Innovation Insight Study

Resource Efficiency/Sustainable Manufacturing in India

June 2023

This report was written in 2022 and the information contained within this report remains correct at the time of production.

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Executive Summary

The efficient use of resources in production processes coupled with the adoption of low carbon, clean energy and sustainable practices is growing across various segments of industries. Industries are transitioning from a linear production model to a circular model. This is primarily guided by their aspiration and commitments to reduce their carbon footprint, decrease resource extraction and enhance productivity, competitiveness and profitability. Indian industries are gradually embracing resource efficiency and integrating sustainability into their value chains.

This Innovation Insight Study aims to highlight the potential of resource efficiency in some key sectors, such as **electrification of transportation, plastic, electrical and electronic equipment, steel, construction and cement, green hydrogen, and biofuel.** It covers India's emerging priorities and policy environment in these sectors in view of its global commitments and self-reliant strategy. Driven by India's policy initiatives, including the recent visions and strategies, announced at COP26 and COP27, and increasing investment from both the public and private sectors in research and innovation, projects are creating a growing opportunity mix for international collaboration.

The report identifies specific collaborative opportunities for research and innovation between Indian and UK organisations that can address shared challenges and contribute to the prosperity of both nations. A closer working relationship between the Indian and UK research and innovation organisations, companies, relevant government bodies, and other stakeholders; and a forward-looking action plan, backed by policy initiatives and financial and other support mechanisms, will be key to moving towards a deeper and stronger tie between the two countries in the field of sustainable manufacturing.

Glossary

Al-Air	Aluminium-Air
BT	Billion Tonnes
C&D	Construction and Demolition
C-MET	Centre for Materials for the Electronics Industry
COP 26	The 26th United Nations Climate Change conference, held in Glasgow, Scotland, United Kingdom, from 31 October to 13 November 2021
COP 27	The 27th United Nations Climate Change conference, held from November 6 to November 20 2022 in Sharm El Sheikh, Egypt
DBT	Indian Department of Biotechnology
EPR	Extended Producer Responsibility
EV	Electric Vehicle
FCDO	Foreign Commonwealth and Development Office
GHG	Greenhouse Gas
GWH	Giga Watt Hour
HDPE	High Density Polyethylene
IDDI	Industrial Deep Decarbonisation Initiative
IEA	International Energy Agency
Li	Lithium
LiB	Lithium-ion Battery
MoEFCC	Ministry of Environment, Forest and Climate Change
MNRE	Ministry of New and Renewable Energy
MTPA	Million Tonnes Per Annum
NITI (Aayog)	National Institution for Transforming India
NREP	National Resource Efficiency Policy
PET	Polyethylene Terephthalate
PLI	Production Linked Incentive
R&D	Research and Development
REE	Rare Earth Elements
RPO	Renewable Purchase Obligation
SDGs	Sustainable Development Goals
TERI	The Energy and Resources Institute
UKRI	UK Research & Innovation
UNFCCC	United Nations Framework Convention on Climate Change
UNFCCC-COP	United Nations Framework Convention on Climate Change-Conference of the Parties
ZEV	Zero Emission Vehicles

India and the UK: A Growing Relationship

India and the UK share a long relationship in language, people, science, innovation, business, and technology. The two countries work closely on many multilateral forums, including the United Nations, the World Trade Organisation (WTO), and the Commonwealth.

The Enhanced Trade Partnership (ETP), launched by the Prime Ministers of India and the UK in May 2021, aims to double the bilateral trade by 2030, currently at about £23 billion, and address various trade barriers to unlock the full trade potential between the two countries. The Roadmap 2030 will pave the way for a deeper and stronger engagement between India and the UK over the next ten years in the key areas of people-to-people contact, trade and economy, defence and security, climate action, and health. The ETP declared India and the UK's shared intent to begin a comprehensive Free Trade Agreement (FTA). India and the UK launched the negotiations on the proposed FTA in January 2022, which will be concluded in October 2022. The UK's Department for International Trade (DIT) is leading in drawing up the UK's strategic approach for this FTA[1]. Aside from many sector-specific initiatives led by DIT, various other programmes such as the UK-India Education and Research Initiative (UKIERI), the UK-India Tech Partnership, the Global Entrepreneurship Programme, Tech Rocketship Awards, the UK-India FinTech Awards, UKFCDO's Technical Assistance Programmes, Newton Fund, and the initiatives of UK Research & Innovation (UKRI) are creating many partnerships between the two countries in the areas of education, science, research, innovation, and business. Moreover, since its launch in India in 1983, the UK's Chevening Scholarships programme has helped more than 3,000 professionals from India pursue a range of courses in the UK, and these "living bridges" are further strengthening the links between the two countries in science, innovation, and business.

During the visit by the UK Prime Minister Rt Hon Boris Johnson to India in April 2022, through a Joint Statement[2], the Prime Ministers of the UK and India acknowledged the need to work together on domestic and international energy security and the clean energy transition in light of the current global energy price volatility. They agreed to strengthen collaboration, including through the Joint Declaration of Intent between India's National Institute of Wind Energy and the UK's Offshore

Renewable Energy Catapult, and they welcomed the progress on offshore wind energy and electric mobility. The statement highlighted a $200 million guarantee by GuarantCo for Axis Bank to accelerate India's transition to electric vehicles. The two Prime Ministers noted the ongoing cooperation on the development and deployment of affordable green hydrogen for both countries, including through the India-UK Science and Innovation Partnership on Green Hydrogen and joint work on a green hydrogen hub. During the visit, both Prime Ministers expressed satisfaction at the progress in the implementation of the ambitious Roadmap 2030 for India-UK future relations that was launched at the Virtual Summit in 2021 and mandated their teams to identify high-impact projects for time-bound implementation in each of the pillars. They also expressed their desire to steer bilateral relations toward Vision 2047 for the shared security and prosperity of their people and the planet. The two leaders reinforced their commitments to cooperate closely on COVID-19 recovery, climate finance, services trade, and multilateral engagement, including intensifying cooperation in financial services, banking, insurance, fintech, green bonds, sustainable finance, and capital market sectors and promoting collaboration between regulators and stakeholders.

Growing opportunities in India are attracting both exports and investment from the UK. The UK is the sixth-largest investor in India. About 572 UK companies are present in India with a combined turnover of around INR 3,390 billion (£33.9 billion) and employing 416,121 people directly in 2019-20.[3] India was the UK's fifteenth largest trading partner in the four quarters to the end of Q2 2021 accounting for 1.6 per cent of total UK trade. In 2019, the outward stock of foreign direct investment (FDI) from the UK in India was £15.3 billion, accounting for one per cent of the total. In 2019, the inward stock of FDI from India was £9.5 billion, accounting for 0.6 per cent of the total UK inward FDI stock. Total UK exports to India amounted to £7.3 billion in the four quarters to the end of Q2 2021 (a decrease of eight per cent compared to the four quarters to the end of Q2 2020). Total UK imports from India amounted to £12.5 billion in the four quarters to the end of Q2 2021 (a decrease of 5.9 per cent compared to the four quarters to the end of Q2 2020).[4] The drop in bilateral trade in the last 18 months was largely due to the disruption caused by the COVID-19 pandemic.

Underpinning this strengthening relationship is the cross-cutting area of sustainability. Partnerships are firmly based on the strong pillar of action against climate change, particularly in light of the commitments made at the COP 26 Climate Summit held in Glasgow, UK, in November 2021.

UK's Sustainable Manufacturing Sector

In November 2020, the UK government published The Ten Point Plan for a Green Industrial Revolution, which announced funding and support for the following areas:

1. Advancing offshore wind.
2. Driving the growth of low-carbon hydrogen.
3. Delivering new and advanced nuclear power.
4. Accelerating the shift to zero emissions vehicles (ZEVs).
5. Green public transport, cycling and walking.
6. "Jet zero" and green ships.
7. Greener buildings.
8. Investing in carbon capture, usage, and storage.
9. Protecting the natural environment.
10. Green finance and innovation.

