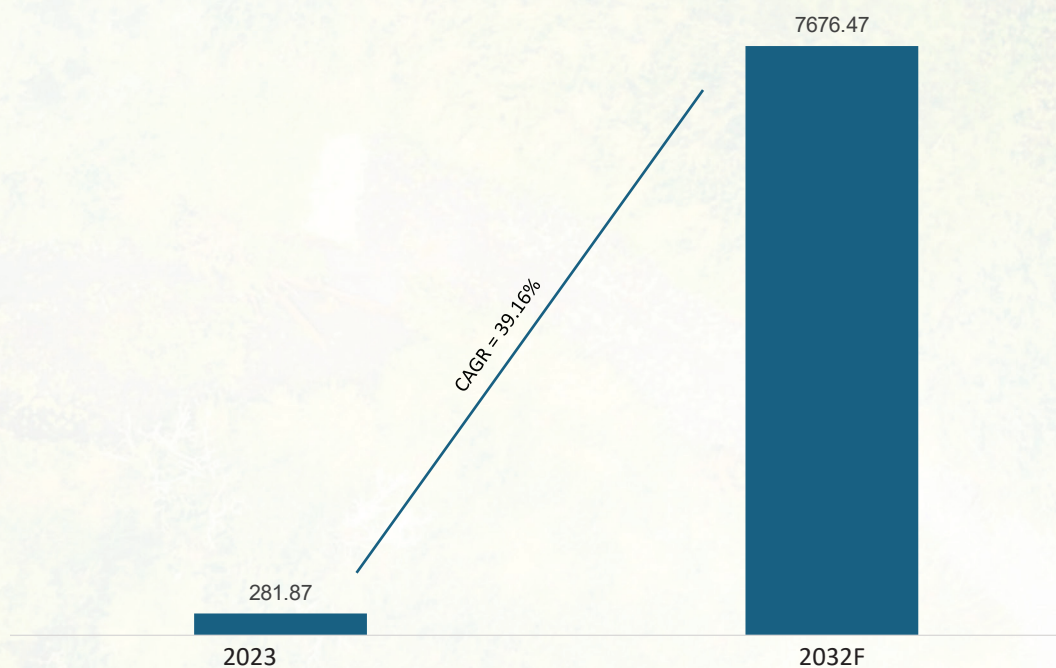
Green Ammonia

Green ammonia refers to the production of ammonia in a fully renewable, carbon-free manner. It has various applications, as it can be stored at -33°C or as a liquid at low pres-

ures (10–15 bar). As a zero-carbon fuel, green ammonia can be burned in engines, used in fuel cells to generate electricity, or serve as a carrier for green hydrogen. It is vital for addressing key challenges such as ensuring sufficient food supply for the growing global population and generating CO₂-free electricity. Additionally, green ammonia holds the potential to become a climate-neutral fuel for transportation and is being explored for the production of carbon-neutral fertilizers.

The global green ammonia market is still in its early stages, largely due to the high cost of electricity. However, many companies are

Figure 9: Global Green Ammonia Market Size, By Value (USD Million), 2023 & 2032F



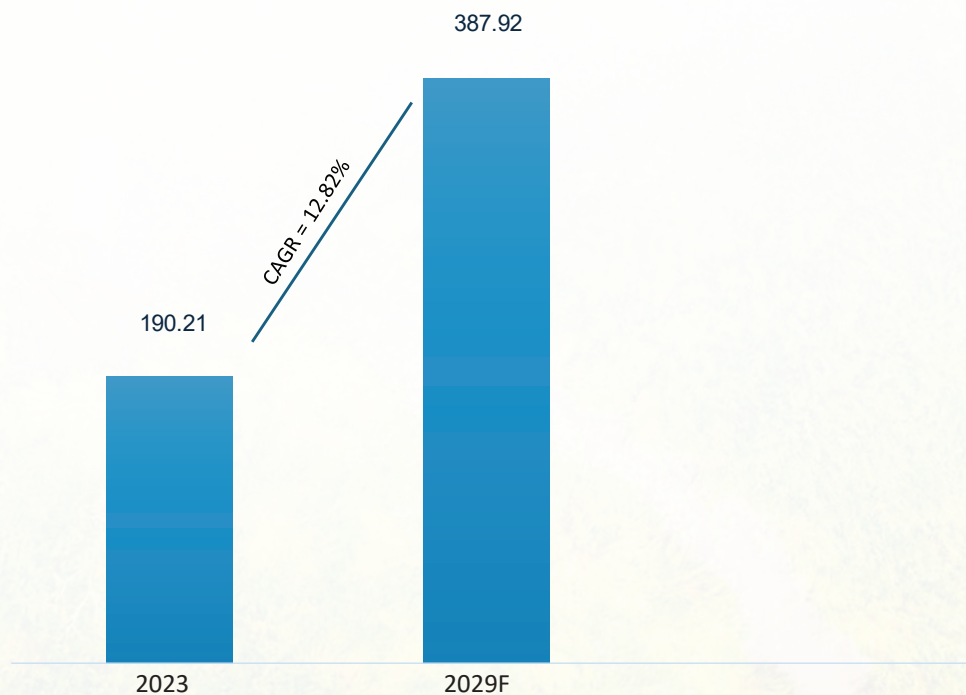
adopting sustainability measures as governments worldwide commit to reducing CO2 emissions under the Paris Agreement by 2050. Yara International ASA, through its Yara Clean Ammonia unit, is actively pursuing carbon-free food production and emission-free fuel for shipping and power generation. Other key players in the market include Haldor Topsoe Holding A/S, Maire Technimont, Thyssenkrup AG, ACME Group, and Fertigllobe plc. These companies are leveraging strategies such as mergers, partnerships, and new product launches to maintain a competitive edge.

For instance, in May 2021, Yara International ASA signed an agreement with Engie to develop a renewable hydrogen plant for the production of green ammonia. The plant, with a capacity of 3,700 tonnes of renewable ammonia, is expected to begin operations in 2023, marking a significant step toward sustainable ammonia production.

Green Methanol

Green methanol, also known as renewable methanol, is produced from sustainable and renewable feedstocks such as biomass and carbon

Figure 10: Global Green Methanol Market Size, By Value (USD Million), 2023 & 2029F



dioxide. It is widely regarded as an environmentally friendly alternative to conventional methanol, especially when used as a renewable fuel or as a raw material in various chemical processes. As a low-carbon fuel, green methanol significantly reduces greenhouse gas emissions. It is produced through the conversion of renewable feedstocks using sustainable processes, with common methods including biomass gasification, CO₂ capture and hydrogenation, power-to-methanol (PTM), biogas reforming, and the extraction of bio-methanol from algae.

Key trends in the global green methanol industry include its application in hydrogen production and methanol fuel cells. For example, the Indian government is seeking to replace inefficient energy systems like diesel generators with eco-friendly energy solutions to substantially cut CO₂ emissions. However, the industry faces challenges such as a lack of distribution networks and an underdeveloped refueling infrastructure for green methanol.

Major players in the industry are adopting strategies such as establishing new production plants, advancing technologies, and increasing investments in research and development to enhance green methanol production. In October 2020, Sweden's Minister for Business, Ibrahim Baylan, officially inaugurated Södra's commercial bio-methanol plant at its pulp mill in Mönsterås. Södra is making significant investments in liquid biofuels and aims to achieve carbon-neutral transportation by 2030. Additionally, in 2023, Mitsubishi Gas Chemical Company, Inc. signed an agreement with Mitsui O.S.K. Lines, Ltd. for the long-term lease of a methanol carrier that can run on either methanol or traditional heavy fuel oil. The vessel, to be constructed at Hyundai Mipo Dockyard and delivered in 2025, will be the first dual-fuel methanol transporter leased by a Japanese company for an extended period. This agreement reflects the companies' commitment to expanding their collaborative efforts in the green methanol sector.



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Chapter - 4

Safety and Waste

Management

Effective resource management is a key component of sustainable development in business. It aims to conserve resources, protect the environment, and reduce production costs through three core strategies: elimination, source reduction, and recycling. Unlike waste treatment or disposal, waste minimization focuses on preventing waste generation rather than diluting or shifting waste between environmental mediums. Additionally, waste minimization presents various intangible benefits, such as:

Waste Minimization Strategies:

Green technologies prioritize reducing waste at its source. By implementing process optimization, efficient design, and improved reaction conditions, chemical industries can significantly cut down on waste production. This includes adopting cleaner production methods such as solvent substitution, process intensification, and continuous flow processes, which not only

Plastic Recycling

Globally, less than 10% of plastics produced are recycled, with the majority being incinerated, sent to landfills, or released into the environment. There is increasing interest in both academic and industrial sectors for innovative technologies that chemically recycle discarded plastics. It is essential for chemists and chemical engineers to understand these technologies' principles to advance systems for the chemical recycling and upcycling of plastic waste.

The global value of exports involving plastics or plastic-based products has more than doubled since 2005, surpassing USD 1 trillion in 2018 and reaching nearly USD 1.2 trillion in 2021¹⁷. While the increase in volume has been more gradual, it

In recent years, there has been a growing recognition of the need for sustainable practices in the chemical industry. Concerns over waste generation and its environmental impact have driven focused efforts to address these challenges. As a result, there is increased emphasis on the development and adoption of eco-friendly technologies that minimize waste and extract value from it.

reduce waste but also boost overall process efficiency.

Additionally, incorporating in-process monitoring and control systems is vital for identifying and mitigating potential waste generation points. This proactive strategy supports the shift toward more sustainable manufacturing practices, reflecting the industry's commitment to environmentally responsible operations.

has grown from 218 million metric tons in 2005 to 369 million in 2021. This rise in international plastic trade includes a wide array of products: plastic items like children's toys, products with plastic components such as electronic devices, and goods wrapped in plastic—from office furniture to DVDs and snacks. It also includes raw materials for plastic production, primarily derived from fossil fuels, and the export of plastic waste, such as discarded smartphones. According to UN estimates, approximately 75% of all plastic produced since 1950 has become waste. Therefore, the significant growth in plastic trade may signal an increasing amount of plastic entering the oceans.

¹⁷ <https://www.genevaenvironmentnetwork.org/resources/updates/plastics-and-trade/>

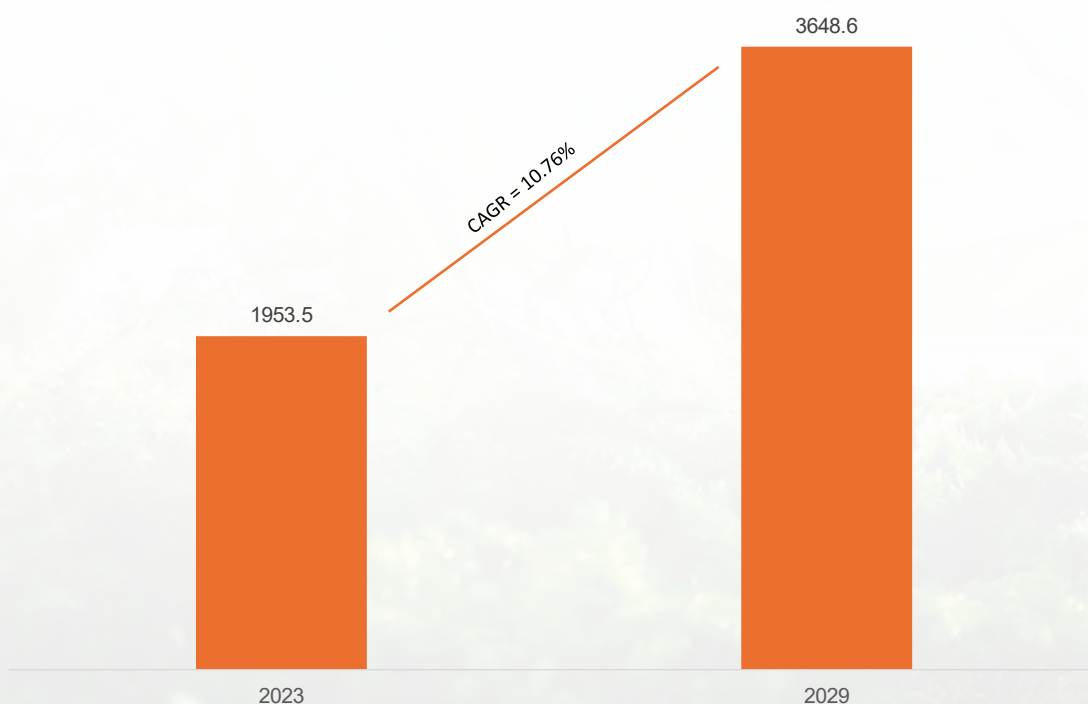
Addressing Plastic Pollution

The growing awareness of plastic pollution’s environmental impact has led to stronger commitments from governments, businesses, and individuals to tackle the issue. Many countries and regions have established ambitious goals to enhance plastic recycling rates and reduce plastic waste. Advances in recycling technologies have significantly improved the efficiency of plastic recycling processes. Innovations such as chemical recycling and advanced sorting methods are promising for increasing the recyclability of various plastics. The concept of a circular economy, which emphasizes reusing, recycling, and reintegrating materials into the production cycle, is gaining momentum. This approach aims to

reduce linear resource consumption and minimize waste. There is also a heightened focus on consumer education to encourage responsible plastic use, effective recycling practices, and reduced plastic consumption overall.

In India, several regulations and policies have been implemented to manage plastic waste. The Plastic Waste Management Rules, 2016, provide guidelines for the segregation, collection, and disposal of plastic waste. These rules emphasize Extended Producer Responsibility (EPR), holding producers accountable for the environmentally sound management of plastic waste from their products. Various states and

Figure 11: The India Plastic Recycling Market Size (USD Million), By Value, 2023 & 2029F



Union Territories in India have introduced bans on single-use plastics to decrease their usage and mitigate environmental impact.

India is also improving its plastic waste management infrastructure through the development of recycling facilities, waste collection systems, and public awareness campaigns. The country has seen the rise of innovative solutions and technologies for plastic recycling, with startups

exploring alternative materials and research focused on more sustainable and efficient recycling methods. Additionally, India is engaging in international collaborations and partnerships to combat plastic pollution, participating in global initiatives, and adopting best practices from other countries. Some waste-to-energy projects in India are converting plastic waste into energy, contributing to both waste management and energy generation.

Handling Dangerous Materials and Ensuring Safety

In India, the surge in industrialization and technological progress has led to a rise in the use of chemicals and hazardous materials, necessitating strong legal and administrative frameworks to manage associated risks. As India's economy positions itself as a manufacturing hub, it is crucial to balance industrial growth with sustainable practices that address resource constraints. The concept of a Circular Economy aims to enhance resource sustainability by keeping materials in use for as long as possible, maximizing their value, and then recovering and regenerating them at the end of their life. Managing toxic and hazardous industrial waste is a priority to protect health and the environment and is central to advancing a resource-efficient economy. India faces a growing challenge with hazardous waste, which increases by 2% to 5% annually, with about 10% to 15% of industrial waste classified as hazardous. Developing Circular Economy solutions for treating industrial waste can foster innovative approaches to utilizing discarded materials. The Indian government is actively working to transition towards a Circular Economy, with NITI Aayog identifying 11 focus areas and delegating them to relevant ministries.

The Department for Chemicals and Petrochemicals (DCPC) has been assigned the management of toxic and hazardous industrial waste in India. DCPC has submitted a report and action plan to NITI Aayog outlining strategies to limit hazardous waste in the economy. The plan includes identifying areas for sustainable reutilization and recycling of hazardous wastes, developing standard operating procedures (SOPs) and technologies in collaboration with academic and research institutions. It also emphasizes promoting circular processes through viable business models and funding incentives. Regular workshops, seminars, and awareness programs on Green Chemistry and Circular Economy are being organized, and industries generating hazardous waste are being geographically mapped for better data analysis and waste management. The implementation of these action plans is underway, with ongoing monitoring of progress by the Department.