Following the Ten Point Plan, in December 2020 the UK government published a white paper, Powering Our Net Zero Future, which sets out the changes needed to transition to clean energy by 2050. In 2021, the Sixth Carbon Budget report (covering 2033-2037), issued by the Climate Change Committee, set a target of an 80 per cent reduction in greenhouse gas (GHG) emissions relative to 1990 levels by 2035.

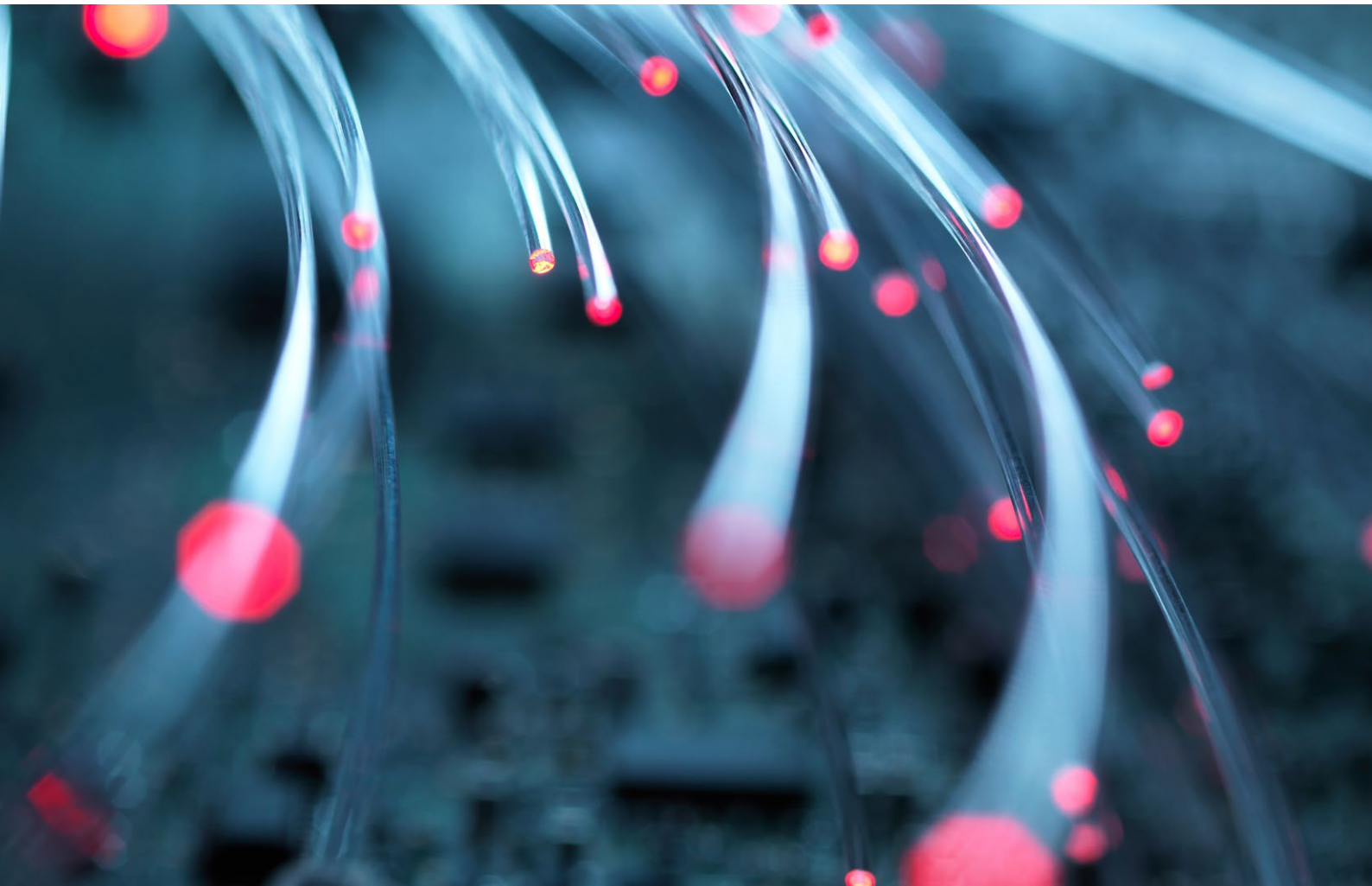
The UK government's Net Zero Research and Innovation Framework, published in 2021, identifies the main net-zero research and innovation (R&I) challenges for the UK over the next five-to-ten years and is a guide to the research and technologies needed to reach net zero by 2050. The framework emphasises the importance of pursuing a whole system, evidence-based approach to public sector R&I and provides information for businesses and academics working on net-zero-related research, including hydrogen technologies.

The manufacturing industry accounts for a considerable amount of carbon emissions in the UK. Manufacturing generates 81 megatonnes of the UK's GHG emissions annually.[5] The four sectors contributing the most GHG to the UK in 2022 were consumer expenditure, energy, manufacturing, and transport. These sectors contribute over 71 per cent of total UK GHG emissions.[6] Industries with large carbon footprints in the manufacturing sector include the steel, chemical, and cement industries.

The UKRI Research and Innovation's (UKRI) Strategy for 2022 to 2027: Transforming Tomorrow Together lists driving green technology development, adoption, and diffusion, building a sustainable circular economy and a greener future for the UK as one of the key outcomes and impact areas. While the UK has seen a reduction in GHG emissions since 1990, there is still a long way to go if the UK is to achieve net zero by 2050 despite the Ten Point Plan. UKRI will leverage national and international R&I strengths across multiple disciplines and sectors to deliver the new knowledge, technologies, skilled people, and multi- and interdisciplinary partnerships needed to keep the UK at the forefront of a new, green industrial revolution.[7]

Many UK universities, Catapult Centres, research bodies and companies have ongoing R&I activities in sustainable manufacturing. Here are a few examples of key centres and initiatives:

- The Sustainable Manufacturing Systems Centre (SMSC) at Cranfield University is a world-leading centre focusing on transforming manufacturing for a low-carbon economy. The centre's areas of research include improving existing and developing new manufacturing processes and systems via enhanced modelling and simulation, developing models for the "eco-factory" that are based on the principles of the circular economy through reducing the use of energy, water, and materials; mapping pathways for the sustainable net zero "factory of the future"; developing and manufacturing products enabled by the use of Industry 4.0 technologies in sustainable resilience environment; and developing new materials and processes that promote sustainable and innovative growth.[8]
- The Centre for Industrial Sustainability (CIS) at the Institute for Manufacturing (IfM) at the University of Cambridge works to develop knowledge and tools that accelerate the transition towards a sustainable industrial system. CIS works collaboratively with many research bodies and universities in the broad research themes of eco-efficient manufacturing: identifying waste and model factory resource flows; sustainable business innovation: re-thinking business models; and industrial system transformation: visions of future industry and mapping future industrial systems. CIS produced a report, Industrial Evolution - Making British Manufacturing Sustainable, for a cross-party Manufacturing Commission in the British Parliament in 2015.
- From hydrogen and nuclear energy to transport electrification and low-carbon composites, the UK's High-Value Manufacturing Catapult (HVMC) Centres enable innovations in technologies,



techniques, materials and energy that can significantly impact reaching net zero. Aside from the core manufacturing sector, HVMC is developing initiatives to reduce emissions from conventional vehicles and drive net-zero transport solutions forward in road, rail, air and sea travel. HVMC is helping UK companies reduce emissions through several measures ranging from data-driven productivity improvements to developing new techniques or materials. HVMC is also leading regional initiatives to decarbonise industry that will lead the way to a much greener UK manufacturing community and help the country embrace nuclear, hydrogen and renewable energy.