Effective Waste Management Practices

The Indian chemicals and petrochemicals industry is undergoing a significant transformation, driven by policy reforms that are accelerating growth. The key challenge, however, is achieving this growth in a sustainable and responsible manner. Globally, major chemical and petrochemical companies are achieving their sustainability goals by streamlining their portfolios. Indian companies, however, lack the option to follow this approach and instead develop effective

strategies for chemical waste management, recycling, and the circular economy.

Many multinational chemical companies have launched sustainability-focused initiatives. Indian companies should consider adopting similar practices, such as process optimization and cleaner production, to reduce waste generation. Establishing recycling facilities or partnering with specialized waste management firms can help convert waste into valuable resources.

Figure 12: Hazardous Waste Management Practices



Rather than viewing waste as a burden, companies are exploring opportunities for resource recovery and implement Extended Producer Responsibility (EPR) programs to manage the waste from their products throughout their lifecycle. Investing in research and innovation is crucial for developing eco-friendly products, processes, and technologies. This includes cre-

ating bio-based alternatives, environmentally friendly chemicals, and advanced recycling techniques that support the circular economy. By embracing these strategies, Indian chemical companies can minimize their environmental impact, conserve resources, and drive the industry's shift towards a more sustainable and circular economy.

Chemical Regulations

There is currently no REACH-like or TSCA-like regulations for chemicals in India. There is no national chemical inventory or any chemical registration requirement either. However, India is developing its own REACH-like regulation.

Overview of Chemical Regulations in India

The following 2 chemical regulations are the most important ones in force in India.

- Manufacture, Storage And Import Of Hazardous Chemical (Amendment) Rules, 1989, 1994, 2000
- Ozone Depleting Substance (R&C) Rules (2000)

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Manufacture, Storage And Import Of Hazardous Chemical (Amendment) Rules, 1989

The regulation was firstly enacted in 1989 by the Ministry of Environment & Forests (MoEF) and later amended in 1994 and 2000. It regulates the manufacture, storage and import of hazardous chemicals in India. The transport of hazardous chemicals must meet the provisions of the Motor Vehicles Act, 1988.

“Hazardous Chemicals” includes 3 schedules. Regulatory requirements are different for each schedule.

1. any chemical which satisfies any of the criteria laid down in Part I of Schedule 1 or listed in Part II of this Schedule 1 ;
2. any chemical listed in Column 2 of Schedule 2;
3. any chemical listed in Column 2 of Schedule 3;

Regulations on Schedule 1 Hazardous Chemicals

Schedule 1 consists of two parts: (1) any hazardous chemicals that meet one of the following criteria and (2) 684 named chemical substances listed in Schedule 1.

- Toxic chemicals: oral LD50 <200mg/kg, or dermal LD50 <2,000mg/kg or inhalation LC50 < 10mg/L
- Flammable gases: i.e gases that are ignitable when in a mixture of 13 percent or less by volume with air

- Flammable liquids: liquids with flash points below than 90 celcius degress
- Explosives

For hazardous chemicals covered in schedule 1, site owners must meet the following obligations:

- identify hazards associated with industrial activity and take adequate steps for prevention and control
- provide relevant information to persons liable to be affected by a major accident
- notify the concerned authorities within 48 hours of the occurrence of a major accident
- provide safety data sheets and label every container of hazardous chemicals.

In addition, any person responsible for importing Schedule 1 hazardous chemicals in India shall provide [before 30 days or as reasonably possible but not later than] the date of import to the Chief Controller Imports & Exports with the information below:

- i. the name and address of the person receiving the consignment in India;
- ii. the port of entry in India;
- iii. mode of transport from the exporting country to India;
- iv. the quantity of chemical (s) being imported; and
- v. complete product safety information

Schedule 2 and Schedule 3 Hazardous Chemicals

Schedule 2 and schedule 3 are some hazardous chemicals with assigned threshold quantities. When a site handles a hazardous chemical more than the thresholds, the site will be regarded as major accident hazards (MAH) installations and

subject to reporting, safety audit and contingency plan requirements.

Ozone Depleting Substance (R&C) Rules (2000)

This regulation strictly controls the production, import and use of ozone depleting substances (ODCs) in India. Most of ODCs are banned in India.

In Aug 2020, Indian Draft Chemicals (Management and Safety) Rules was published. These Rules provide for Notification, Registration and Restrictions, or prohibitions, as well as labelling and packaging requirements related to the Use of Substances, Substances in Mixtures, Substances in Articles and Intermediates Placed or intended to be Placed in Indian Territory and introduce REACH-like registration requirements to certain priority substances. The rules are also known as “India REACH”.¹⁸

The Indian Department of Chemicals and Petrochemicals has introduced additional Quality Control Orders (QCOs) for various chemical compounds. These new regulations are designed to enhance safety in the handling of these chemicals, benefiting both human health and the environment. GPOI is assisting the German industry by submitting feedback on the draft regulations to the appropriate Indian regulatory bodies.

India is seeing a rise in technical regulations, which often mandate certification according to specific Indian Standards. These measures aim to improve product safety and quality in the Indian market. In mid-November of 2021, the De-

¹⁸https://www.chemsafetypro.com/Topics/India/Overview_of_Chemical_Regulations_in_India.html

partment of Chemicals and Petrochemicals released eight draft QCOs for chemical products. Industry stakeholders have a 60-day period to review and comment on these drafts. Following this, the Department will consider the feedback and issue the final QCOs. Once finalized, these QCOs will require affected chemicals to obtain a mandatory standard mark under the Bureau

of Indian Standards (BIS) certification schemes, based on the Indian Standards referenced in the regulations. The new rules may introduce technical market access challenges. Economic operators have until mid-January 2022 to submit their comments on the draft regulations.

Table 1: ISO Standards for Different Chemicals

Product category	Indian Standard
Lauric Acid	IS 10931:1984
Acid Oil	IS 12029:1986
Palm Fatty Acids	IS 12067:1987
Rice Bran Fatty Acids	IS 12068:1987
Coconut Fatty Acids	IS 12069:1987
Rubber seed Fatty Acids	IS 12124:1987
Hydrogenated Rice Bran Fatty Acids	IS 12361:1988
1,3 Phenylenediamine	IS 17450:2020

²² https://www.gpqi.org/news_en-details/india-announces-new-regulations-for-chemicals.html

Chapter - 5

Technologies

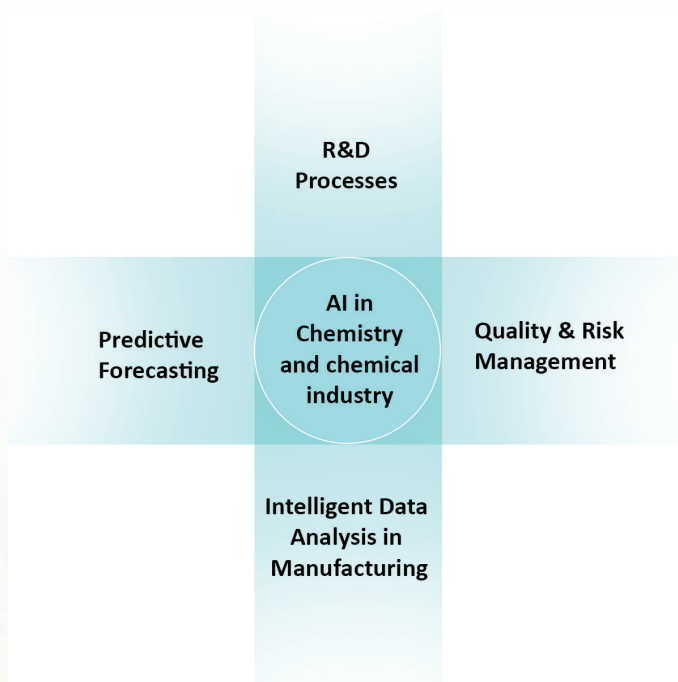
AI and Digitalization for Sustainability

Alongside advancements in green technology, digitalization is reshaping the chemicals and petrochemicals industry. Technologies such as artificial intelligence (AI), the Internet of Things (IoT), and advanced analytics are being used to optimize processes, boost productivity, and facilitate predictive maintenance. These innovations support real-time monitoring, data-driven decision-making, and automation, resulting in enhanced operational efficiency and reduced resource consumption. Digitalization also promotes greater transparency and traceability throughout the value chain. Blockchain technology, for instance, helps track raw materials, ensuring their sustainable sourcing and mitigating the risk of unethical practices. Digital platforms and collaborative tools enhance communication and cooperation among stakeholders, fostering the development of sustainable supply chains and sharing best practices.

The integration of greentech and digitalization provides synergistic benefits to the industry. Digital tools facilitate the monitoring and optimization of greentech initiatives, offering real-time insights into energy use, emissions, and waste. By employing these tools, companies can identify improvement areas, adopt sustainable practices, and better track progress toward environmental goals.

Successful adoption of greentech and digitalization requires collaboration among stakeholders, including governments, industry associations, research institutions, and companies. Joint efforts are essential to develop supportive policies, advance research and development, and create knowledge-sharing platforms. Cross-sector partnerships are crucial to leveraging diverse expertise and accelerating the implementation of innovative solutions.

Figure 13: AI in Chemistry & Chemical Industry

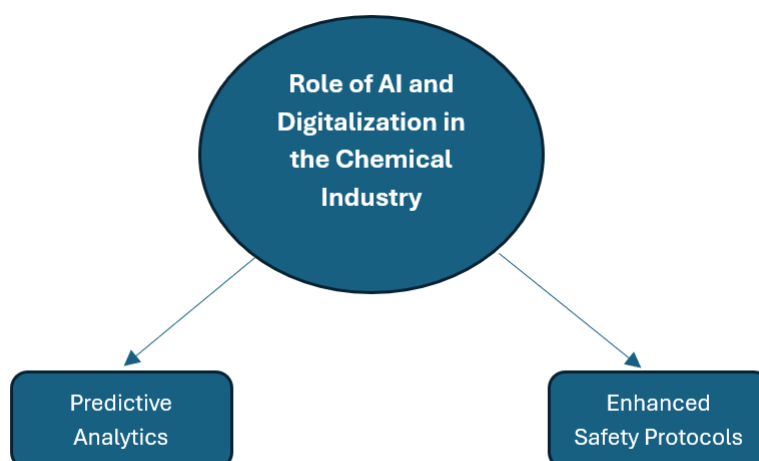


The chemicals and petrochemicals industry is undergoing a significant transformation towards sustainability, driven by the dual forces of greentech and digitalization. Embracing greener alternatives, optimizing energy use, and leveraging digital technologies will allow the sector to reduce its environmental impact while remaining economically viable. This transition demands collaboration, innovation, and a

long-term commitment, ultimately benefiting both the environment and the industry's future viability.

Artificial Intelligence (AI) is emerging as a pivotal force in transforming chemistry towards a more sustainable and eco-friendly future, spearheading the sustainability revolution. The integration of AI with green chemistry is more

Figure 14: Role of AI in Digitalization and Chemical Industry



than an academic exercise—it's a groundbreaking business initiative that is deploying scalable, real-time solutions to significantly reduce environmental impacts on a global scale. Artificial Intelligence (AI) plays a crucial role in advancing green chemistry through the development of innovative, sustainable materials. A notable example is IBM Research's use of AI to discover a new range of recyclable and self-healing polymers. AI algorithms accelerate the discovery of new materials by employing predictive analytics to analyze vast chemical datasets and forecast the properties of potential materials, ensuring environmental compliance.

AI is also revolutionizing chemical production by optimizing energy consumption. For instance,

BASF, a leading global chemical company, has implemented AI-driven processes to enhance energy efficiency. Through machine learning algorithms, BASF can predict and adjust energy usage in real time, resulting in substantial reductions in carbon emissions and energy costs. The integration of AI with green chemistry marks the beginning of a new era in sustainability. AI's advanced applications and real-world industry implementations are significantly speeding up the shift towards greener chemical processes. This transition is crucial for ensuring a healthier planet for future generations and achieving global sustainability goals. Although still in its early stages, AI's impact on green chemistry is already substantial and represents a critical step towards a more sustainable future.

Digitalization and the integration of AI/ML are revolutionizing the chemical industry in India, bringing significant benefits such as increased efficiency, improved safety, and enhanced sustainability. Nonetheless, challenges including

high initial costs, data privacy issues, and skill shortages must be overcome to fully realize the potential of these technologies.

Figure 15: Advantages of Digitalization in Chemical Industry



As India's chemical sector advances in its digital journey, the collaborative efforts of industry leaders, policymakers, and technology innovators will be crucial in shaping a resilient and competitive future. Embracing digitalization and AI/ML will not only boost the industry's global standing but also contribute significantly to the nation's economic growth and sustainable development. The transformative potential of these technologies heralds a future where innovation and efficiency are intertwined, driving India towards the vision of Viksit Atmanirbhar Bharat.

The chemical industry, long considered a pillar of modern industrialization, has experienced a

significant transformation with the advent of digitalization and the integration of Artificial Intelligence (AI) and Machine Learning (ML). In India, this shift is more than a passing trend; it represents a fundamental change that promises to improve efficiency, safety, and innovation. Digitalization involves incorporating digital technologies to reshape business models, optimize processes, and enhance productivity. In the chemical sector, this transformation encompasses a range of technologies, including the Internet of Things (IoT), big data analytics, cloud computing, and AI/ML.

As a major player in the global market, India's chemical industry is adopting these advance-

ments to address longstanding issues such as operational inefficiencies, safety concerns, and environmental sustainability. The integration of AI and ML is particularly transformative, offering revolutionary improvements to traditional practices. Several Indian chemical companies have effectively adopted digitalization and AI/ML, demonstrating the transformative power of these technologies.

- **Reliance Industries Limited (RIL)** - Reliance Industries Limited, a major player in the chemical sector, has been a leader in digitalization. RIL has implemented AI-driven predictive maintenance across its refineries and petrochemical facilities. By utilizing

real-time data and machine learning algorithms, RIL has significantly reduced unplanned downtime and maintenance costs.

- **Tata Chemicals** - Tata Chemicals has embraced digitalization to improve its manufacturing processes. The company employs IoT sensors and AI analytics to monitor and optimize production in real-time, leading to increased operational efficiency, reduced energy consumption, and enhanced product quality. Tata Chemicals' commitment to sustainability is further supported by AI-driven initiatives designed to minimize environmental impact.

Building Leadership in R&D, Innovation, and Digitalization

As the global landscape rapidly evolves due to technological advancements and sustainability pressures, the Indian petrochemicals sector is focusing more to rely on research and development (R&D) to remain competitive and address future needs. The Ministry of Chemicals and Fertilizers has introduced several initiatives, such as the Petroleum, Chemicals, and Petrochemicals Investment Regions (PCPIRs) and plastic parks, but there is a pressing need to accelerate these efforts.

The industry needs to focus on domestic requirements, as India imports a significant amount of chemicals. The government has identified around 500 chemicals that should be produced domestically to conserve foreign reserves and enhance self-reliance. The national petrochemicals policy, established in 2007, led to the creation of PCPIRs, with three currently operational. Additionally, the policy called

for the establishment of Centers of Excellence (CoEs), resulting in 13 such centers being set up. The Central Institute of Plastics Engineering and Technology (CIPET) operates three CoEs dedicated to green transportation, sustainable materials, and 3D printing for biomedical applications. CIPET also boasts three world-class R&D centers in Bhubaneswar, Chennai, and Bengaluru.

Indian chemical companies have increasingly recognized the significance of research and development (R&D), leading to consistent investments in this area and resulting in more innovative, efficient, and value-added products. For the 21 major Indian chemical companies, the average R&D expenditure as a percentage of revenue has averaged 0.6% annually from FY15-22. The total R&D expenditure for these companies has grown at a 13% compound an-

nual growth rate (CAGR) from FY12-22, outpacing their revenue CAGR of 9% over the same period. In FY22, these companies spent INR 5.9 billion on R&D, as compared to INR 1.8 billion in FY12.²⁰

The journey of digitalization and AI/ML in India's chemical industry is still in its early stages, with a promising future full of potential advancements and innovations.