- Working with the UK Circular Plastics Network (UKCPN), Innovate UK KTN has built a robust community around the sustainable use of plastics, and works across sustainable manufacturing sectors such as automotive, medical devices, packaging, and sustainable fashion.[9] The UK's smart, sustainable plastic packaging (SSPP) challenge is working to make plastic packaging fit for a sustainable future. SSPP's ambition is to establish the UK as a leading innovator in intelligent and sustainable plastic packaging for consumer products. As a £60 million five-year programme, it is the most significant and ambitious UK government investment in sustainable plastics R&I. The challenge combines academia and industry and is underpinned by delivering the 2025 UK Plastics Pact targets. This will drive cleaner growth across the supply chain and dramatically reduce plastic waste entering the environment by 2025.[10]
- To make rapid progress towards decarbonising the transport sector, UKRI's Faraday Battery Challenge, delivered by Innovate UK, has announced support of £27.6 million for 17 projects in the areas ranging from battery recycling, digital twins, new battery materials, and new manufacturing techniques in January 2023. The projects aim to enable UK competitiveness across the battery value chain by building and securing the UK supply chain, improving battery performance, reducing the cost of batteries, developing more sustainable batteries, accelerating the development and scale-up of battery technologies, and developing more efficient and globally competitive manufacturing processes.[11]
- The UK has a vibrant hydrogen R&I ecosystem with several public and publicly backed organisations possessing unique capabilities, expertise, know-how, testing facilities, and available funding. Collectively, they support UK hydrogen R&I across the whole value chain and TRLs, from discovery and applied research to innovation, demonstration and deployment. The Department for Business, Energy and Industrial Strategy (BEIS) leads on UK hydrogen policy, providing strategic direction, policy development and funding for hydrogen R&I. Funding for hydrogen R&I is provided mainly through the £1 billion Net Zero Innovation Portfolio, which funds programmes including the £60 million Low Carbon Hydrogen Supply 2 Competition and the Industrial Hydrogen Accelerator Programme, a £26 million innovation funding programme to support the demonstration of end-to-end industrial fuel switching to hydrogen in the UK. To support the commercial deployment of hydrogen production, BEIS is launching the £240 million Net Zero Hydrogen Fund and designing a Hydrogen Business Model. BEIS works alongside industry and academia via the Hydrogen Advisory Council and plays a vital part in the government's Net Zero Innovation Board, which provides strategic direction on net zero R&I across government departments.[12]
- The UK announced support for its sustainable aviation fuel (SAF) industry to take flight as the government awarded five projects a share of the £165 million Advanced Fuels Fund in December 2022. The successful projects include SAF plants in Teesside, Immingham and Ellesmere Port which will convert everyday household and commercial waste, such as black bin bags, into sustainable jet fuel. Other successful projects include an SAF plant in Port Talbot which will convert steel mill off-gases into sustainable jet fuel and the early development of a SAF plant using carbon capture and hydrogen from renewable electricity.[13]

India's Sector and Innovation Landscape

India announced the years 2010-2020 as the Decade of Innovation. Kick-started with the setting up of the National Innovation Foundation in 2000, the decade saw a series of policy initiatives. The 4th Science, Technology, and Innovation (STI) Policy was launched in 2013, and the next edition, the 5th STI Policy 2020 is now being introduced.

In between, the Government of India (GoI) introduced Make in India, Skill India, and Start-up India – three flagship initiatives respectively for developing a strong manufacturing sector, supporting Indian youths with vocational and market-relevant training programmes, and creating a robust start-up ecosystem in India. India's Gross Expenditure on R&D (GERD) increased by more than three times in the last decade and India's per capita R&D expenditure at purchasing power parity (PPP) doubled in the last ten years. India moved to the 40th rank in the Global Innovation Index (GII) 2022, published by the World Intellectual Property Organization. When compared to India's 81st ranking in 2015, this is substantial progress.

India's Research and Innovation Strengths

- India went from being ranked 81st in the Global Innovation Index in 2015, to 40th in 2022.
- India moved up 79 places in the last six editions in the World Bank's Global Ranking in Ease of Doing Business (from 142nd to 63rd).
- India's GERD increased by more than three times in the last decade. India's per capita R&D expenditure at PPP doubled in the last ten years.
- India has the third-largest start-up ecosystem in the world and is home to 88 unicorns with a total value of £226 billion. Start-ups such as Log9 Materials have successfully raised VC funding.
- More than 50 per cent of the world's largest R&D spenders have a research and innovation presence in India.
- The R&I initiatives are supported by government policies, production-linked incentive schemes and global commitments. Indian companies are setting up R&D centres on sustainable manufacturing: IndianOil is setting up Innovation Centres, Ola India is investing £100 million in R&D in Coventry, UK; and Reliance recently acquired Faradion and Lithium Werk. Most of the R&D programmes by Indian companies focus on resource and energy efficiency, and clean energy.
- Substantial bilateral funding and collaborations in policy issues will lead to investments in start-ups and many R&I initiatives.
- Strong international interest in India's sustainable industry with growing FDIs and support from bodies such as the EU and GIZ.

The efficient use of resources in production processes, coupled with the adoption of low carbon, clean energy, and sustainable practices, is growing across various segments of industries. Industries are transitioning from a linear production model to a circular model. This is primarily guided by their aspiration and commitment to reducing their carbon footprint, decreasing resource extraction and enhancing productivity, competitiveness, and profitability. Indian industries are gradually embracing resource efficiency and integrating sustainability into their value chains.

Innovation for manufacturing in resource efficiency and sustainability spans a wide range of areas, such as efficient material processing, resource-efficient machinery that generates less effluent, waste, and air pollutants, enhancing energy storage capacity, shifting towards renewable energy, reducing energy and water intensity, applying the circular-economy model to designing products keeping in mind the end-of-product lifecycles, redesigning of manufacturing processes, the greening of the supply chain, sourcing and use of raw materials and co-creation of production by treating waste as a resource.

Resource efficiency/Sustainable manufacturing practices

From linear to circular economy: Key priority areas

As per the Ministry of Environment, Forest and Climate Change (MoEFCC), India's resource extraction is 1,580 tonnes/acre, which is higher than the global average of 450 tonnes/acre. It has the third greatest material demand in the world. It has lower material productivity compared to the global average. The recycling rate is 20-25 per cent (that of Europe is 70 per cent). Total material consumption by India in 2030 is projected to be 14.2 BT (billion tonnes), consisting of about 2.7 BT of biomass, 6.5 BT of minerals, 4.2 BT of fossil fuels, and 0.8 BT of metals. India has high import dependence on several critical raw materials such as molybdenum, nickel, cobalt, lithium, copper, oil, steel scrap, and others.[14] India's carbon emissions are the third largest in the world.

India announced its net zero target by 2070 at COP 26. It has also announced that 50 per cent of its energy requirements will be met by renewable sources by 2030 and that it will reduce its projected carbon emissions by 1 BT between 2021 and 2030.

India aspires to be a global manufacturing hub. A linear manufacturing model will lead to increased use of raw materials and waste disposal. This will have a huge environmental and climate impact unless policies and regulatory frameworks for production using a circular economy approach are implemented. The adoption of circular economy practices in India can result in an annual benefit of INR 40 trillion (approx £400 billion) by 2025.[15] Furthermore, the innovations can reduce GHG emissions by 44 per cent, bringing environmental, social, and economic benefits.

To drive resource efficiency across various sectors, GoI has drafted an overarching policy framework called the National Resource Efficiency Policy (NREP) 2019. This policy aims to put sustainability at the heart of the development of Indian industries by fostering cross-sectoral collaboration and creating an enabling ecosystem to augment productivity whilst contributing to the Sustainable Development Goals (SDGs).

This Innovation Insight Study aims to highlight the potential of resource efficiency in key areas, such as **electrification of transportation, plastic, electrical and electronic equipment, steel, construction and cement, green hydrogen, and biofuel**. It covers India's emerging priorities and policy environment in these sectors, given its global commitments and self-reliant strategy. The report has also identified potential collaborative opportunities for innovation between Indian and UK organisations in these areas that can address shared challenges and contribute to the mutual prosperity of both countries.

Domestic Resource Efficiency Policy and India's Global Commitments

Resource use accounts for half of the global climate emissions. Resource efficiency and sustainable waste management play crucial roles in the decarbonisation of economies across value chains. India is prioritising this across sectors through domestic sectoral policies and global commitments.

India's policy landscape and global commitments to enable resource efficiency

Social benefits
India aspires to be a global manufacturing hub. Sustainable Manufacturing and Circular Economy approach will create millions of new green jobs and contribute to better health and environment.

Climate benefits
Innovations in Circular Economy can reduce india's Greenhouse Gas Emissions by 44%.

Economic benefits
Circular Economy practices in India can result in annual benefits of INR 40 trillion (£400 Billion) by 2025

- India's resource extraction is 1,580 tonnes/acre (global average is 450 tonnes/ acre).
- India has the third-largest material demand but low material productivity compared to the global average.
- Total material consumption of India in 2030 is projected to be 14.2 billion tonnes.

Domestic Policy

The draft NREP 2019 seeks to create a facilitative and regulatory environment to mainstream resource efficiency across different sectors by fostering cross-sectoral collaborations, development of policy instruments, action plans, and efficient implementation and monitoring frameworks. The draft NREP 2019 is primarily guided by these principles:

1. Reduction in primary resource consumption to “sustainable” levels, in keeping with the achievement of the SDGs and staying within the planetary boundaries.
2. Creation of higher value with less material through resource-efficient and circular approaches.
3. Waste minimisation.
4. Material security.
5. Creation of employment opportunities and business models beneficial to the cause of environment protection and restoration.

The draft NREP 2019 aims to create a dedicated institution for fostering resource efficiency, the National Resource Efficiency Authority (NREA) that draws its power from the Environment (Protection) Act, 1986, to provide for the regulatory provisions of this policy. The proposed NREA should have a collaborative institutional structure with a wide range of key stakeholders, including members from line ministries, state governments, government agencies, and other experts. The policy also mentions setting up an inter-ministerial National Resource Efficiency Board (NREB), whose aim would be to guide all sectors across resources and lifecycle stages.
Based on the share in national income, use of raw materials, and import dependency, the draft NREP 2019 focuses on enhancing resource efficiency practices in the following industries: automotive, steel, plastic, electronic waste, construction, solar photovoltaic (PV), and aluminium.

Sectoral Relevance of the Draft NERP 2019 Based on a Share in National Income, use of Raw Materials (Including Import Dependency)

Sector	Share of India's national income	Key raw materials	Import dependency
Automobile sector (including electric vehicles)	7.1%	**Internal combustion engine vehicles (ICEV):** steel, copper, aluminium, zinc, nickel, lead, glass, rubber, various plastics/synthetics **E-vehicles:** lithium, cobalt, nickel, rare earth elements (REE), various plastics/synthetics, steel, copper, aluminium	copper (50-60%), lithium (100%), cobalt (100%), aluminium scrap (90%), steel scrap (20-25%), lead (75%), REE (100%)
Plastics	2% (0.5-0.8%)	crude oil	oil (80%)
Construction	9%	cement, limestone, clay bricks, steel, aluminium, copper	aluminium scrap (90%), steel scrap (20–25%), copper (50–60%)
Electronics (including e-waste)	1.8%	gold, silver, REE, plastics, platinum, copper	silver (75%), REE (100%), gold (90%), platinum (95%), copper (50-60%)
Solar PV	2.1%	aluminium, silver, copper, silicon	aluminium scrap (90%), silver (75%),copper (50-60%)
Steel	2%	iron ore, molybdenum, nickel, tungsten	steel scrap (20–25%), molybdenum(100%), nickel (100%), tungsten (100%)
Aluminium	0.8%	bauxite, aluminium scrap	aluminium scrap (90%)

Source: Annual Survey of Industries (2015), NIPFP (2016), MoSPI (2017) and TERI, 2019

These sectors are regulated by a range of domestic environmental policies. However, the purpose of an umbrella policy such as the draft NREP 2019 is to ensure that innovation drives transition faster and in a more structured way. This policy is being finalised with inputs from various ministries. Sector leaders are also part of global campaigns such as EP 100, CDP and net zero ambitions.

The circular economy strategy balances economic, environmental, and social objectives. Investments in resource efficiency can bring about benefits through a reduction in material use and waste generation, and increased job creation. It also reduces the risk of high and volatile resource prices. As per the NITI Aayog 2017 and TERI 2019 reports, resource efficiency can bring about:

- Savings of INR 60.8 billion (£608 million) in the material used in the manufacturing sector.
- Savings in the steel sector in material costs of 21 million tonnes (MT) iron ore, 8.25 MT coking coal, and 3.75 MT limestone by 2025 whilst resulting in a reduction of 31.5 MT of carbon emissions.
- Savings in the aluminium sector cost of 36 million barrels of crude oil by 2025 whilst reducing 13.5 MT of carbon emissions.

Role of the Government of India as Specified in the Draft NREP 2019

- Set up an in-house resource efficiency institution (resource efficiency cell) in the Ministry of Environment, Forest and Climate Change.
- Develop strategies, policy frameworks, and efficiency targets for sectors/regions and standards for secondary raw materials.
- Facilitate the setting up of infrastructure for recovery and recycling e.g. material recycling zones (MRZs) that co-locate recyclers and end-use producers with common facilities and shared infrastructure.
- Facilitate industrial symbiosis by setting up industrial parks and clusters to enable the utilisation of waste of one sector/industry as secondary raw material in another.
- Implement green public procurement e.g. procurement of products manufactured from recycled scrap materials, and use of recycled materials.
- Incentivise production and consumption of resource-efficient products.
- Facilitate access to finance for technology and process improvement and create an R&D fund to acquire technology for resource-efficient design, production, and management of waste.
- Implement extended producer responsibility for the management of end-of-life products.

Global Commitments at COP 26

The adoption of a circular economy approach by industries will play a pivotal role in helping India reach net-zero targets and meet the Paris Agreement goals. COP 26 witnessed India's 2070 net zero commitment. COP 26 also provided the platform for several countries to join global initiatives that will drive a circular economy across industry segments. India announced and endorsed several initiatives at COP 26 that will have regional implications for key sectors. Some of these commitments and endorsements have been highlighted below.

Announcements at COP 26 that will give further impetus to the uptake of resource efficiency measures by Indian industries:

Net zero by 2070 and 2030 commitments	Five panchamrit (elements) announced by the Indian Prime Minister to deal with climate change: • India will achieve net zero by 2070. • Non-fossil-fuel-based energy generation capacity of the country will be increased to 500 GW. • By 2030, 50 per cent of the energy generation capacity will be from renewable sources. • By 2030, India will reduce the carbon intensity of the economy by 45 per cent. • India will reduce total projected carbon emissions by 1 BT between 2021 and 2030.[16]
COP 26 World Leaders Summit – Statement on Glasgow Breakthroughs	Forty five countries launched the Breakthrough Agenda — a commitment to work together internationally in this decade to accelerate the development and deployment of clean technologies and sustainable solutions needed to meet Paris Agreement goals, ensuring they are affordable and accessible for all. It states that to limit the increase of global temperature by 1.5°C, the 2020s needs to be the decade of strong climate action and delivery across all major emitting sectors. The Breakthrough Agenda calls for collaborative work in each sector, public-private partnership, and mobilisation of finance and delivery across sectors. As a first step under the Breakthrough Agenda, the Glasgow Breakthroughs were launched with global goals that aim to make clean technologies and sustainable solutions the most affordable, accessible, and attractive options in each emitting sector globally before 2030. 1. Clean power. It is the most affordable and reliable option for all countries to meet their power needs efficiently by 2030. 2. Road transport. Zero-emission vehicles are the new normal, to be made accessible, affordable, and sustainable in all regions by 2030. 3. Steel. Near-zero emission steel is the preferred choice in global markets, with efficient use of resources and near-zero emission steel production established and growing in every region by 2030. 4. Hydrogen. Affordable renewable and low-carbon hydrogen to be globally available by 2030.[17]