- **Autonomous Chemical Plants** - The idea of autonomous chemical plants, where AI systems manage and optimize all production aspects with minimal human intervention, is gaining momentum. These plants would rely on AI for decision-making, process control, and safety management, offering benefits such as increased efficiency, fewer human errors, and enhanced safety.
- **Digital Twins** - Digital twin technology, which involves creating virtual replicas of physical systems, is poised to transform the chemical industry. Digital twins allow for real-time monitoring, simulation, and optimization of chemical processes. This technology facilitates predictive maintenance, process optimization, and scenario analysis, leading to improved performance and reduced operational risks.
- **Collaboration and Innovation** - The future success of digitalization and AI/ML in the chemical industry will hinge on collaboration among industry stakeholders, academia, and technology providers. Open innovation platforms, joint research efforts, and knowledge sharing will drive the advancement and adoption of these technologies.²¹

Carbon Capture, Utilization, and Storage

The increasing adoption of Carbon Capture, Utilization, and Storage (CCUS) in the chemical and petrochemical industries is becoming more pronounced as these sectors seek to address their environmental impact. This shift is driven by the need to reduce greenhouse gas emissions and comply with stringent climate regulations. According to ChemAnalyst, the global Carbon Capture Utilization and Storage Market stood at USD 3.61 Billion in 2023 is expected to grow at a CAGR of 4.53% and reach USD 4.72 Billion by 2029.

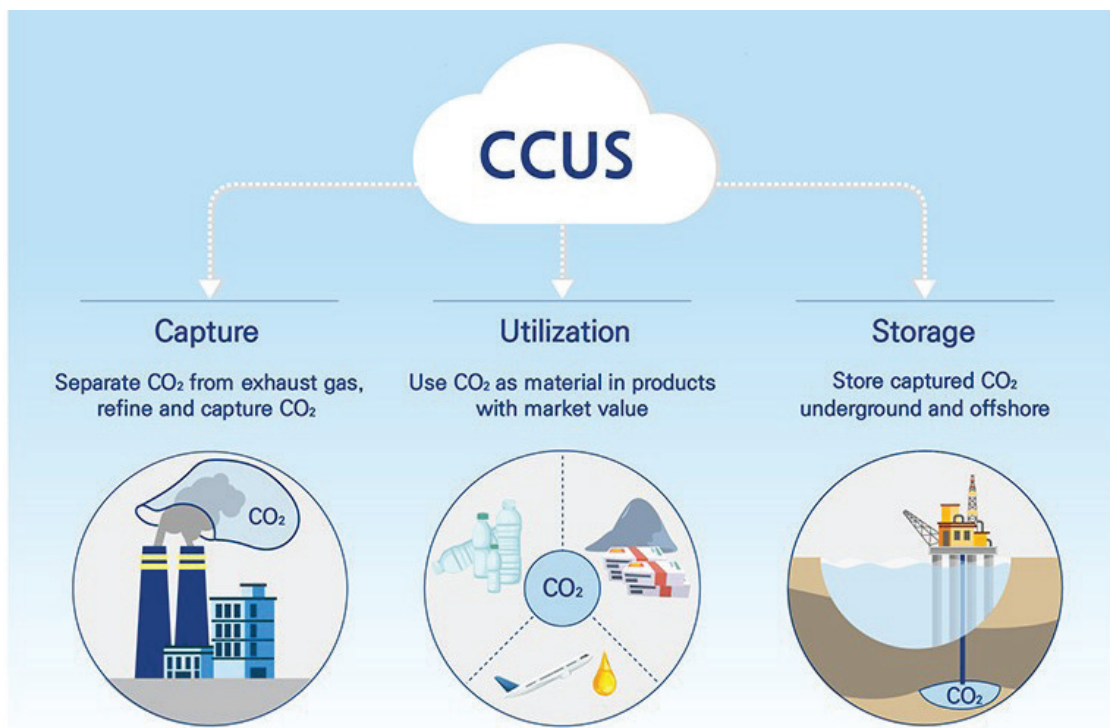
The adoption of Carbon Capture, Utilization, and Storage (CCUS) in India's chemical and petrochemical industries is increasingly becoming a pivotal strategy for mitigating carbon emis-

sions and addressing climate change. These sectors, known for their substantial greenhouse gas emissions, are under growing pressure to implement sustainable practices. In response, there has been a notable rise in the integration of CCUS technologies, driven by a combination of governmental support, industry investment, and technological advancements. The Indian government has played a significant role by establishing supportive policy frameworks and financial incentives, as well as creating roadmaps such as the '2030 Roadmap for CCUS,' which guides and encourages the adoption of these technologies. Additionally, increasing industry awareness and the need to comply with global environmental standards have accelerated the implementation of CCUS solutions. This

²⁰ <https://www.indianchemicalnews.com/rd/indian-chemical-industry-unlocking-the-value-of-knowledge-rd-hdfe-securities-15670>

²¹ <https://www.indianchemicalnews.com/opinion/digitalisation-and-use-of-ai-ml-in-indian-chemical-industry-advantages-and-shortcomings-shrey-b-patel-founder-angiras-rasayan-22690>

Figure 16: Carbon Capture, Utilization, and Storage (CCUS) in the Chemical and Petrochemical Industries



collective effort is not only aiding in reducing emissions but also fostering innovation and positioning India’s chemical and petrochemical industries as leaders in sustainable practices.

The Ministry of Petroleum and Natural Gas, Government of India, has launched initiatives to foster collaboration and knowledge sharing within the industry, aiming to develop and implement a unified and practical strategy for Carbon Capture, Utilization, and Storage (CCUS) and Carbon Capture and Storage (CCS) techniques in the oil and gas sector. To this end, a task force named ‘Upstream for CCS/CCUS’ (UFCC) is working on the ‘2030 Roadmap for CCUS,’ which will provide essential guidance and direction for oil and gas companies to advance and expand CCS/CCUS technologies.

Initially centred on refining, the partnership between TCS and TotalEnergies is leveraging digital technologies to enhance collective knowledge and advance various aspects of refining, including production units, processes, the supply chain, and petroleum product markets. This effort aims to improve refinery performance and promote sustainability in the oil and gas industry. The ‘entrepreneurship-in-residence’ model allows TotalEnergies to work closely with TCS’s technology and domain experts, with TCS contributing its expertise in structured co-innovation approaches. While the innovation center initially focused on the refinery sector, its scope has broadened to encompass other areas and related industries, including exploration and production, renewable gas, and power.²²

²² <https://www.tcs.com/what-we-do/pace-innovation/article/sustainability-oil-gas-iot-energy>

Implementation Challenges

The Indian chemical industry, is one of the key pillars of the country's manufacturing sector, contributing around 7% of India's GDP. It is also the sixth-largest producer of chemicals in the world. However, despite its growth potential, the integration of cutting-edge technologies such as Artificial Intelligence (AI) and Machine Learning (ML) in this sector has been relatively slow, with several obstacles hindering its widespread adoption. AI and ML have the power to optimize processes, reduce waste, enhance safety, and drive innovation in product development. Globally, AI in the chemical industry is projected to grow at a CAGR of 40.2% from 2020 to 2030, reflecting the enormous potential of these technologies. Yet in India, where the chemical industry remains highly fragmented with over 80,000 small and medium-sized enterprises (SMEs), several key challenges have slowed down their implementation.

1. Data Availability and Quality

The effectiveness of AI and ML depends heavily on data—particularly its availability, quality, and accuracy. In India, a significant portion of the chemical industry, especially SMEs, lacks the robust digital infrastructure needed to generate and manage high-quality data. According to a report by the Federation of Indian Chambers of Commerce & Industry (FICCI), only 25% of Indian chemical companies have adopted digital technologies at scale, while the majority still rely on manual or semi-automated processes. Many facilities are not equipped with sensors, IoT devices, or advanced monitoring systems to capture real-time process data. As a result, Indian chemical companies often struggle with

incomplete or inconsistent datasets, making it difficult to build reliable AI models. Additionally, the absence of standardized data collection practices leads to fragmented, siloed information across different departments, limiting the potential of AI for predictive maintenance, process optimization, or product development.

2. Legacy Infrastructure

A substantial portion of India's chemical plants are based on legacy infrastructure that is not designed to integrate with AI and ML technologies. These older plants lack the modern automation systems necessary to harness the full benefits of AI. According to a survey by the Indian Chemical Council (ICC), more than 60% of chemical plants in India operate with outdated machinery and minimal automation, particularly in SME sectors.

For AI to function optimally, chemical plants need to be fitted with sensors, advanced control systems, and data integration platforms. Retrofitting these systems to accommodate AI solutions is expensive and requires significant downtime, which many companies are unwilling to risk. The financial burden of upgrading legacy infrastructure further discourages investment in AI technologies.

3. High Implementation Costs

The financial outlay required to implement AI and ML solutions is one of the major hurdles for the Indian chemical industry. The industry is heavily fragmented, with SMEs making up 70-80% of the market. These smaller firms operate on tight profit margins and are often unable to

afford the substantial upfront costs associated with AI adoption, such as upgrading equipment, installing sensors, and developing custom AI models.

4. Lack of Skilled Workforce

The AI talent gap in India is a critical challenge, particularly in specialized industries like chemicals. Data suggests that 80% of chemical companies globally cite a shortage of AI-skilled professionals as a significant barrier to adoption. In India, this gap is even more pronounced. While India is home to a large pool of IT and software talent, the intersection of AI expertise and chemical industry knowledge is rare.

To effectively implement AI in chemical manufacturing, companies need professionals who understand both chemical engineering and data science. However, fewer than 20% of chemical engineers in India have formal training in digital technologies or AI, according to a study by the Indian Institute of Chemical Engineers (IICChE). Upskilling workers and developing a digital-first mindset will require time and significant investment from both industry and academia.

5. Regulatory and Compliance Issues

India's chemical industry is subject to stringent environmental, health, and safety regulations, which adds complexity to AI implementation. AI-driven changes to manufacturing processes must meet regulatory standards and obtain approvals, which can be time-consuming and difficult.

Incorporating AI solutions into highly regulated environments means ensuring that AI-driven decisions or optimizations meet safety requirements. The use of AI in areas like hazardous materials handling or emissions control needs thorough validation and can face delays due to regulatory hurdles.


6. Cybersecurity Concerns

The increasing digitalization of chemical plants through AI, ML, and IoT opens up new vulnerabilities to cyber threats. The Indian chemical industry, operates critical infrastructure, making it a prime target for cyber-attacks.

Cyber threats are increasingly posing significant challenges and obstacles to the growth of the chemical sector. As the industry becomes more reliant on digital technologies across various sectors, the frequency and severity of cyberattacks are leading to substantial financial losses and infrastructural damage. This situation is driving companies to invest heavily in advanced cybersecurity systems to safeguard their operations and ensure data privacy.

7. Scalability Issues

Scaling AI solutions across multiple plants or operations presents another challenge. Even when companies successfully deploy AI at one plant or for a specific process, replicating these results at scale can be difficult. The chemical industry is highly diverse, with different processes, materials, and plant designs that may not easily accommodate uniform AI solutions.



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Chapter - 6

Regional Contributions

Gujarat is the top exporter of various chemical sub-sectors, including inorganic chemicals, organic chemicals, petrochemicals, plastics, rubber, man-made filaments, and man-made fibers, contributing 41% to India's national chemicals and petrochemical exports. Currently, Gujarat accounts for 14% of India's specialty chemicals production and aims to increase this share to 40% by 2047. The state's advanced chemical sector infrastructure and skilled workforce are expected to attract further investment in specialty chemicals and related products.

Gujarat has a turnover of over USD32 billion in Chemical Industry. Gujarat accounts for 41%

of India's total chemical and petrochemical exports, representing 5% of the country's overall exports and 27% of the state's total exports. The state hosts four refining complexes with a combined capacity of 102 MMTPA, which constitutes 41% of India's total refining capacity. Gujarat is the leading exporter in India for chemical and petrochemical products, including inorganic chemicals, organic chemicals, plastics, rubber, man-made filaments, man-made fibers, and miscellaneous chemicals. The top ten export destinations for these products are the USA, China, Brazil, the UAE, Germany, Indonesia, the UK, the Netherlands, South Africa, and Belgium.²³

Gujarat's Role in Sustainable Development

Gujarat, often referred to as the "Growth Engine of India," has been a leader in driving economic progress and industrialization in the country. Over the past few decades, the state has made remarkable strides in various sectors, contributing significantly to India's overall development. However, alongside this rapid industrialization, Gujarat has also been a pioneer in adopting sustainable development practices, balancing economic growth with environmental protection and social equity.

The state's unique approach to sustainability spans renewable energy, water conservation, waste management, and eco-friendly industrial practices, making it a model for sustainable development in India. Below are some key aspects of Gujarat's contribution to sustainable development.

1. Leadership in Renewable Energy

Gujarat has emerged as one of India's top leaders in the renewable energy sector, particularly in solar and wind energy. The state's emphasis on renewable energy aligns with India's larger goal of achieving 500 GW of renewable energy capacity by 2030. Gujarat is known for setting up Asia's first commercial-scale solar park, the Gujarat Solar Park in Charanka, which has a capacity of over 700 MW.

As of September 2023, the vast majority of Gujarat's installed renewable capacity came from wind power, with approximately 11.1 gigawatts. Meanwhile, Gujarat's total installed renewable electricity capacity stood at around 23.7 gigawatts that year. Notably, the state's wind energy capacity stands at over 11,000 MW, making Gujarat one of the largest producers of wind energy in the country. The state's Surya Urja Rooftop

²³ <https://www.tcs.com/what-we-do/pace-innovation/article/sustainability-oil-gas-iot-energy>

Yojana has further encouraged the adoption of solar energy in residential and industrial sectors, promoting decentralized power generation.

Moreover, Gujarat's Hybrid Renewable Energy Park in Kutch, which is expected to generate 30,000 MW of solar and wind energy, will be the largest of its kind in the world. This ambitious project will contribute significantly to India's renewable energy targets while reducing carbon emissions.

2. Water Conservation and Management

Water scarcity is a critical issue in India, especially in drought-prone regions like Gujarat. The state has implemented several innovative water conservation programs to address this challenge. One of the most successful initiatives is the Sujalam Sufalam Yojana, a water conservation program aimed at reviving water bodies, deepening lakes, and building check dams to store rainwater. This initiative has helped increase the water table in many regions, making water more accessible for agriculture and domestic use.

Gujarat has also been a leader in micro-irrigation technologies. The state's Narmada Canal-based drip irrigation system has not only improved water-use efficiency but has also helped conserve water in agriculture, which accounts for about 80% of the total water usage in the state. By promoting drip irrigation and water-efficient cropping patterns, Gujarat has set an example for sustainable agricultural practices.

The Sardar Sarovar Dam on the Narmada River is another key infrastructure project that has played a vital role in addressing water scarcity in Gujarat and neighboring states. While the project faced environmental and social concerns,

the dam has provided drinking water, irrigation, and hydroelectric power to millions, contributing to sustainable water resource management.

3. Promotion of Green and Eco-Friendly Industries

As one of India's most industrialized states, Gujarat is home to numerous large-scale industries, including petrochemicals, chemicals, and textiles. However, the state has also been proactive in promoting green industrial practices. The Gujarat Industrial Development Corporation (GIDC) has been working on establishing eco-friendly industrial estates with wastewater treatment plants, green spaces, and pollution control measures.

Gujarat's Petroleum, Chemicals, and Petrochemicals Investment Region (PCPIR) near Dahej is designed with sustainable industrial practices in mind. The Dahej SEZ is equipped with centralized effluent treatment facilities, ensuring that industrial waste is managed in an environmentally responsible way. Moreover, the state has been actively promoting circular economy practices by encouraging industries to reuse waste and byproducts, reducing the environmental impact of industrial activity.

The Vibrant Gujarat Summits, organized biennially, also play a key role in bringing attention to sustainable practices, as they focus on green technology and eco-friendly investments.

4. Afforestation and Biodiversity Conservation

Gujarat has made substantial efforts in afforestation and biodiversity conservation, recognizing the importance of ecological balance.