UK and the IEA launched the COP 26 Product Efficiency Call to Action, the largest-ever global initiative on appliance energy	At COP 26, India joined a group of 14 countries to endorse the Joint Statement in Support of the Product Efficiency Call to Action and take forward efforts to advance this through the Super-Efficient Equipment and Appliance Deployment (SEAD) initiative.[18]
Launch of the Clean Energy Ministerial procurement campaign under the Industrial Deep Decarbonisation Initiative	The Industrial Deep Decarbonisation Initiative (IDDI) is coordinated by the United Nations Industrial Development Organisation (UNIDO) and co-led by the UK and India. IDDI is a global coalition of public and private organisations working to stimulate demand for low-carbon industrial materials. It brings together a strong coalition of related initiatives and organisations, including the Mission Possible Platform, the Leadership Group for the Industry Transition (LeadIT), the International Renewable Energy Agency (IRENA), and the World Bank, to tackle carbon-intensive construction materials such as steel and cement. IDDI will focus on a range of areas, including: • Engaging with governments and industries to standardise carbon assessments throughout the lifecycles of key industrial products. • Establish ambitious public and private sector procurement targets. • Incentivise investments in the development of sustainable products. • Design industry guidelines.[19]
Launch of Mission "Integrated Bio-refineries" under Mission Innovation	At COP 26, the Indian Minister of Science and Technology, Dr Jitendra Singh, mentioned that through "Mission Innovation", India is actively engaged in collaborative efforts to catalyse inspiring innovation goals that will lead to affordable and scaled-up clean energy solutions. India launched "Mission Integrated Bio-refineries" with the Netherlands, aiming to leverage its extensive experience in research and innovation, enhance support for the start-up ecosystem, and harness international collaborations. Dr Singh said that Mission Innovation brings together a dynamic and delivery-focused alliance of countries, respective private sectors, research institutes, and civil societies to accelerate innovation in renewable fuels, chemicals, and materials for a low-carbon future. He mentioned that GHG emissions from the transport and chemical sectors account for about one-third of the global emissions and are projected to increase. He also announced that India, through the Department of Biotechnology, has been promoting R&D in sustainable biofuels, including sustainable aviation fuels. Twenty-two governments and the European Commission, collaborating through Mission Innovation, committed to four new missions to catalyse investment to accelerate technologies that facilitate urban transitions, eliminate emissions from industry, enable carbon dioxide removal, and produce renewable fuels, chemicals, and materials.

	India joined the following three missions: 1. Urban Transitions Mission: To deliver at least 50 large-scale, integrated demonstration projects in urban environments around the world by 2030, providing a pathway for all cities to adopt net-zero carbon solutions as the default option. India is a core-group member of this mission. 2. Carbon Dioxide Removal (CDR) Mission: To enable carbon dioxide removal technologies that achieve a net reduction of 100 MTPA of CO2 emissions globally by 2030. India is a supporting member of the CDR Mission. 3. Bio-refineries Mission: To realise this potential and make bio-based alternatives cost-competitive, India and the Netherlands are leading the development of the Integrated Bio-refineries Mission.[20]
COP 26 ZEV Declaration under the Emerging Economies category	At COP 26, on Transport Day, India joined nine other emerging economies to support a non-binding, global ambition on Zero-Emission Vehicles (ZEV) Declaration. The objective is to work collaboratively towards accelerated ZEV transition.[21]
Climate Investment Funds announced India as one of five initial recipients of funding under the Accelerating Coal Transitions (ACT) programme	India, Indonesia, the Philippines, and South Africa announced partnerships with the Climate Investment Funds to accelerate their transition from coal power, backed by a dedicated £1.53 billion facility. India will receive up to £383 million funding under the Accelerating Coal Transitions (ACT) programme.[22]
India Green Guarantee to the World Bank	The UK will also provide an "India Green Guarantee" to the World Bank, to unlock an additional £750 million ($1 billion) for green projects across India. The financing will support clean and resilient infrastructure in sectors such as clean energy, transport, and urban development.[23]

Taking a step further, at COP 27 held in November 2022, India submitted its Long-Term Low Emission Development Strategy (LT-LEDS) to UNFCCC. The salient features of India's LT-LEDS include:[24]

- Focus on the rational utilisation of national resources with due regard to energy security. The transition from fossil fuels will be undertaken in a just, smooth, sustainable, and all-inclusive manner.

- Rapid expansion of green hydrogen production, increasing electrolyser manufacturing capacity in the country, and a three-fold increase in nuclear capacity by 2032.

- Increased use of biofuels, especially ethanol blending in petrol, the drive to increase electric vehicle penetration, and the increased use of green hydrogen fuel to drive the low carbon development of the transport sector. India aspires to maximise the use of electric vehicles, ethanol blending to reach 20 per cent by 2025, and a strong modal shift to public transport for passenger and freight.

- Future sustainable and climate-resilient urban development will be driven by smart city initiatives, integrated planning of cities for mainstreaming adaptation and enhancing energy and resource efficiency, effective green building codes, and rapid developments in innovative solid and liquid waste management.

- India's industrial sector to continue on a strong growth path, in the perspective of "Aatmanirbhar Bharat" and Make in India. Low-carbon development transitions in the sector should not impact energy security, energy access, and employment. The focus will be on improving energy efficiency through the Perform, Achieve and Trade (PAT) scheme, the National Hydrogen Mission, a high level of electrification in all relevant processes and activities, enhancing material efficiency, and recycling, leading to the expansion of the circular economy, and exploring options for hard-to-abate sectors, such as steel, cement and aluminium.

- Provision of climate finance by developed countries will play a very significant role and needs to be considerably enhanced, in the form of grants and concessional loans, ensuring scale, scope, and speed, predominantly from public sources, in accordance with the principles of the UNFCCC.

Innovation will be the fundamental driver of sustainable manufacturing and resource efficiency across key sectors. The following sectors have been selected for this Innovation Insight Study based on the focus given by the GoI's draft NREP 2019 and global priorities and commitments – **electrification of transportation, plastic, electrical and electronic equipment, steel, construction and cement, green hydrogen, and biofuel.**

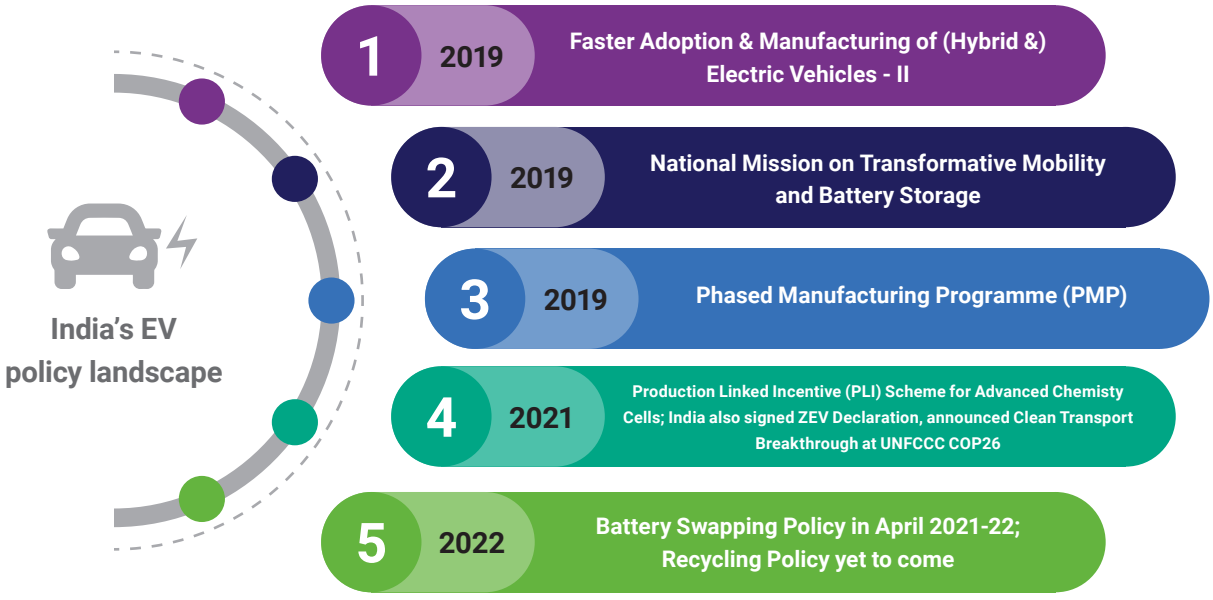
Electrification of Transportation

Introduction

Electrification of the transportation sector in India is gaining momentum, and this development offers several opportunities for resource efficiency and sustainable manufacturing practices in the automotive industry. This section of the report focuses on resource efficiency potential in battery manufacturing (storage) and recycling of electric vehicles and their supply chain.

To address air pollution and contribute to energy security, India is implementing innovative steps to accelerate the adoption of electric mobility. India aspires to emerge as a Global EV Manufacturing Hub within five to seven years and to build a robust indigenous EV value chain based on ethical and sustainable practices. As signalled by GoI's think-tank, NITI Aayog, in 2018, India plans to have EV sales penetration of at least 30 per cent in private cars, 70 per cent in commercial vehicles, 40 per cent in buses, and 80 per cent in two-wheelers and three-wheelers by 2030.

Electrification of Transportation

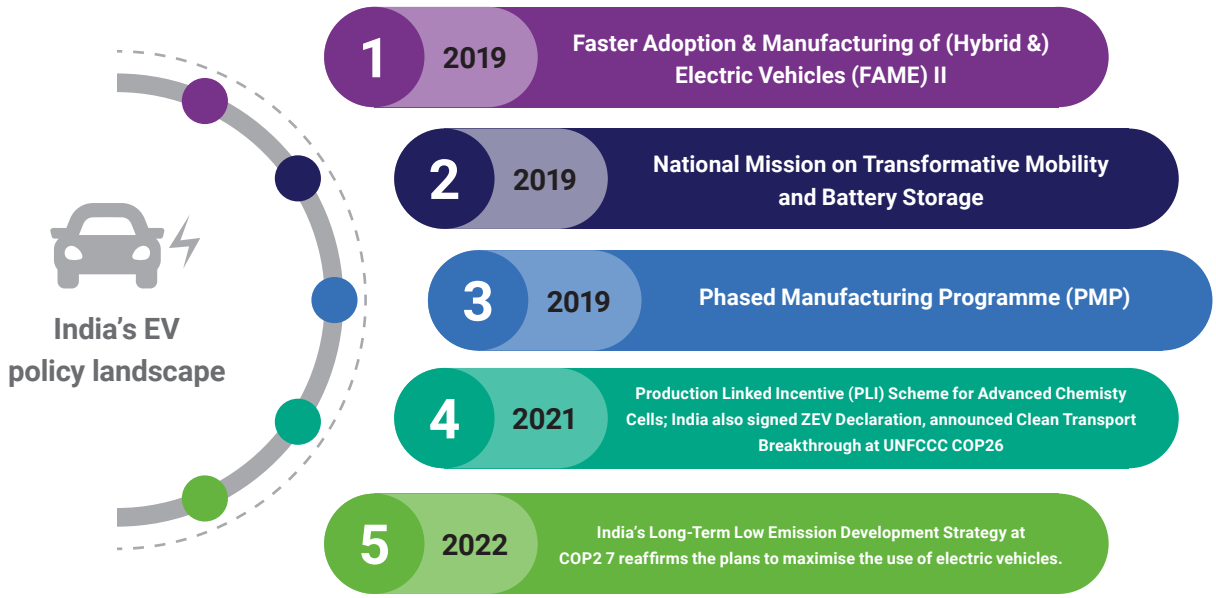


Policy Landscape

The uptake of electric vehicles in India is driven by the following policies, some of which encourage innovation in the sustainable manufacturing of EVs:

- Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME) scheme Phase II to provide impetus to the adoption of electric and hybrid vehicles by offering an upfront incentive for the manufacturing and purchase of electric vehicles and establishing necessary charging infrastructure. Phase I of the scheme was launched on 13 March 2015, and Phase II on 1 April 2019, with overall funding of £1 billion.
- National Mission on Transformative Mobility and Battery Storage, launched in March 2019, is a multi-disciplinary and inter-ministerial programme (chaired by the CEO of NITI Aayog) to set up and drive a five-year Phased Manufacturing Programme (PMP) across the entire EV value chain. The policy focuses on manufacturing batteries at giga-scale and producing innovative, competitive, and diverse multi-modal mobility solutions that can be deployed globally.
- Innovation in battery manufacturing in India has received a fresh impetus from the Production Linked Incentive (PLI) Scheme launched in May 2021 under the National Programme on Advanced Chemistry Cell Battery Storage introduced by the Department of Heavy Industries, GoI. The INR 181 billion (£1.81 billion) programme has set a target of manufacturing 50 giga watt hours (GWh) of advanced chemistry cells to reduce dependence on imported raw materials needed for storage and ensure that the cost of battery manufacturing in India is globally competitive. Ten companies have responded to the tender with a cumulative capacity of 130 GWh against the 50 GWh planned capacity.
- Battery Swapping Policy. In April 2022, NITI Aayog, GoI announced the Draft Battery Swapping Policy.
- India's LT-LEDS at COP 27 mentioned plans to increase electric vehicle penetration to the low carbon development of the transport sector.[26]

Policy Roadmap for EV



Research and Innovation Ecosystem

In India, several automotive and energy storage companies are investing in innovation to optimise their operations and move towards sustainable manufacturing through a wide range of measures. Some of these include improvement in the efficiency of batteries, reduction in the cost of batteries (which make up for about 50 per cent of the cost of an EV), decreased dependence on the import of raw materials, research on next-generation batteries, and recycling of batteries. These also include innovation and techno-commercial developments in powertrain and electric motor drives. Innovations in lithium-ion battery (LiB) manufacturing, battery recycling, and next-generation battery development are fundamental to bringing about a circular economy. Some of the key stakeholders and their activities are mentioned below.

UK-India bilateral collaborations:

- The Prime Ministers of the UK and India launched Roadmap 2030 in April 2021, within which battery manufacturing, recycling, and innovation have been identified as areas of cooperation.
- The UK Foreign Commonwealth and Development Office (FCDO) is working with GoI on battery manufacturing and recycling. It is providing recommendations to NITI Aayog on battery recycling policies through the Green Growth Equity Fund. FCDO's Green Growth Equity Fund Technical Cooperation Facility (GGEF TCF) aims to catalyse private investment into Indian green infrastructure projects. The project is being delivered by an OPM-led consortium of PwC, Arup, Vivid Economics and the UK India Business Council (UKIBC). The GGEF TCF supports a flexible portfolio of technical assistance in developing and strengthening the pipeline of investable projects, tackling policy and regulatory barriers, strengthening poverty and social benefits, and undertaking to monitor their programme delivery, while drawing from international expertise on expanding green markets. Launched in 2020, the programme will run until 2024. It is funded by FCDO.
- The Joint UK-India Clean Energy Centre (JUICE) – a virtual joint centre partnership between the UK and India focuses on energy storage among other areas. It brings together premier research institutions from both sides to develop decarbonisation technologies, including energy storage. JUICE partners include Loughborough University, Swansea University, University of Birmingham, University of Manchester, Cardiff University, Imperial College, University of Southampton, University of Exeter, and the University of Warwick from the UK, and several Indian institutes of technology, Indian Institute of Science, Central Electrochemical Research Institute, Karaikudi; and IIEST Shibpur from India.
- The UK-NITI Aayog Electric Mobility Accelerator Programme focuses on the uptake of electric mobility and creating a supportive ecosystem through innovative tools, policies, and knowledge exchange.

Lithium-Ion Battery Manufacturing Scenario and Scope for Innovation

Rising demand for LiBs and GoI's policies to encourage domestic manufacturing have prompted several players to firm up their plans to set up battery and cell manufacturing units in the coming years.