The state's Van Mahotsav, an annual tree-planting festival, has resulted in the planting of millions of trees across the state, improving forest cover and carbon sequestration. Additionally, Gujarat's Social Forestry Program has involved local communities in planting trees on barren and fallow lands, contributing to both environmental sustainability and rural livelihoods.

The Gir National Park, home to the world's last population of Asiatic lions, reflects Gujarat's commitment to conserving biodiversity. The state has taken numerous measures to protect endangered species and restore ecosystems. The conservation efforts in Gir have led to a remarkable increase in the lion population, which has grown from just 180 in the 1970s to over 670 lions today. Gujarat's efforts to protect marine ecosystems along its 1,600 km coastline, including mangrove plantations and coral reef conservation, also showcase its focus on sustainable biodiversity management.

5. Waste Management Initiatives

Waste management is a critical component of sustainable development, and Gujarat has made significant progress in this area. The state has implemented several solid waste management initiatives to reduce, reuse, and recycle waste generated by its growing population and industries.

Cities like Ahmedabad and Surat have developed integrated waste management systems that include waste segregation at the source, composting, and waste-to-energy plants. Ahmedabad, in

particular, became the first city in India to issue a municipal green bond to fund a waste-to-energy project. This initiative converts solid waste into energy, reducing the burden on landfills and contributing to clean energy generation.

Gujarat has also focused on hazardous waste management by establishing multiple Treatment, Storage, and Disposal Facilities (TSDFs). These TSDFs help manage industrial hazardous waste, ensuring that it does not contaminate land or water sources, aligning with the state's broader environmental protection goals.

6. Sustainable Urban Development

Urbanization is another critical aspect of Gujarat's development strategy. The state has been at the forefront of promoting smart and sustainable urbanization. The Gujarat International Finance Tec-City (GIFT City), located between Ahmedabad and Gandhinagar, is India's first operational smart city, designed with sustainability as a core principle. GIFT City incorporates energy-efficient buildings, sustainable water management systems, and green transportation options, positioning Gujarat as a leader in smart and sustainable urban development. In addition, Gujarat's cities have shown significant improvements in waste management, water conservation, and air quality under the Smart Cities Mission, with cities like Surat and Ahmedabad making notable progress in terms of sustainable urban infrastructure.

Successful Case Studies

Gujarat is a major player in India's chemical industry. With rapid industrial growth, Gujarat has placed a strong emphasis on adopting sustainable practices, especially in the chemical sector, which is traditionally resource-intensive and prone to environmental challenges. Below are several case studies that highlight Gujarat's efforts to balance industrial growth with sustainable development in the chemical industry.

1. The Gujarat Green Petrochemical Complex, Dahej

Location: Dahej, Bharuch District

Year of Initiative: 2019 onwards

Focus Area: Sustainable petrochemicals production, green energy, and waste management.

Background: The Dahej Petroleum, Chemicals and Petrochemicals Investment Region (PCPIR) is a major industrial hub designed to attract large-scale investments in the chemical and petrochemical industries. Spread over 453 square kilometers, this region houses several of India's largest chemical companies. However, given the environmental impact of petrochemicals, sustainability has been a core focus in its development.

Sustainable Measures: The Gujarat government, in collaboration with private players like ONGC Petro Additions Limited (OPaL), has established green infrastructure and sustainable production practices in the Dahej PCPIR. Key sustainability initiatives include:

- **Plantation Drive:** The company is focusing on prioritizing the sustainable management

of ecosystems and embarked upon a mega plantation drive of 31,000 trees in their petrochemical complex in Dahej. OPaL's green belt, called the 'Oxyzone', is spread across 51-hectare land out of which 40 hectares are covered with fully grown trees with a lively ecosystem. The mega plantation drive aims to cover another 11.3-hectare area to expand to boost biodiversity with flora and fruit-laden trees that will emit more oxygen to produce clean and healthy air.

- **Focus on Energy Conservation:** Energy conservation and preservation is one of the key sustainability goals for the company. Driven by the focused intent of the top management, their activities are based on adopting sound and sustainable actions and technologies towards continual improvement in the environment and energy. Every year they celebrate "National Conservation Week" as well with the primary objective of creating awareness about energy conservation.

2. The Gujarat Cleaner Production Centre (GCPC)

Location: Gandhinagar

Year of Initiative: 1998 (ongoing)

Focus Area: Promoting cleaner production and resource efficiency in the chemical industry.

Background: Gujarat, with its large chemical manufacturing base, faces significant environmental challenges, including air and water pollution. To address these issues, the Gujarat government, in partnership with the United Nations Industrial Development Organization

(UNIDO), established the Gujarat Cleaner Production Centre (GCPC). The GCPC promotes the adoption of cleaner production technologies and helps industries transition to more sustainable operations.

Sustainable Measures: GCPC has undertaken multiple initiatives to promote sustainability in Gujarat's chemical sector, including:

- The organization is promoting 'Sustainable Consumption and Production' (SCP) and Resource Efficiency and Cleaner Production (RECP) in Industries and Academic Institutions. Internationally, the centre is regular member of Global Resource Efficient and Cleaner Production Network (RECPnet) hosted by UNEP & UNIDO. The centre is also a regular member of Climate Technology Centre and Network (CTCN) an operational arm of UNFCCC. Nationally, the centre is recognized as Programme Centre- Resource Partner (PC-RP) under Environment, Information, Awareness, Capacity Building and Livelihood Programme of Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India.
- GCPC had played an active role in framing Industrial Policy 2004, 2009 and 2015 and also supported in developing many financial assistance schemes pertaining to CP/CT. GCPC is a Regular Member of RECP (Resource Efficiency and Cleaner Production) Network of UNIDO and also, GCPC is a regular member of Climate Technology Centre and Network (CTCN), a working arm of UNFCCC of UNEP.

3. Narmada Clean Tech (NCT) Common Effluent Treatment Plant (CETP), Ankleshwar

Location: Ankleshwar, Bharuch District

Year of Initiative: 1997 (ongoing, with expansions)

Focus Area: Industrial effluent treatment and pollution control.

Background: Ankleshwar is one of India's largest chemical industrial hubs, home to more than 1,000 chemical manufacturing units. Due to the nature of chemical production, the region has historically faced severe environmental pollution, particularly water contamination from untreated industrial effluent.

Sustainable Measures:

In response to rising environmental concerns, the Gujarat Industrial Development Corporation (GIDC) established Narmada Clean Tech (NCT), a state-of-the-art Common Effluent Treatment Plant (CETP) in Ankleshwar. It is based on PPP model, and is a subsidiary of Gujarat Industrial Development Corporation (GIDC) and also jointly promoted by Member Industries of Ankleshwar, Jhagadia and Panoli Industrial Estates.

Key features of the NCT CETP include:

- **Zero Liquid Discharge (ZLD):** NCT has adopted ZLD technology, ensuring that no untreated water is discharged into the Narmada River. Treated water is either recycled back into the production process or safely evaporated.
- **Advanced Treatment Technology:** The plant employs advanced treatment techniques, including reverse osmosis and multi-effect evaporation, to treat even the most toxic industrial effluents. This ensures that the final

discharge meets stringent environmental standards.

- **Waste-to-Resource:** NCT also converts the solid waste generated during effluent treatment into usable byproducts, such as gypsum and treated sludge, which are used in cement manufacturing and agriculture.

4. **Tata Chemicals: A Sustainable Approach to Soda Ash Production**

Location: Mithapur, Devbhoomi Dwarka District

Year of Initiative: Ongoing

Focus Area: Sustainable production of chemicals, water management, and biodiversity conservation.

Background: Tata Chemicals is one of India's largest chemical manufacturers, and its Mithapur plant is the largest producer of soda ash in India. Given the water-intensive nature of soda ash production and its environmental impact, Tata Chemicals has been proactive in implementing sustainable practices at its Mithapur plant.

The Pivotal Role of Gujarat PCPIR in Driving Inclusive Growth

In May 2007, the Government of India introduced a Policy Resolution aimed at fostering the development of Petroleum, Chemicals, and Petrochemical Investment Regions (PCPIRs). This initiative draws inspiration from successful chemical and petrochemical hubs in the Middle East, Southeast Asia, and Europe, which have significantly advanced their sectors and spurred regional growth.

The policy aims to encourage investment in the petroleum and petrochemical industries by establishing an effective regulatory framework

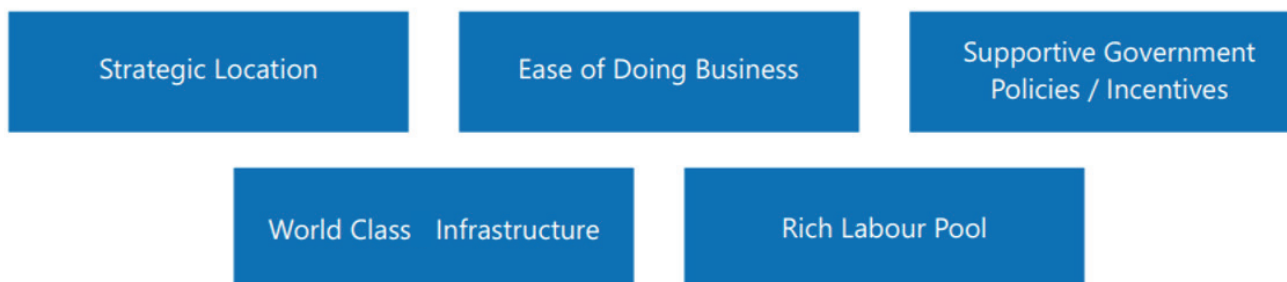
Sustainable Measures:

- Mithapur unit started using biomass as feedstock which will help reduce conventional energy consumption. The Innovation Centre successfully commissioned a 100 kW Rooftop Solar Project which will reduce the electricity from grid by 25 per cent.
- The company commissioned UK's first at scale Carbon Capture and Utilisation facility (CCU) that not only reduces carbon intensity but provides a sustainable inhouse source of critical input. Successfully operationalised in FY22, the CCU facility captures food and pharmaceutical grade CO₂ for consumption in the Sodium Bicarbonate plant. The Indian operations installed a quadruple effect evaporator at the Mithapur plant, resulting in 150 equivalent kilo tonnes of carbon savings.

and state-of-the-art infrastructure. It provides broad guidelines and sets minimum standards for developing PCPIRs, while also detailing the roles of both the Central and State Governments in terms of budget and institutional support.

The Gujarat Government, through its nodal agency, the Gujarat Industrial Development Corporation (GIDC), sought to capitalize on this opportunity and engaged Mott MacDonald Private Limited (referred to as Consultants) to prepare the application for Gujarat. Based on this

Figure 17: Key Investment Drivers



application, a 453 sq. km area in Bharuch District, Gujarat, was approved as one of the first three PCPIRs in India, alongside the PCPIRs in Andhra Pradesh and West Bengal. ONGC Petro Additions Ltd (OPaL), a joint venture between Oil and Natural Gas Commission (ONGC) and Gujarat State Petroleum Corporation (GSPC), has been designated as the 'lead anchor' for promoting the Gujarat PCPIR.

The establishment of PCPIRs is crucial for the chemical industry, as this policy is anticipated to draw significant investments from both domestic and international sources. Currently, three PCPIRs have been announced: Dahej, Paradip, and Vizag. Additionally, several SEZs, including those in Mangalore and Dahej, host petrochemical complexes. These SEZs are dedicated to becoming net foreign exchange earners, thereby intensifying their focus on penetrating export markets.

Government of India has approved 4 Petroleum, Chemical and Petrochemical Investment Regions (PCPIRs) in the state of Andhra Pradesh (Vishakhapatnam), Gujarat (Dahej), Odisha (Paradeep) and Tamil Nadu (Cuddalore and Naga-pattinam) to promote investment and indus-

trial development in these sectors. The PCPIR is envisioned to reap the benefits of co-siting, networking and greater efficiencies through use of common infrastructure and support services. Each PCPIR is a specifically delineated region having an area of about 250 sq. km. wherein 40% of the area has to be for processing activities.

Once fully established, these PCPIRs are expected to attract investment of Rs. 7,62,894 crores approximately. As on 31.12.2014 investments worth Rs. 70,649 crores approximately have been made in these regions. Infrastructures with investment of Rs. 53,468.7 crore approx. is expected to be created in the PCPIRs, out of which the contribution of Government of India would be 4646.30 crore. The four PCPIRs are expected to generate employment for around 33.96 lakh persons. As on 31.12.2014 around 2.23 lakh persons have been employed in direct and indirect activities related to PCPIRs.

With companies such as Reliance, Shell, ONGC, and others already established in Gujarat, the state is poised to become a leader in the chemicals and petrochemicals sector. The Petroleum, Chemicals, and Petrochemicals Investment Re-

gion (PCPIR) at Dahej in Gujarat's Bharuch district is one of the four PCPIRs designated by the Centre under the PCPIR Policy 2007. Covering an area of 452.98 square kilometers, the Gujarat PCPIR boasts excellent connectivity through road, rail, port, and air.

The ONGC Petro Additions Limited (OPaL) facility within the PCPIR is one of South Asia's largest petrochemical complexes. Spanning 5 square kilometers, OPaL has the capacity to produce 1.4 million tons of polymers and 500,000 tons of chemicals annually. Besides OPaL, the PCPIR also hosts manufacturing and processing facilities for major companies including BASF, ONGC, Reliance Industries (RIL), Welspun, Pidilite, and GNFC.

Reliance Industries Ltd's (RIL) Jamnagar refinery is the world's largest and most intricate single-site refinery, with a crude processing capacity of 1.4 million barrels per day (MMBPD). According to RIL's official website, the Jamnagar refinery complex features some of the globe's largest units, including those for fluidized catalytic cracking, coking, alkylation, paraxylene production, polypropylene, refinery off-gas

cracking, and petcoke gasification.

Dahej is a prominent investment hub with a robust industrial base spanning sectors such as chemicals and petrochemicals, textiles, pharmaceuticals, and ports and shipbuilding. The development of the GPCPSIR, the Dahej SEZ, and its proximity to the Delhi-Mumbai Industrial Corridor (DMIC) is expected to further drive industrial and economic growth in the district. Dahej has successfully attracted significant investments into the PCPIR, totaling approximately US\$ 13.6 billion. This includes US\$ 2.4 billion allocated for infrastructure development in the PCPIR region by the Gujarat Infrastructure Development Corporation (GIDC), and a major investment of US\$ 4.0 billion from OPaL.

Key investors in the region include Reliance, BASF, Aditya Birla, Welspun, GACL, Adani, SRF, GSPL, Torrent, and Lanxess. Additionally, various projects by Nayara Energy, Godrej Agrovet, Polyplastics, Thermax, Astral Pipes, Neogen Chemicals, and others are currently under development.

A photograph of an industrial chemical plant featuring several tall distillation columns and a complex network of pipes and walkways. The scene is set against a clear blue sky. The image is overlaid with a semi-transparent white banner at the bottom containing text.

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Chapter - 7

Collaboration between

Industry, Government,

and Academia

Collaboration between Industry, Government, and Academia

Similarly, the companies are taking initiatives. To advance green energy and green hydrogen goals and support the Government of India's carbon-neutrality efforts, a Memorandum of Understanding (MoU) was signed between NTPC RE Limited (NTPC REL) and Gujarat Alkalies and Chemicals Limited (GACL) on July 6, 2022, in New Delhi. The MoU outlines a collaboration in Renewable Energy, Green Methanol, and Green Ammonia. It aims to explore opportunities for supplying 100 MW of Round-The-Clock (RE-RTC) power and producing 75 tons per day (TPD) of Green Methanol and 35 TPD of Green Ammonia. These will be used for chemical production at GACL's Vadodara and Dahej facilities in Gujarat. This initiative represents the country's first commercial-scale Green Ammonia and Green Methanol project, aligning with the vision of Atmanirbhar Bharat as outlined by the Hon'ble Prime Minister.

Arete Group has announced a major transaction involving the acquisition of 35 acres of prime industrial land at Payal Industrial Park (PIP) in Dahej, Gujarat, by Silox India. Silox India, a Belgium-based manufacturer of inorganic chemicals, is entering this strategic partnership to drive growth, innovation, and sustainability in the chemical manufacturing sector. PIP, developed and promoted by Arete Group, is India's largest privately integrated industrial park, strategically positioned within the Gujarat PCPIR (Petroleum, Chemicals, and Petrochemicals Investment Region). Endorsed by the Gujarat government, PIP provides world-class infrastructure and facilities, making it an ideal location for manufacturing plants and large-scale industries. Spanning over 3,500 acres and planned

by CH2M Hill, the park is designed to meet the needs of water-intensive and polluting industries.

In July 2024, UPL University of Sustainable Technology, part of the UPL Group, and the Indian Space Research Organisation (ISRO)'s Space Application Centre (SAC) entered into a significant partnership to advance research in chemical sciences. This MoU aims to foster innovation in chemical applications, particularly in materials science, through access to ISRO's cutting-edge research resources. UPL University's collaborations with CSIR, ICT Mumbai, and international partners like Gexcon further boost research in environmental engineering, safety standards, and sustainable technologies, directly benefiting the local chemical industry and promoting environmental stewardship.

The Gujarat government's recent MoUs signed in October 2023 with two German companies—Starlinger and Covestro—are poised to significantly benefit the state's burgeoning chemical industry. These investments reinforce Gujarat's position as a hub for both packaging machinery and specialty chemicals, two sectors critical to the chemical industry.

Starlinger's packaging machinery plant will bolster the chemical industry by enhancing local access to advanced packaging technologies, crucial for safely transporting chemicals. Packaging solutions are vital in maintaining the quality and safety of chemical products, which will be made more efficient and cost-effective through local production. Covestro's investment in specialty chemical manufacturing in-

troduces cutting-edge chemical products to Gujarat. This will help meet the growing demand for advanced chemical solutions in industries like automotive, electronics, and construction, where Gujarat already plays a key role.

These MoUs signal growing global confidence in Gujarat as a destination for high-tech chemical and manufacturing industries. The introduction of German technologies and expertise will not only boost local industry standards but also attract further foreign investments, encouraging the growth of a more diversified chemical manufacturing ecosystem. By expanding the specialty chemicals sector and improving packaging solutions, Gujarat will be able to support a wider range of industries, from petrochemicals to pharmaceuticals. This creates a synergy that enhances supply chains, reduces dependencies on imports, and fosters innovation within the local chemical industry. The establishment of these production bases will create direct employment opportunities, helping to develop a skilled workforce with expertise in advanced machinery and specialty chemical production, further empowering Gujarat's chemical sector.

Godrej Locks & Architectural Fittings and Systems-At its eco-friendly manufacturing facility in Goa, Godrej Locks & Architectural Fittings and Systems has embraced green chemistry for the production of locks. The plant employs an ion exchange process for the selective removal of heavy metals, enhancing energy efficiency. It also features an automated online effluent treatment plant that has replaced eco-hazard-

ous materials with more bio-friendly alternatives. The green chemistry approach uses trivalent chrome, a non-cyanide-based option, instead of the environmentally harmful hexavalent chromium. Similarly, the plating process employs an alkaline copper system in place of hazardous cyanide copper. Additionally, the company prioritizes the use of recycled materials, such as brass and Mazak, and ensures that processed scrap is sent back to the smelter to be converted into raw material for reuse.

Swedish Steel India is advancing its green manufacturing initiative through the HYBRIT project, which aims to replace coking coke with hydrogen in the steel production process. The steel industry is one of the largest contributors to global carbon dioxide emissions, accounting for 7% of the total. The HYBRIT (Hydrogen Breakthrough Ironmaking Technology) project seeks to replace coal with hydrogen in steelmaking, replacing the traditional blast furnace method. Currently, coke is used to convert iron ore to iron, but the new process will use hydrogen gas, produced from fossil-free energy sources, instead. The by-product will be water, which can be recovered and used to produce more hydrogen gas. According to the company, reduction reactions in ironmaking account for approximately 85-90% of the total carbon dioxide emissions in ore-based steelmaking. HYBRIT's method will significantly reduce these emissions by using hydrogen gas as the primary reductant.

Roadmap for Sustainability

The Indian chemical industry is currently grappling with several sustainability challenges. The sector is highly energy-intensive, consuming approximately 12-15% of the country's total energy. This substantial energy use leads to significant greenhouse gas emissions, contributing to climate change. The chemical industry is one of the largest consumers of water in India, accounting for around 20% of total industrial water usage. This high level of water consumption strains limited water resources, exacerbating water scarcity in certain regions. The industry generates considerable amounts of hazardous waste and emissions, which can pose serious environmental and health risks if not managed effectively. It is also susceptible to accidents such as leaks, spills, and explosions, which can result in severe environmental damage and harm to human health. The chemical industry faces social sustainability issues, including poor working conditions, low wages, and human rights violations, especially among contract workers.

Gujarat stands as India's most industrialized state, leading the nation in manufacturing output. The state benefits from a highly developed business ecosystem, supported by robust infrastructure and investment-friendly policies, which have drawn substantial investments across various sectors. With its extensive manufacturing base, Gujarat is ideally positioned to play a key role in the large-scale production, storage, and transportation of green hydrogen. This is vital for establishing a strong, localized supply chain for green hydrogen development. To capitalize on Gujarat's industrial prowess and its pivotal role in green chemical development, companies should prioritize sustainable practic-

es in the chemical and petrochemical sectors. By leveraging the state's advanced infrastructure, investment-friendly policies, and abundant renewable energy resources, businesses can drive innovation and efficiency. Key measures include investing in green technologies, adopting energy-efficient processes, and ensuring robust waste management systems. Companies should also collaborate with local stakeholders to enhance the state's hydrogen production and infrastructure capabilities, aligning with the National Green Hydrogen Mission's goals and contributing to Gujarat's leadership in sustainable industrial growth.

India is committed to achieving its Net Zero emissions target by 2070, with green hydrogen expected to be a pivotal factor in decarbonizing hard-to-abate sectors and reaching this ambitious goal. In January 2023, the country launched the National Green Hydrogen Mission (NGHM), aiming for a production of at least 5 Million Metric Tons per Annum (MMTPA) by 2030. Gujarat is well-positioned to capitalize on this opportunity and develop a robust green hydrogen economy. The state boasts significant domestic hydrogen demand and extensive resources, including abundant renewable energy potential, skilled workforce, dedicated transmission and distribution infrastructure, and large land areas suitable for establishing a green hydrogen ecosystem. Gujarat plays a vital role in India's hydrogen sector, contributing nearly 25% of the nation's hydrogen demand, mainly driven by refineries and fertilizers.

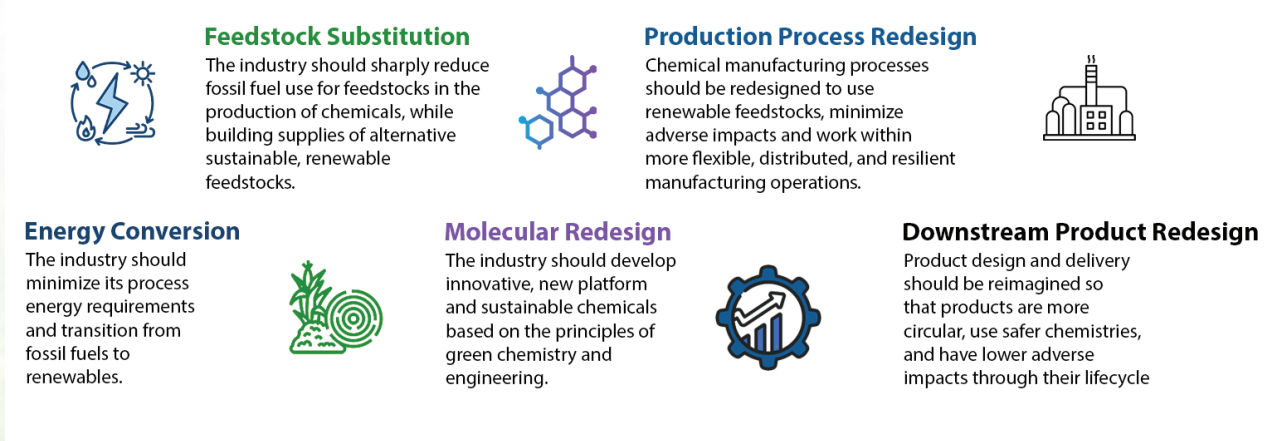
The strategic location of Gujarat, with vast fallow lands available for renewable energy and

hybrid plant development and proximity to Deendayal Port—designated as an export hub for green hydrogen—provides a significant advantage. As demand is expected to grow and new applications in steel, shipping, and mobility emerge over the next decade, the state’s hydrogen demand could reach approximately 2 to 2.5 MMTPA.

The Gujarat Government is also undertaking extensive efforts to ensure the success of the Vibrant Gujarat Global Summit (VGS) 2024, positioning it as a premier platform for global investors and industrialists. As part of the lead-up to the summit, the state has initiated multiple Memorandums of Understanding (MoUs) with various industries. In the second phase of this

initiative, four industries have committed to invest a total of ₹1,401 crores. These MoUs were signed on August 2, 2023, in Gandhinagar, and pertain to the chemical sector. The investments will be allocated to the Saykha and Dahej GIDC areas in Bharuch district. As part of the MoUs signed on August 2, Gujarat Fluorochemicals will invest ₹50 crores in Dahej 2 to produce lithium hexafluorophosphate, a key chemical for electric vehicle batteries. Savita Green Tech Limited will launch a plastic bottle recycling project with an investment of ₹493 crores in Saykha GIDC. Harcros Chemicals Pvt. Ltd. will set up a specialty chemicals plant in Dahej-1 with an investment of ₹300 crores, and Ashu Organic (India) Pvt. Ltd. will establish a manufacturing plant for dyes and pigment intermediates in Dahej-3, investing ₹108 crores.

Figure 18: Conversion Strategies to Transition the Chemical Industry towards Sustainability

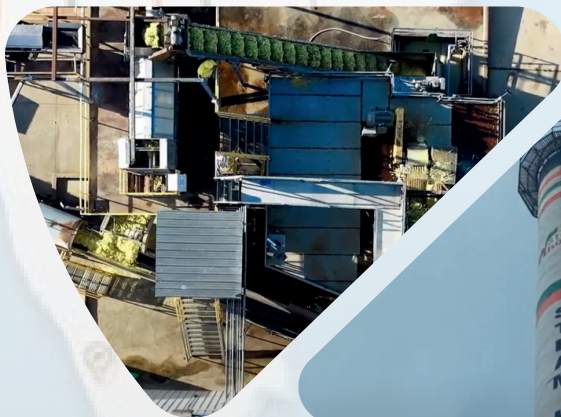




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Chapter - 8

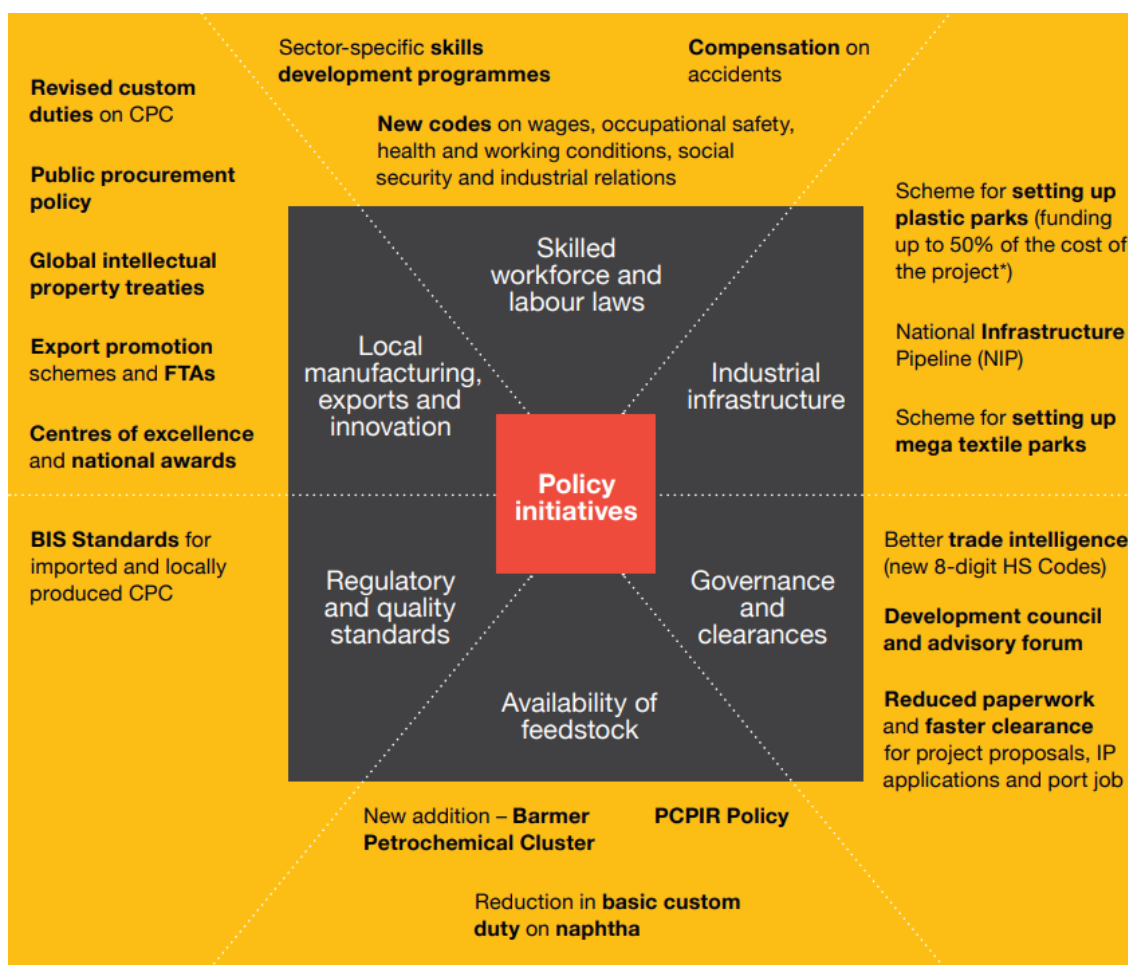
Policy Framework

Overview of Government Policies Supporting the Chemical and Petrochemical Industries

The Government of India (GoI) aims to position India as a leading hub for CPC (Chemicals, Petrochemicals, and Pharmaceuticals) manufacturing through various initiatives and policy reforms designed to foster a more business-friendly en-

vironment for both domestic and international investors. India's Ease of Doing Business (EoDB) ranking has significantly improved from 142 in 2014 to 63 in 2019. The government is also advancing bold reforms, including the Chem-

Figure 19: Policy Initiatives



²⁴ <https://www.pwc.in/assets/pdfs/industries/oil-and-gas/publications/evolving-horizons-indian-chemical-and-petrochemical-industry.pdf>

ical (Management and Safety) Rules (CMSR), Extended Producer Responsibility (EPR) regulations, and the rationalization of basic customs duties on raw materials for domestic manufacturers. The focus is on addressing anomalies and challenges in the indirect tax regime, particularly the inverted duty structure that hampers the Make in India initiative.

To further enhance the domestic manufacturing sector, the GoI has announced multiple economic stimulus packages to revitalize the COVID-affected economy, introduced the Production Linked Incentive (PLI) Scheme across 13 sectors, and implemented various tax and labour reforms. Additionally, the National Infrastructure Pipeline (NIP) has been established, and several sector-specific policies and schemes, including public procurement policies, have been developed. The government has also set mandatory Bureau of Indian Standards (BIS) regulations, launched skill development programs, and renewed the PCPIR policy to support CPC sector growth.

The PLI Scheme, with a total allocation of USD 28 billion, has been extended to cover 13 sectors. This initiative aims to achieve a minimum production output of approximately USD 500 billion over the next five years. The scheme offers cashback and incentives ranging from 2-20% of incremental sales revenue and incremental export revenue, depending on the sector.