Below is a summary of some of the innovations and announcements:

India: Key Energy Storage Materials Projects and Announcements

- Several Tata Group companies are working together in the EV and energy storage space. While Tata Chemicals is leading in battery technology, Tata Power will bring its expertise in setting up charging stations. Tata Motors and Tata Auto Components are working on EVs and powertrain systems, and Tata Motor Finance will look after the vehicle financing options. TCS and Tata Technologies will provide support in the areas of software and design. [27]
- Tata Chemicals is creating an electrochemical platform to become one of India's leading players in the energy storage sector. The company is partnering with Indian R&D centres (like the Indian Space Research Organisation [ISRO], CSIR-CECRI, and the Centre for Materials for the Electronics Industry [C-MET]) for the indigenous development of battery materials actives, cells, and recycling. Tata Chemicals has committed an investment of INR 40 billion (£400 million) to set up an LiB plant in Dholera Special Investment Region (DSIR) in Gujarat.
- Tata Chemicals has established a process of recovering valuable materials from used LiBs. Recycling spent batteries provides valuable metals in the form of salts of lithium, cobalt. nickel, and manganese, along with byproducts like graphite, iron, copper, and aluminium. Their InsperiCo™ is the world's first branded recycled cobalt. The technology can be used for LiBs, including those based on lithium cobalt oxide, nickel manganese cobalt oxide, and nickel cobalt aluminium oxide. [28,29]
- While Tata Chemicals will cater to the energy storage needs of the EV sector, Tata Power will pursue opportunities for battery storage solutions for grid integration. They won India's first large-scale battery storage project in 2021 to build a 50 MW Solar PV Plant, co-located with a 50 MWh battery energy storage system at Phyang village in Leh, Ladakh. [30]
- Japan's Suzuki Motor Corp (SMC), Toshiba Corp, and Denso Corp are jointly investing INR 37.15 billion (£371.5 million) in the second phase of their battery venture in Gujarat's Hansalpur. The joint venture will manufacture 30 million lithium-ion cells per year by 2025, with a production capacity of more than 1 GWh. These batteries could be deployed in pure electric vehicles, hybrids, and electric two-wheelers.[31]
- Matter, a start-up electric mobility solutions and energy storage provider, recently planned to invest INR 15 billion (£150 million) over the next five years in Gujarat. Of this, INR 3 billion (£30 million) will be invested in energy storage and create 4,000 jobs in the state over the next five years. [32]
- Reliance New Energy, a wholly-owned subsidiary of Reliance Industries, acquired Sheffield and Oxford-based company Faradion in January 2022 for £100 million and plans to invest £25 million as growth capital to accelerate the commercial rollout.[33] Faradion is the world leader in sodium-ion battery technology that provides low-cost, high-performance, safe, and sustainable energy. Its proprietary technology delivers leading-edge, cost-effective solutions for a broad range of applications, including mobility, energy storage, backup power, and energy in remote locations. Reliance will use Faradion's technology at its proposed fully integrated energy storage factory at the Dhirubhai Ambani Green Energy Giga Complex in Gujarat. [34]

- In March 2022, Reliance New Energy acquired Lithium Werks BV for US$ 61 million, including funding for future growth. Headquartered in the Netherlands, Lithium Werks has offices, R&D and production facilities in the USA, Europe, and China. Lithium Werks is a leading provider of cobalt-free and high-performance lithium ferro-phosphate (LFP) batteries. With the recent rise in demand for LFP batteries, Lithium Werks with its experience in battery innovation and manufacturing for over 30 years, is reportedly uniquely positioned to take advantage of the global opportunities through its integrated portfolio of LFP solutions.[35]
- Ola Electric, the EV arm of the leading India rideshare company, Ola, is investing £100 million in Coventry, UK, in their "Futurefoundry" project. The R&D facility will focus on both EVs and batteries for EVs. [36]
- India's largest battery manufacturer, Exide Industries, is planning to set up a multi-gigawatt lithium-ion cell manufacturing plant. They are entering the ACC sector through their subsidiary, Exide Leclanche Energy (under the brand Nexcharge), in a joint venture with Leclanche SA, Switzerland. With its state-of-the-art R&D centre, the subsidiary aims to build LiBs and provide energy storage systems for the EV market and grid-based applications.[37] In March 2022, Exide Industries announced an investment of INR 60 billion (£600 million) to set up one of India's largest giga-scale advanced chemistry cell manufacturing facilities in Karnataka.[38]
- Indian battery major, Amararaja, invested in the European EV battery company, InoBat, in December 2021. InoBat has a LiB R&D facility and production line in Voderady, Slovakia. The project's next phase will focus on a manufacturing scale-up through several gigafactories planned across Europe and globally. The company is backed by a consortium of partners, including CEZ, a major European utility company, and Rio Tinto, the global mining giant. As a part of its global expansion plans, InoBat opened an office in the University of Warwick Science Park's Warwick Innovation Centre in March 2022.[39,40]
- The Chatterjee Group (TCG) is setting up a battery research laboratory in Kolkata at their Research Institute for Sustainable Energy, by TCG Centre for Research, Education, Science, and Technology (TCG Crest).[41]
- India-based start-up Log9 Materials is in the process of developing a graphene-enhanced battery for electric vehicles. Log9 Materials claims that its rapid-charging battery technology can fully charge an electric vehicle in under 15 minutes and that it has a lifetime of over 15 years. The company plans to deploy over 3,000 electric two-wheelers and three-wheelers with rapid-charging battery packs within the next five years.

Electric Vehicles Battery Recycling Scenario and Scope for Innovation

Researchers estimate that India's annual LiB battery market will grow from 2.9 GWh in 2018 to 132 GWh in 2030[42]. The projected increase in the use of electric vehicles and the use of LiBs will generate large volumes of end-of-life LiBs. If sustainability in this sector is not addressed, it will create environmental hazards. The LiB recycling market is expected to be worth £756 million.[43] Lithium-ion batteries consist of several precious and common metals: aluminium, copper, cobalt, iron, nickel, titanium, and lithium. The anode consists of copper foil covered by a fine layer of carbon, while the cathode contains aluminium, cobalt, and lithium metals. Of these, cobalt and nickel are rare metals available in selected regions of the world. India is dependent on other countries for importing these, which is one of the primary reasons India is in the early stages of manufacturing LiBs.

India is also keen to develop a battery recycling infrastructure that will support its battery manufacturing sector. Ninety-five per cent of batteries in electric vehicles can be recycled and reused. This will enhance the affordability of batteries and reduce emissions while cutting down on the import dependency on raw materials. Secondary usage and recycling of used LiBs will lead to the setting up of a circular economy in this sector. Sustainable manufacturing, reuse, and recycling of LiBs require innovative technologies and regulatory frameworks. India is yet to come up with a battery recycling policy. It introduced the Draft Battery Swapping Policy on 20 April 2022. It will create a framework for greater interoperability and has proposed to offer incentives to electric vehicles with swappable batteries and to companies manufacturing swappable batteries. The policy is expected to safeguard the innovation potential of the EV battery ecosystem.[44]

Case studies on battery recycling and swapping

India is keen to develop its battery recycling infrastructure to support the battery manufacturing sector.

Attero Recycling

Tied up with MG Motors India to recycle EV batteries. Plans to invest £30 million to recycle end-of-life batteries in a sustainable manner

Summobility

Has set up 65 points across 14 Indian citites that offer battery swapping within 2 mins. It has partnered with Tata Power DDL to set up Lithium Battery Swapping Stations in Delhi.

During Budget 2022-2023, Government of India annouced plans to introduce Battery Swapping Policy and Interoperability Standards. Following this NITI Aayog introduced Draft Battery Swapping Policy on April 2022.

Secondary usage and recycling of used Lithium Ion Batteries will lead to setting up of a circular economy as India moves towards electrification of its transportation sector.