The 'Make in India' initiative, launched by the Government of India, focuses on boosting manufacturing through investment, innovation, and state-of-the-art infrastructure. Gujarat has been instrumental in this initiative, helping transform India into a global design and manufacturing

hub with its supportive infrastructure and business-friendly environment. The state government has also introduced significant reforms to foster a favorable business climate. Additionally, the ZED (Zero Defect in Manufacturing and Zero Effect on Environment) initiative aims to improve product quality and position India as the "World's Manufacturing Hub." Gujarat's manufacturing sector has embraced ZED principles, which have been pivotal in helping its MSMEs establish a strong presence in the global supply chain.

Gujarat stands as India's foremost pharmaceutical manufacturing hub, representing 33% of the sector's turnover and 28% of the country's pharma exports. With over 3,500 licensed private companies and a prominent biotech sector, the state is also home to 130 USFDA-certified drug manufacturing plants.

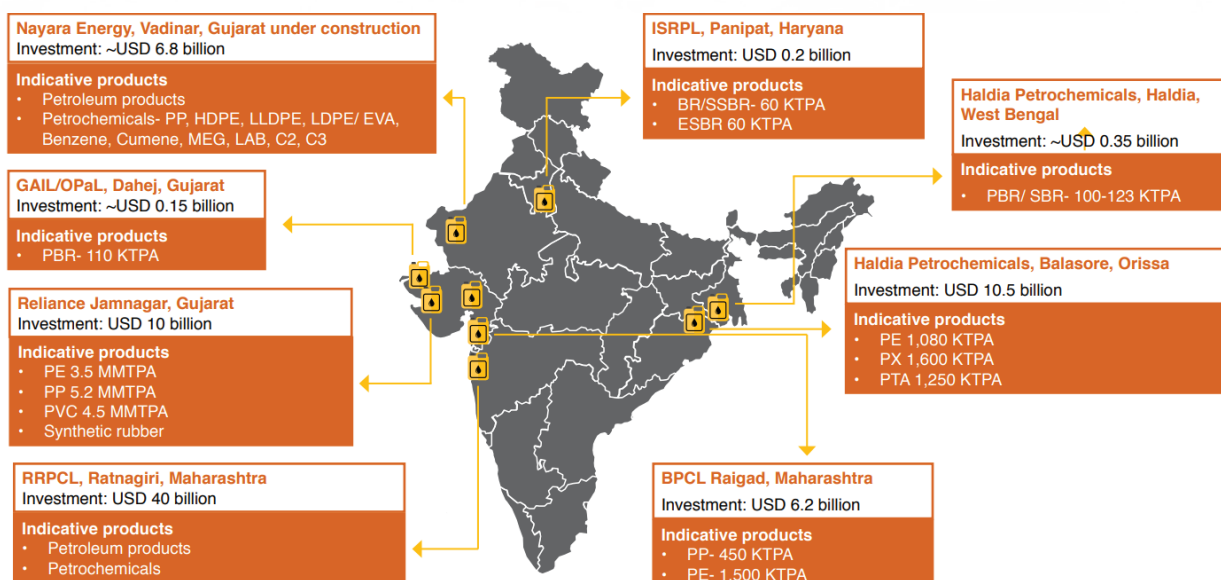
Ahmedabad and Vadodara are the primary locations for pharmaceutical facilities within Gujarat. Gujarat benefits from a well-developed industrial ecosystem, including ancillary industries such as packaging, chemicals, engineering, and pharma plant machinery manufacturing. This robust infrastructure has fostered a skilled workforce to support the pharmaceutical sector. Additionally, Gujarat contributes 62% of India's total petrochemical production and 35% of its chemical production. In the marine sector, the state is responsible for 70% of India's salt production, 20% of caustic soda, and 90% of soda ash.

In alignment with the Government of India's Green Hydrogen Mission, the Government of Gujarat ("GoG") introduced a new policy on May 8, 2023, titled the 'Policy on Leasing Government Waste Land for Green Hydrogen Pro-

duction (Using Non-Conventional Energy Sources)’ (“Policy”). This Policy aims to encourage and support the establishment of green hydrogen production units in Gujarat. Its objectives include generating employment, fostering small

industries, and advancing new technologies and methods for green hydrogen production. The Policy outlines various provisions to ensure the optimal and efficient use of waste land for green hydrogen production.

Figure 20: Petrochemical Projects Under Consideration in India



Strategic Initiatives for Sector Growth

Government initiatives such as the “Make in India” and “Atmanirbhar Bharat” campaigns have significantly advanced India’s petroleum industry by providing crucial support and fostering sector growth. Alongside technical assistance, substantial government investments have played a pivotal role in enhancing the industry’s development. In addition to these programs, several other initiatives have further

strengthened the sector, including the National Petrochemical Policy of 2007, Hydrocarbon Vision 2030 of 2016, Skill India, automatic approval for 100% FDI in the petrochemical industry, and the Production Linked Incentive Scheme 2021. These efforts have collectively provided an unparalleled boost to the petroleum sector in India.

²³ <https://www.pwc.in/assets/pdfs/publications/2021/india-a-global-manufacturing-hub-for-chemicals-and-petrochemicals.pdf>

National Policy on Petrochemicals

Establishment of Plastic Parks

This initiative aims to create state-of-the-art plastic parks through a cluster development model, consolidating and enhancing the capabilities of the domestic downstream plastic processing industry. The objective is to boost sectoral investment, production, and exports while generating employment opportunities. The scheme has approved ten Plastic Parks across various states including Madhya Pradesh (two), Odisha, Jharkhand, Tamil Nadu, Uttarakhand, Chhattisgarh, Assam, Uttar Pradesh, and Karnataka.

Creation of Centres of Excellence in Polymer Technology

The goal of this scheme is to advance petrochemical technology and research, as well as to support the development of new polymer and plastic applications. During Phase I (2013-2017), the Government of India provided financial support covering up to 50% of the project cost, with a maximum limit of (Rs. 6 crore) over three years. The scheme was extended until 2020 with updated parameters to promote applied research and technology transfer. To date, 13 Centres of Excellence (CoE) have been established within prominent educational and research institutions.

Petrochemicals Research & Innovation Commendation Scheme 2023

The scheme for establishing Plastic Parks, Centres of Excellence, and the National Petrochem-

icals Awards has been reviewed and renamed the Petrochemicals Research & Innovation Commendation Scheme, effective January 2023. This new framework aims to foster R&D and human resource development in the petrochemicals sector, institutionalizing the commendation scheme to achieve these objectives.

Revised Petroleum, Chemical, and Petrochemical Investment Regions (PCPIRs) Policy (2020-35)

Under the PCPIR Policy of 2007, four PCPIRs are being developed in Andhra Pradesh (Visakhapatnam), Gujarat (Dahej), Odisha (Paradeep), and Tamil Nadu (Cuddalore and Nagapattinam) to encourage investment and industrial growth. The revamped PCPIR Policy 2020-35 targets attracting a total investment of USD 142 billion (Rs. 10 lakh crore) by 2025, USD 213 billion (Rs. 15 lakh crore) by 2030, and USD 284 billion (Rs. 20 lakh crore) by 2035. The updated policy will reduce the size of each region from 250 to 50 square kilometers, using a specialized cluster integration approach. The Centre will provide Viability Gap Funding (VGF) of up to 20% for infrastructure projects in these regions. The PCPIRs are designed to promote the petroleum, chemical, and petrochemical sectors on a large scale in an integrated and environmentally friendly manner. They are expected to create approximately 33.83 lakh jobs, with around 4.21 lakh people already employed in related activities. The PCPIR initiative is projected to attract around USD 276.46 billion (Rs. 20 lakh crore) in investment by 2035.

Chemical (Management and Safety) Rules (CMSR)

The fifth draft of the Chemical (Management and Safety) Rules (CMSR) has been released, which will replace the Manufacture, Storage, and Import of Hazardous Chemicals Rules (1989) and the Chemical Accidents (Emergency Planning, Preparedness, and Response) Rules (1996). This regulation requires manufacturers, importers, or Authorized Representatives to register chemicals that need to be registered when they are produced, imported, or placed in Indian territory.

Extended Producer Responsibility (EPR)

Extended Producer Responsibility (EPR) requires producers (including brand owners and importers) to manage their products in an en-

vironmentally sound manner throughout their lifecycle. This policy is a step towards more sustainable waste management. The Indian government has introduced an EPR Policy to support this approach.

Additional Measures

The government has allowed 100% Foreign Direct Investment (FDI) in the petrochemical sector through the automatic route. Additionally, various tax benefits have been granted to the petrochemical industry, including exemptions or reduced rates for excise duty, customs duty, and value-added tax (VAT) on specific petrochemical products such as polymers, plastics, and synthetic fibers.²⁶

²⁶<https://www.ibef.org/blogs/expansion-opportunities-for-petrochemicals-in-india>

Chapter - 9

Micro, Small, and

Medium Enterprises

(MSMEs)

Contribution of MSMEs in the Chemical Industry

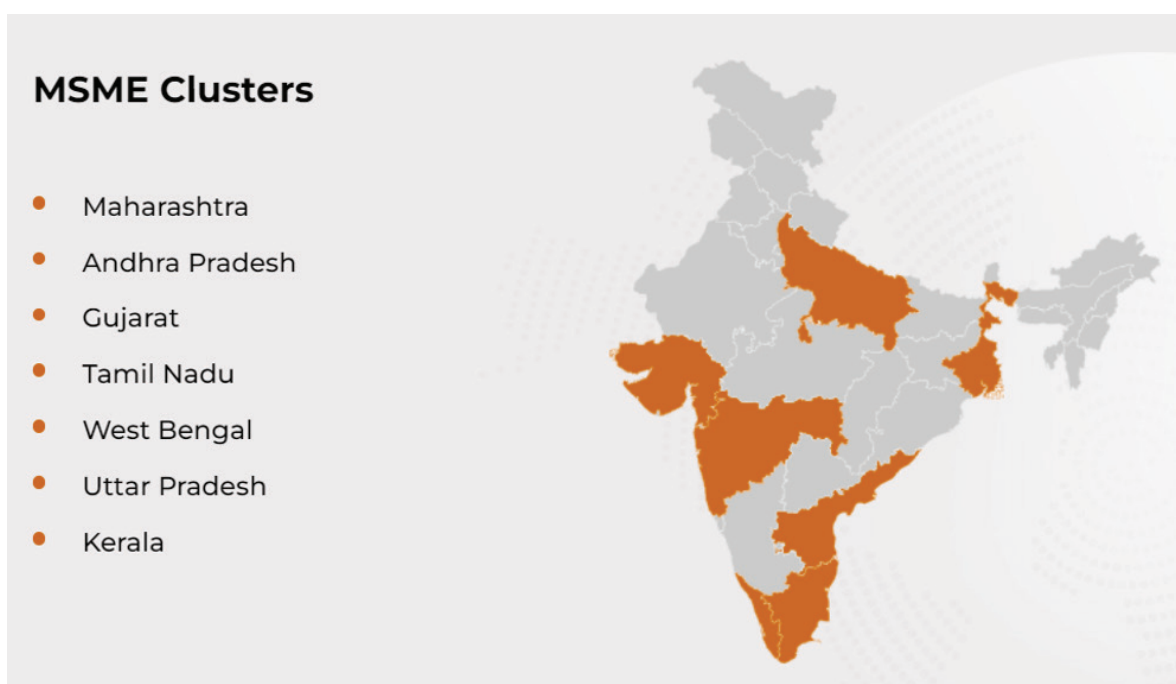
The MSME sector is pivotal in the chemical manufacturing industry value chain. On one hand, it contributes by producing low value-added products, performing job work for larger domestic players, and carrying out processes such as purification and blending. On the other hand, MSMEs also serve niche markets by providing high-quality specialty ingredients, where the market size is smaller but competition is limited due to the high standards required.

India's chemical sector is both diverse and robust, with Micro, Small, and Medium Enterprises (MSMEs) playing a vital role. Data from the Ministry of Chemicals & Petrochemicals shows that MSMEs make up approximately 30% of the domestic chemical industry. Major clus-

ters of these enterprises are located in Thane, Mumbai, and Ahmedabad. About half of these MSMEs are involved in organic manufacturing, while the remainder specialize in producing dyes, pigments, soaps, detergents, and agrochemicals.

Although the chemical sector is dominated by large players, the MSME (Micro, Small, and Medium Enterprises) segment is estimated to represent approximately 25-30% of the industry. This segment is vital for domestic chemical manufacturing and job creation. MSMEs typically focus on areas where scale is less critical and R&D requirements are minimal, but they also have a significant presence in niche specialty chemical sectors.

Figure 21: MSME Clusters in India

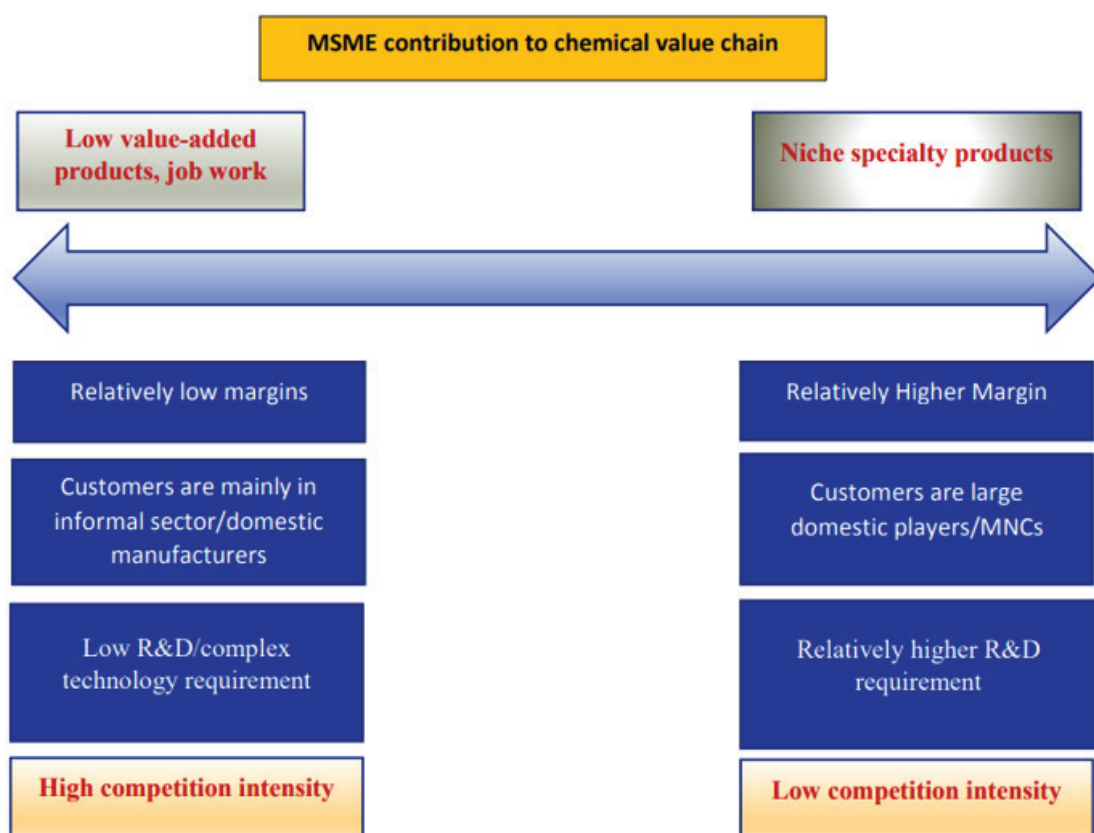


Gujarat has emerged as a leading manufacturing hub, excelling in industries such as automotive and auto components, chemicals and petrochemicals, pharmaceuticals, cement, textiles, engineering, gems and jewellery, and ceramics. The state is home to over 100 Fortune 500 companies and plays a crucial role in their supply chains through its extensive network of MSMEs. These small and medium-sized enterprises serve as vital ancillary units to large industries, significantly contributing to the state's industrial growth. Gujarat boasts more than 100 MSME multiproduct activity clusters, and the

number of MSMEs in the state surged by 60% between 2014 and 2015. Today, Gujarat hosts over 3.5 million MSMEs, which are a key source of employment.

With its 42 ports, 18 domestic airports, and one international airport, Gujarat has become a prominent center of industrial activity. The state hosts 106 product clusters and 60 designated special economic zones (SEZs), drawing significant investments in sectors such as petrochemicals, chemicals, pharmaceuticals, minerals, ceramics, dairy, gems and jewellery, tex-

Figure 22: MSME's Contribution to Chemical Value Chain



²⁷ <https://energy.economicstimes.indiatimes.com/files/cp/800/cdoc-1632303852-ICRA%20White%20Paper%20on%20Chemical%20and%20Plastic%20Industry%20-%20Final%20-%20Sep%202021.pdf>

tiles, automotive and engineering, IT, power, and ports.

Gujarat's strategic location has made it a key player in exports of chemicals, textiles, processed foods, and agricultural products. The state is rapidly evolving into a manufacturing hub, attracting numerous global healthcare companies eager to invest. As a result, Gujarat is solidifying its position as India's manufacturing capital. The state has also prioritized the development of small and medium enterprises (SMEs) through various policy initiatives, including interest subsidies, venture capital support, and quality certification programs. These efforts empower many MSMEs in Gujarat to undertake new initiatives, bolstering the economy. MSMEs are vital to Gujarat's economy, providing employment for both unskilled and skilled workers and significantly contributing to the nation's economic growth. The Gujarat gov-

ernment is dedicated to enhancing the quality of life and prosperity in the state by fostering a business-friendly environment, simplifying the ease of doing business, and encouraging entrepreneurship among youth.

MSMEs in Gujarat play a vital role in the state's development and significantly contribute to India's socio-economic growth. According to data presented by the Union government, Gujarat ranks as the fourth largest state for MSMEs, following Maharashtra, Tamil Nadu, and Uttar Pradesh. Gujarat is home to approximately 11.26 lakh registered MSMEs, representing 7.5% of the total 1.48 crore MSMEs registered nationwide. This highlights the state's robust entrepreneurial spirit and has fostered a dynamic business environment. Gujarat is rapidly evolving into a major Multi-Product MSME hub, offering substantial economic opportunities for its residents.

Enhancing MSME Capabilities and Competitiveness

With the implementation of the "Make in India" initiative, investment in the manufacturing sector has become more appealing. This has provided the chemical and petrochemical industries with global exposure, driving expansion, job creation, and establishing a competitive edge. In the realm of research and development, the government offers a 200% tax deduction under Section 35 (2AB) of the Income Tax Act for both capital and revenue expenditures related to scientific R&D. Additionally, the new "59-minute loan" scheme for MSMEs allows for loans up to ₹1 crore, supporting industry growth and enhancement. India benefits from lower pharmaceutical production costs compared to the US

and significantly lower than in the UK. Despite the accelerated growth and government incentives, the industry faces several challenges. There is often a lack of understanding in structuring innovation, marketing, sales, manufacturing, and portfolio management. Experienced chemical consultants can assist by analyzing a company's market position and guiding it towards progress. Compliance with government policies is another major challenge for the chemical industry. Companies frequently struggle with low profit margins due to government pricing policies. Pharmaceutical and chemical consultants can alleviate these challenges by

ensuring compliance with regulations, staying updated on policy changes, and helping companies take advantage of available benefits.

The Micro, Small, and Medium Enterprises (MSMEs) sector plays a crucial role in the socio-economic development of India. This sector is vital for the country's Gross Domestic Product (GDP) and export performance. It also significantly contributes to entrepreneurship development, particularly in semi-urban and rural areas.

On May 13, 2020, a revision in the definition of MSMEs was announced under the Aatmanirbhar Bharat Abhiyaan Scheme. The Ministry of Micro, Small, and Medium Enterprises issued a gazette notification on June 1, 2020, which introduced updated definitions and criteria for MSMEs. These new classifications took effect

on July 1, 2020. Under the revised Aatmanirbhar Bharat Abhiyaan Scheme, MSMEs are now classified based on investment in plant and machinery and turnover criteria.

The Gujarat Government launched the 'Aatmanirbhar Gujarat' scheme to advance the manufacturing sector by offering various forms of support and incentives. This initiative aligns with Prime Minister's vision of 'Aatmanirbhar Bharat' and underscores Gujarat's reputation as a leading hub for entrepreneurs and industry in India. The scheme provides substantial support for MSMEs in Gujarat, including a capital subsidy of up to Rs 35 lakh for micro industries, an annual interest subsidy of up to Rs 35 lakh for up to 7 years, and a 10-year Employees' Provident Fund (EPF) reimbursement. Additional benefits

Table 2: Criteria for Classification of Industries Based on Turnover and Investment

Criteria	Manufacturing Enterprises and Enterprises rendering Services (Revised classification with effect from July 1, 2020)	
	Turnover	Investment
Micro	Rs. 5 crore (US\$ 610,000)	Less than Rs. 1 crore (US\$ 120,000)
Small	Rs. 50 crore (US\$ 6.1 million)	More than Rs. 1 crore (US\$ 120,000) but less than Rs. 10 crore (US\$ 1.2 million)
Medium	Rs. 250 crore (US\$ 30.4 million)	More than Rs. 10 crore (US\$ 1.2 million), but less than Rs. 50 crore (US\$ 6.1 million)

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²⁸ <https://www.ibef.org/industry/msme>

are available for women, young entrepreneurs, startups, and differently-abled entrepreneurs. Launched on October 5, 2022, the scheme will remain in effect for five years.

The number of MSMEs in the country is projected to increase from 6.3 crore to approximately 7.5 crore in the near future, growing at a compound annual growth rate (CAGR) of 2.5%. As of March 2024, the number of MSMEs registered

on the Udyam portal, including the Udyam Assist Platform (UAP), has reached 4,00,42,875. In October 2023, gross bank credit extended to MSMEs under priority sector lending totalled USD 279.18 billion. This represents a 22.8% increase from the previous year and an 11.8% rise from September 2023, according to the latest RBI data on sectoral credit deployment.

Support and Incentives for MSMEs

Gujarat leads India's chemical industry, housing over 11,000 chemical units. The state produces more than half of the country's major chemicals. Gujarat is a key center for manufacturing fertilizers, pharmaceuticals, dyes, and pigments, and is home to numerous MSMEs in these sectors. The state also boasts several research and development centers and institutes focused on advancing chemical technology. The Gujarat government supports the chemical industry with initiatives such as investment incentives, infrastructure improvements, and access to skilled labor.

- The Self-Reliant India (SRI) fund, with a total corpus of ₹50,000 crore (US\$6 billion), has allocated ₹7,593 crore (US\$910 million) to

425 MSMEs. This investment, made under the Aatmanirbhar Bharat package, supports various sectors including agriculture, pharmaceuticals, automotive, and chemicals.

- On December 15, 2023, DCM Shriram Ltd announced its entry into the "Advanced Materials" sector within its Chemicals business. As of November 30, 2023, the Self-Reliant India (SRI) Fund, established by the government in May 2020 and managed by SBICAP Ventures, has invested ₹6,448 crore (US\$777.62 million) in MSMEs, with a 15-year period for equity infusion.



Chapter - 10

Skill Development

Addressing the Skill Gap in the Chemical and Petrochemical Industry

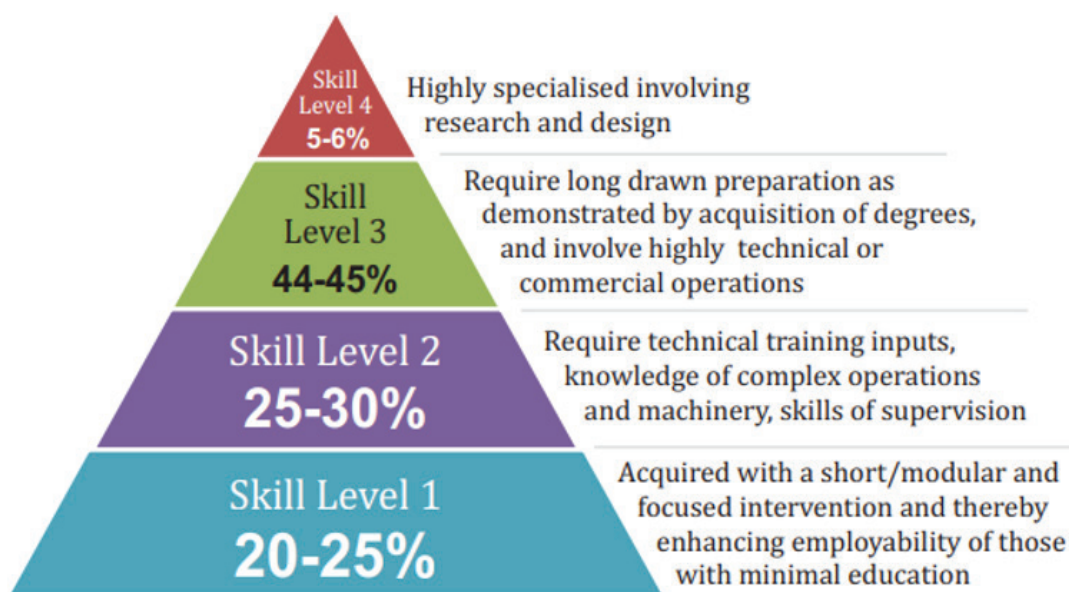
The Rubber, Chemical, and Petrochemical Sector Skill Development Council (RCPSDC), formerly known as RSDC, is dedicated to enhancing skills within India's rubber, chemical, and petrochemical industries. The plastic industry, in particular, offers substantial employment opportunities and entrepreneurial potential. RCPSDC, in collaboration with the Central Institute of Petrochemicals Engineering & Technology (CIPET), provides skill development training programs aimed at unemployed youth, including those from SC/ST/OBC/EWS/BPL categories. These initiatives offer young people the chance to enhance their skills and secure positions within the industry.

The chemical industry is encountering significant difficulties in sourcing skilled and employable personnel to meet its workforce

needs. New employees primarily acquire skills through on-the-job training (OJT). This shortage of skilled workers could hinder the industry's growth. Therefore, it is crucial to identify skill gaps, assess the demand for various skill sets, and develop a skilled workforce. Addressing these issues will require a collaborative effort from all stakeholders involved.

As one of the fastest-growing sectors, the chemical industry presents significant opportunities for youth across a range of skill levels, from high school graduates to Ph.D. and M.Tech. holders. Approximately 20-25% of roles in the industry require skills that can be acquired through short or modular training programs, thus improving employability for individuals with minimal education. Additionally, various companies, including public sector units, offer apprentice-

Figure 23: Skill Pyramid for the Chemicals Industry



²⁸ <https://facilities.aicte-india.org/KARMA/ssc-documents/Rubber,%20Chemical%20&%20Petrochemical%20Skill%20Development%20Council.pdf>

ship training in diverse areas such as industrial chemical analysis, QA/QC of pesticides and formulations, hazardous chemical handling, indus-

trial and chemical safety, process and plant operations, and chemical packaging and labeling.

Training Programs to Enhance Workforce Capabilities

The National Employability Enhancement Mission (NEEM) aims to address the issue of unemployment by equipping millions of job-seeking youths with essential skills for various industries. Many traditionally educated individuals lack the specific skills required for employment, and the NEEM scheme addresses this gap by offering skill development training through apprenticeships. This initiative seeks to tackle both the challenges of unemployment and the shortage of skilled workers in the country.

National Apprenticeship Promotion Scheme (NAPS)

The National Apprenticeship Promotion Scheme (NAPS), launched by the Government of India in 2016, aims to incentivize industries and enhance apprenticeship opportunities. The scheme's primary objective is to encourage apprenticeship training across the country by partnering with employers who wish to take on apprentices, aligning with the Skill India vision and mission.

Major Benefits:

- Access to pre-approved courses on the apprenticeship portal, with the option for industries to customize courses according to their specific needs.
- Flexible training durations, ranging from 6 to 24 months, as determined by industry preferences.
- Training is conducted on the industry prem-

ises, tailored to the organization's requirements.

- Financial support of up to 25% of the prescribed stipend, with a maximum of Rs. 1,500 per month per apprentice.
- No obligation for industries to retain apprentices after their training is completed.
- Industries can use their CSR funds to provide additional "skill training" beyond the minimum requirements set by the Apprenticeship Act (2.5% of the workforce).

RPL- Recognition of Prior Learning

Recognition of Prior Learning (RPL) is an assessment process designed to evaluate an individual's existing skills, knowledge, and experience acquired through formal, non-formal, or informal learning and certification.

Major Benefits:

- Aligns the competencies of the unregulated workforce with the standardized National Skills Qualification Framework (NSQF).
- Enhances employability opportunities for individuals and offers alternative pathways to higher education.
- Provides opportunities to address and reduce inequalities by valuing diverse forms of knowledge.
- Connects with the extensive uncertified workforce nationwide through direct collaborations with industry.

Short Term Training (STT)

The Short-Term Training offered at approved Training Centres (ICs) aims to assist Indian nationals who are either school or college drop-outs or unemployed. In addition to providing training aligned with the National Skills Qualification Framework (NSQF), these centres also cover Soft Skills, Entrepreneurship, and Financial and Digital Literacy. The training duration varies by job role, ranging from 240 to 500 hours.

Upon successful completion of the assessment, candidates receive placement assistance from Training Partners (TPs).

Benefits to Corporates:

- Access to skilled manpower for their operations.
- Ability to develop a new workforce tailored to their specific needs.
- Opportunities to re-skill and certify existing employees.
- Option to integrate CSR initiatives for skill development aligned with RCPSDC job roles.
- Support for TPs by offering their facilities for practical training under CSR.
- Contribution to building a more skilled workforce nationwide.

Placement Portal

RCPSDC has launched a dedicated placement portal to cater to the hiring needs of the Rubber, Chemical, and Petrochemical industries. This platform allows candidates from across the country to apply directly for job opportunities offered by employers. The portal features advanced filtration tools that enable both em-

ployers and job seekers to refine their searches based on interests, location, skills, and more.²⁹

Capacity-building initiatives by Research and Development (R&D) institutions are crucial for shaping the future of the global chemical industry. These efforts encompass a broad range of activities aimed at enhancing the skills, capabilities, and resources of professionals and organizations within the sector. Key initiatives include:

- **Research Collaboration:** R&D institutions facilitate partnerships between academia, industry, and government agencies to advance scientific knowledge, develop innovative technologies, and tackle industry challenges. Collaborative projects offer opportunities for knowledge exchange and interdisciplinary work.
- **Technology Transfer and Licensing:** Institutions support the dissemination of cutting-edge research, patents, and technologies through licensing agreements. This helps industry players adopt new technologies, accelerate product development, and gain a competitive edge.
- **Training and Workshops:** By organizing programs on topics such as chemical process optimization, sustainability, regulatory compliance, and emerging trends, R&D institutions enhance the skills and capabilities of chemical industry professionals, empowering them to address complex challenges and drive innovation.
- **Incubation and Start-up Support:** Many institutions operate incubators, accelerators, and technology parks to support start-ups

²⁹<https://facilities.aicte-india.org/KARMA/ssc-documents/Rubber,%20Chemical%20&%20Petrochemical%20Skill%20Development%20Council.pdf>

and small businesses in the chemical sector. These initiatives provide access to infrastructure, funding, mentorship, and networking opportunities.

- **Education and Training Programs:** Institutions collaborate with universities and technical schools to offer specialized degree programs, courses, and certifications in fields like chemical engineering, polymer science, materials science, and nanotechnology, creating a skilled workforce for the industry.
- **Open Innovation Platforms:** R&D institutions establish platforms for industry stakeholders to collaborate on pre-competitive research projects, share resources, and address common challenges, fostering a culture of collaboration and co-innovation.
- **Policy Advocacy and Advisory Services:** Institutions engage in advocacy and provide advisory services on research funding, intellectual property rights, environmental regulations, and technology standards, helping shape a supportive regulatory environment.

- **Global Networking and Partnerships:** By forming strategic partnerships and participating in international research consortia, R&D institutions enhance their visibility and impact, promoting cross-cultural collaboration and knowledge exchange.

Overall, these capacity-building initiatives are vital for driving innovation, competitiveness, and sustainability in the global chemical industry. By promoting collaboration, facilitating technology transfer, providing education and training, and advocating for supportive policies, R&D institutions contribute significantly to the advancement of science and technology and the growth of the chemical sector worldwide.

In the Indian chemical industry, training and capacity building are essential for fostering growth, innovation, and sustainability. Companies that invest in their workforce can overcome challenges, seize opportunities, and establish themselves as leaders in a competitive market. With strategic planning, collaboration, and a focus on continuous learning, the Indian chemical industry can unlock its full potential and contribute to national economic prosperity and industrial development.

Partnerships with Educational Institutions for Skill Development

Human resources are crucial for the growth of the Indian Chemical Industry, which is currently facing a significant challenge in attracting world-class talent. To address this issue and draw skilled professionals to the sector, it is essential to enhance technical education and establish new institutions with state-of-the-art facilities. Major challenges include inadequate quality education and insufficient investment in skill

development. Therefore, a substantial policy focus on skill development is necessary to meet these demands.

- On July 9, 2015, the Ministry of Chemicals and Fertilizers and the Ministry of Skill Development and Entrepreneurship signed three memorandums of understanding (MoUs) to address the need for skilled man-

power in the industry. These MoUs aim to collaboratively meet the growing demand for skilled workers in the fertilizer, pharmaceutical, and chemicals & petrochemical sectors. The agreements include setting standards and quality assurance processes to support the implementation of various projects. The three departments within the Ministry of Chemicals and Fertilizers will coordinate their budgets under existing or new schemes to execute the initiatives outlined in the MoUs. This coordination will encompass advocacy, marketing, training, certification, and, if necessary, the establishment of a project management unit.

- In April 2024, BASF, in partnership with Somaiya Vidyavihar (SVV) and the Indian Chemical Council (ICC), is celebrated the success of the inaugural batch of the

We-Chemie program—Women Enabled for Careers in Chemistry. This initiative recognizes the achievements of students who have completed the training. With women representing less than 30% of the global chemical sector, and likely even fewer in India, BASF leads this CSR effort alongside SVV and ICC to address the gender imbalance in the industry. The We-Chemie program aims to build a pipeline of skilled female graduates and postgraduates from underprivileged backgrounds, equipping them to embark on successful careers in the chemical industry. The program offers participants vital knowledge, skills, and a supportive mindset through a combination of industry visits, mentorship, and self-development activities.

Chapter - 11

Conclusion

SUMMARY OF KEY INSIGHTS

India's chemical and petrochemical industry is entering a critical phase in its evolution, marked by a growing recognition of the need for sustainability, innovation, and global competitiveness. As the country aims to achieve its Viksit Bharat 2047 vision, the sector must undergo a transformative shift to remain a cornerstone of India's economic growth while aligning with global environmental standards. Several key insights underscore the urgency and potential of this transformation.

1. Sustainability is No Longer Optional – It is Imperative

The chemical and petrochemical industry is one of the most resource-intensive sectors in the global economy. Historically, the sector has been associated with high levels of greenhouse gas emissions, energy consumption, and waste production. However, the pressure to mitigate climate change, reduce environmental impact, and improve resource efficiency has never been more significant. India's commitment to achieving net-zero emissions by 2070 has placed sustainability at the forefront of industrial strategy, and the chemical industry is at the heart of this transformation.

As one of the world's leading chemical producers, India is uniquely positioned to take advantage of the global push for greener industrial practices. To remain competitive, Indian chemical companies must adopt sustainable production processes, including renewable energy, biotechnological alternatives to fossil fuel-based feedstocks, and advanced carbon capture tech-

nologies. Sustainability must be integrated into every aspect of the business model, from production to supply chain management.

2. Technological Innovation is Key to the Industry's Future

The adoption of advanced technologies is reshaping the chemical and petrochemical industry. Artificial intelligence (AI), machine learning (ML), the Internet of Things (IoT), and blockchain are transforming how companies monitor, optimize, and control their operations. These technologies offer real-time insights into energy consumption, emissions levels, and production efficiencies, enabling businesses to make informed decisions that reduce their environmental impact. For instance, AI can predict equipment failures and suggest optimizations that reduce energy consumption, while blockchain ensures transparency in supply chains by tracking raw materials from their source to their final use.

Indian companies must invest heavily in these technologies to drive both sustainability and competitiveness. Digitalization is no longer a luxury but a necessity for companies that want to operate at peak efficiency, minimize waste, and reduce costs. By leveraging these advancements, Indian chemical firms can improve their environmental performance while increasing operational efficiency and productivity.

3. Gujarat as the Pioneering Hub for Sustainable Growth

Gujarat's chemical and petrochemical industry plays a central role in India's industrial landscape. The state contributes over 35% of the nation's chemical output and 62% of its petrochemical production. Gujarat's leadership in the sector is exemplified by the Petroleum, Chemical, and Petrochemical Investment Region (PCPIR) at Dahej, which has attracted major investments from leading global corporations such as Reliance Industries, ONGC, and BASF.

Gujarat's focus on infrastructure, industry-friendly policies, and a commitment to sustainability has made it the chemical hub of India. The state has set an example by integrating renewable energy sources, adopting circular economy practices, and fostering sustainable development across its industrial zones. Its role as a frontrunner in the sector is expected to grow, further positioning Gujarat as a critical player in India's journey toward achieving its sustainability and industrial goals.

4. Government Policies as Catalysts for Sustainable Development

India's government has introduced several key policies and initiatives aimed at accelerating the growth and sustainability of the chemical and petrochemical industry. Initiatives such as Make in India and AtmaNirbhar Bharat focus on reducing import dependency, enhancing domestic production, and promoting India as a global manufacturing hub. These programs are complemented by the National Chemical Policy and Production Linked Incentive (PLI) schemes,

which provide financial incentives for companies that invest in clean technologies and sustainable manufacturing processes.

The government's focus on improving the ease of doing business, coupled with policies designed to attract foreign direct investment (FDI), creates an ideal environment for the sector's growth. However, for these policies to succeed, companies must embrace innovation, sustainability, and new business models that prioritize environmental stewardship. As the regulatory landscape continues to evolve, companies that are early adopters of green technologies and sustainable practices will be well-positioned to benefit from both government incentives and global demand for sustainable products.

5. The Circular Economy is the Future of Sustainable Industry

The transition to a circular economy is one of the most significant opportunities for the Indian chemical and petrochemical industry. Unlike the traditional linear model of "take, make, dispose," the circular economy focuses on designing products and processes that maximize resource efficiency, minimize waste, and promote the recycling and reuse of materials. This approach not only reduces environmental impact but also creates new economic opportunities by turning waste into valuable resources.

By embracing circular economy principles, the Indian chemical industry can reduce its reliance on finite natural resources, lower production costs, and improve the sustainability of its supply chains. Companies that invest in recycling technologies, waste-to-energy solutions, and

resource-efficient manufacturing processes will be able to differentiate themselves in an increasingly competitive global market. The circular economy also offers a path toward greater resilience by reducing dependence on volatile global supply chains and ensuring more sustainable production systems.

6. Collaboration and Partnerships are Essential for Success

Collaboration across sectors and industries is vital to achieving the sustainability and innovation goals of India's chemical and petrochemical sector. Public-private partnerships (PPPs) must be strengthened to foster the development and scaling of clean technologies and sustainable practices. By working together, government agencies, industry leaders, academic institutions, and research organizations can accelerate innovation, reduce costs, and share best practices.

Gujarat's example shows the importance of collaboration between state governments and industry leaders in driving industrial growth and sustainability. Other regions in India can follow suit by fostering similar collaborations that align with national policies and global sustainability standards. Cross-sector partnerships that prioritize sustainability and innovation will not only help the industry meet its economic and environmental goals but will also attract greater investment from both domestic and international sources.

7. A Global Outlook is Critical for India's Competitiveness

To remain competitive on the world stage, India's chemical and petrochemical industry must

align with international environmental, social, and governance (ESG) standards. Global investors and consumers are increasingly demanding that companies demonstrate responsible business practices, particularly around sustainability. Indian companies that meet or exceed these global standards will gain access to new markets, attract foreign investment, and strengthen their position as leaders in sustainable manufacturing.

Gujarat's robust chemical sector, combined with India's growing policy support, positions the country to play a leading role in global supply chains. As international trade shifts toward more sustainable models, companies that prioritize ESG performance will enjoy a competitive edge. Furthermore, India's participation in global environmental agreements and trade deals will provide additional opportunities for the industry to grow while contributing to global sustainability goals.

8. Workforce Transformation and Upskilling Will Drive the Industry Forward

As the chemical and petrochemical industry embraces digitalization and sustainability, a skilled workforce will be essential to implement and manage these advanced technologies. Companies must invest in upskilling their employees, ensuring they are equipped with the necessary knowledge and expertise to operate in a more complex, technologically-driven environment. Collaboration with educational institutions and training organizations will be key to building a talent pipeline that can support the sector's long-term growth.

The shift toward sustainable production processes will also create new job opportunities, particularly in areas such as clean energy, circular economy practices, and digitalization. Companies that invest in workforce development will be better positioned to attract and retain top talent while maintaining their competitive edge in an increasingly dynamic global marketplace.

In conclusion, India's chemical and petrochemical industry is at a pivotal moment, with the

potential to lead the global shift toward sustainability and innovation. By embracing advanced technologies, aligning with government policies, fostering collaboration, and focusing on the circular economy, the sector can not only drive economic growth but also ensure a sustainable and prosperous future for India. With Gujarat as a leading example, and with collective action from all stakeholders, India is well-positioned to achieve its goal of becoming a developed nation by 2047.

FUTURE DIRECTIONS AND RECOMMENDATIONS

The future of India's chemical and petrochemical industry lies in its ability to embrace sustainability, innovation, and global competitiveness. As the sector transitions toward a more sustainable model, key future directions will shape its growth and ensure it aligns with India's broader vision of becoming a developed nation by 2047. One of the most critical future **directions is the decarbonization of the industry**. To meet India's target of achieving net-zero emissions by 2070, the industry must adopt greener production processes, including the use of renewable energy sources such as wind and solar power. Investing in carbon capture technologies and energy-efficient systems will be essential to reducing the sector's carbon footprint. The **shift to biotechnological alternatives** and sustainable feedstocks will also be vital in reducing reliance on fossil fuels, supporting the industry's move towards cleaner, low-emission practices.

Embracing digitalization and advanced technologies is another key direction for the industry's future. Artificial intelligence (AI), machine

learning (ML), and IoT will continue to revolutionize operations, enhancing predictive maintenance, optimizing processes, and reducing resource consumption. These technologies enable real-time monitoring of emissions and resource use, facilitating the industry's commitment to sustainability goals. **Incorporating blockchain for supply chain transparency** will also ensure responsible sourcing and promote ethical practices throughout the production cycle.

The transition to a **circular economy** will play a crucial role in ensuring sustainable growth. The industry must focus on reducing waste, improving recycling processes, and enhancing resource efficiency across the value chain. By adopting circular economy principles, such as reusing materials and designing products for longevity, the chemical and petrochemical sector can unlock significant environmental and economic benefits. Collaboration across industries to create integrated circular systems will be necessary to close the loop on production processes and optimize resource utilization.

Government policies and incentives will continue to shape the industry's growth trajectory. The government should further enhance policy frameworks that encourage investments in clean technologies and sustainable practices, particularly through financial incentives, tax benefits, and subsidies for adopting green technologies. Strengthening regulatory frameworks such as the National Chemical Policy and expanding the scope of the Production Linked Incentive (PLI) schemes will drive innovation and encourage industries to pursue sustainable development. The government must also focus on **upskilling the workforce** to manage and implement these advanced technologies effectively.

Collaboration between government, industry, and academia must be reinforced to foster innovation and accelerate the transition towards sustainability. Public-private partnerships should focus on research and development (R&D) in areas such as green chemistry, sustainable manufacturing practices, and resource-efficient technologies. Knowledge-sharing platforms should be established to promote best practices and facilitate the scaling of successful innovations across the sector.

To succeed on the global stage, **India must enhance its global competitiveness** by aligning with international sustainability standards and ensuring that Indian companies meet global ESG (Environmental, Social, and Governance) criteria. By positioning itself as a leader in sustainable chemical production, India can attract more foreign investment and expand its influence in global markets. Participation in global trade and environmental agreements will further support the country's goal of becoming a responsible leader in the global chemical industry.

In conclusion, the future of India's chemical and petrochemical industry will be defined by its commitment to sustainability, innovation, and global competitiveness. By embracing advanced technologies, transitioning to a circular economy, and fostering collaboration, the sector can lead India toward its goal of becoming a developed nation by 2047, while contributing to both economic growth and environmental stewardship. The successful realization of these goals will require collective efforts, visionary leadership, and a long-term commitment to driving responsible industrialization.



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About ASSOCHAM

The Associated Chambers of Commerce & Industry of India (ASSOCHAM) is the country's oldest apex chamber. It brings in actionable insights to strengthen the Indian ecosystem, leveraging its network of more than 4,50,000 members, of which MSMEs represent a large segment. With a strong presence in states, and key cities globally, ASSOCHAM also has more than 400 associations, federations, and regional chambers in its fold. Aligned with the vision of creating a New India, ASSOCHAM works as a conduit between the industry and the Government. The Chamber is an agile and forward-looking institution, leading various initiatives to enhance the global competitiveness of the Indian industry, while strengthening the domestic ecosystem.

With more than 100 national and regional sector councils, ASSOCHAM is an impactful representative of the Indian industry. These Councils are led by well-known industry leaders, academicians, economists, and independent professionals. The Chamber focuses on aligning critical needs and interests of the industry with the growth aspirations of the nation.

ASSOCHAM is driving four strategic priorities – Sustainability, Empowerment, Entrepreneurship and Digitisation. The Chamber believes that affirmative action in these areas would help drive an inclusive and sustainable socio-economic growth for the country.

ASSOCHAM is working hand in hand with the government, regulators, and national and international think tanks to contribute to the policy making process and share vital feedback on implementation of decisions of far-reaching consequences. In line with its focus on being future-ready, the Chamber is building a strong network of knowledge architects. Thus, ASSOCHAM is all set to redefine the dynamics of growth and development in the technology-driven 'Knowledge-Based Economy. The Chamber aims to empower stakeholders in the Indian economy by inculcating knowledge that will be the catalyst of growth in the dynamic global environment.

The Chamber also supports civil society through citizenship programmes, to drive inclusive development. ASSOCHAM's member network leads initiatives in various segments such as empowerment, healthcare, education and skilling, hygiene, affirmative action, road safety, livelihood, life skills, sustainability, to name a few.



About Chemanalyst

Welcome to ChemAnalyst, your definitive source for comprehensive market analysis and pricing intelligence across the global chemical and petrochemical sectors. Our platform equips companies with critical, up-to-date information on market trends, news, and deals that shape the chemical industry worldwide.

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We take pride in our achievements and are honored to have been awarded 'The Product Innovator of the Year, 2023' and to be recognized among the "Top 100 Digital Procurement Solutions." These accolades reflect our commitment to innovation and excellence in serving the chemical sector.

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**The Associated Chambers of Commerce
and Industry of India**

ASSOCHAM Corporate Office:

4th Floor, YMCA Cultural Centre and Library Building, 01

Jai Singh Road, New Delhi – 110 001

Ph: 011-46550555 • Fax: 91-11-23017008/9

Web: www.assochem.org

ASSOCHAM Regional Office (Gujarat)

*608, 6th Floor, Income Tax Cross Road, SAKAR III,
Ashram Rd, opposite Old High Court Road, Usmanpura,
Ahmedabad, Gujarat 380014*

Follow us on:     



ChemAnalyst Data Private Limited

B-44, 2nd Floor, Sector-57 Noida,

National Capital

Region, India - 201301

+91- 7428761330