Next-Generation Battery Manufacturing Scenario and Scope for Innovation

Next-generation batteries, including solid-state and sodium-ion batteries, are at different stages of R&D. Thin-film batteries (TFBs) are also being developed. Polymer/gel electrolyte solid state batteries are at a commercial prototype stage. Companies are also working on Metal-air and Aluminium-air (Al-air) batteries. Sodium-Ion batteries are in the advanced prototype stage and have substantial potential for the Indian market. A pipeline of opportunities is being created to help manufacturers shift from an import-dependent model toward a more sustainable, efficient, and self-reliant production model. The Indian EV and energy storage companies and ongoing research by the Department of Science and Technology (DST) and GoI-supported laboratories are looking at a wide range of materials solutions for energy storage systems. The future areas of collaboration mainly comprise further work on LiBs with the existing and new Indian stakeholders and emerging research areas in alternative materials. In a strategic move toward energy storage materials, there is a conscious move to look at alternative material platforms which could offer similar or superior energy intensity. Some of the alternative battery chemistries that India could look at are summarised overleaf.[45]

Energy Storage: Alternative Material Platforms

Battery type	Cathode material	Anode material
Li-Air, Mg-Air, Al-Air, Fe-Air, Zn-Air, Lead flow batteries, Vanadium flow batteries, Na-S, Li-S, Thermal batteries, Na-NiCl2 (Zebra batteries), Ag-Zn, Mg-AgCl reserve batteries, Ultra lead-acid Batteries, Lead – Carbon, Li-Carbon, dual carbon	Lithium Nickel Cobalt Manganese Oxide (LiNiCoMnO2), Lithium Nickel Cobalt Aluminum Oxide (LiNiCoAlO2), Lithium Cobalt Oxide (LiCoO2), Lithium Manganese Oxide (LiMn2O4), Lithium Iron Phosphate (LiFePO4/C), Lithium Titanium Oxide, NiMn-Co-Al cathode materials, amorphous carbon, hard carbon, graphite (natural, synthetic graphite, Krish carbon), Metal, Organic Frameworks - cathode and composite cathodes	Si–Graphite composite anodes, Tin composite anodes, Li metal anodes, Metal-Organic Frameworks - anode

Potential Areas of Collaboration

As the sector expands and the demand for EVs accelerates, potential areas of collaboration in the EV battery segment will be guided by the reduction in battery cost, volume, and weight and improvement in efficiency and performance for resource-efficient energy storage. Resource efficiency will also depend on recycling technologies of raw materials and next-generation battery development. Innovations in power electronics, machines and drives will also be critical to bringing about efficiency.

Potential areas for collaboration in the LiB manufacturing segment
• Silicon anode and polymer binder for high energy density LiB. • Synthetic graphite, produced from coke as an alternative anode material. • High energy density anode and cathode materials.
Potential areas for collaboration in LiB recycling
• Hydrometallurgical process for recovery of copper, manganese, nickel, and lithium. • Recovery of graphite. • Development of cathode materials from recycled metals. • Reuse of second life application of LiBs in solar energy. • Second life applications of battery swapping.
Potential areas for collaboration in next-generation battery development
• Development of high-energy-density cells with gel electrolytes. • Innovation using aluminium air cells. • Developing solid-state batteries.

Plastic

Introduction

Resource efficiency in manufacturing plastic and managing plastic waste are high priorities for the GoI and Indian industries. Plastic production has increased from 2 MT in 1950 to a stupendous 400 MTPA. Globally, this industry is valued at £395 billion and is expected to double in capacity by 2040. India's plastic manufacturing industry is valued at £30 billion. Top industries are embarking on sustainable initiatives and collaborating with start-ups to bring about a transformational shift in the manufacturing, packaging, and use of plastic and phasing out of single-use plastic. Technologies and innovations have the potential to infuse an additional £1.5 billion into the Indian economy and create 1.4 million new jobs while avoiding 51 MT of GHG emissions by 2030.[46]

In December 2021, Indian Commerce and Industry Minister Piyush Goyal convened a meeting with different line ministries, various industry associations, and trade bodies in the petrochemical and plastic sectors, such as the Federation of Indian Chambers of Commerce and Industry, the Confederation of Indian Industry, All India Plastics Manufacturers Association, Organization of Plastics Processors of India, Process Plant and Machinery Association of India, Plastic Export Promotion Council (PLEXCONCIL) and Material Recycling Association of India. The objective of the meeting was to discuss a way forward to increase the turnover of the plastic manufacturing industry from £30 billion to £100 billion by 2025 through self-reliant and efficient manufacturing processes. The plastic sector is one of the biggest employment generators in India.[47]

The Indian plastics industry produces and exports a wide range of products and raw materials, such as plastic-moulded extruded goods, polyester films, moulded/soft luggage items, writing instruments, plastic woven sacks and bags, polyvinyl chloride (PVC), packaging, consumer goods, sanitary fittings, electrical accessories, laboratory/medical/surgical ware, tarpaulins, laminates, fishnets and travel ware. The industry is supported by many polymer producers, plastic process machinery, and mould manufacturers. One of the industry's major strengths is the domestic availability of raw materials such as polypropylene, high-density polyethylene, low-density polyethylene, and PVC.[48]

India's Department of Chemicals and Petrochemicals has approved ten plastic parks that will focus on resource-efficient manufacturing of plastic. These plastic parks are located in the Indian States of Tamil Nadu, Karnataka, Odisha, Jharkhand, Chhattisgarh, Uttarakhand, Uttar Pradesh, Assam, and Madhya Pradesh (two parks).[49]

Generation of Plastic Waste

The exponential increase in plastic waste will impact human health, biodiversity, climate, and the global economy. Globally, plastic waste accounts for at least 85 per cent of total marine litter. Approximately 11 MT of plastic waste ends up in oceans. This volume is expected to double by 2030 and triple by 2040. The COVID-19 pandemic has also increased the use of disposable packaging. In 2015, GHG emissions from plastics were 1.7 gigatonnes of CO2 equivalent (GtCO2e). By 2050, GHG emissions from plastic production, along with the use and disposal of plastic, would account for 15 per cent (approx 6.5 GtCO2e) of the global carbon budget, which can limit temperature rise to 1.5 °C.[50]

Globally, India is the fifth largest generator of plastic waste[51]. According to the Central Pollution Control Board, India generated approximately 3.5 MT of plastic waste in 2020. The per capita plastic waste generation doubled between 2016 and 2020. A very high percentage of this waste is not collected and is either burnt, lost, or dumped into landfills and waterways. Waste-to-energy plants and refuse-derived fuels can lead to high emissions. Products like single-use packaging, plastic resins, foamed plastic insulation, bottles, and containers, among many others, add to global GHG emissions. Most plastic cannot be recycled, only downgraded, and is often incinerated, or used as fuel in waste-to-energy plants, sometimes known as chemical recycling. These recycling processes also lead to GHG emissions.

Policy Landscape

At the fifth session of the United Nations Environment Assembly held on 2 March 2022 in Nairobi, 175 nations, including India, endorsed a landmark agreement to address the full lifecycle of plastic from source to sea and forge an international legally binding agreement by 2024.[52,53] One of the objectives of this historic resolution signed by parties to the United Nations Environment Assembly is to eliminate single-use plastic and achieve a new circular economy. Globally, around 44 leading financial institutions, 19 converters and producers, 26 brand owners, 10 retailers, 16 waste management organisations, and 28 other companies have signed a manifesto calling for a global treaty on plastic pollution. The resolution will steer stakeholders towards the adoption of diverse alternatives across the lifecycle of plastics, the design of reusable and recyclable products and materials, and the promotion of technology partnerships, research, and innovation.

India has decided to ban single-use plastic from 1 July 2022. It has notified rules for the sustainable management of plastic for producers and brand owners of plastic materials. India is implementing measures to tackle the plastic menace through extended producer responsibility for plastic packing.

India's Plastic Waste Management Rules 2018 mandates all plastic manufacturing/recycling units must be registered with State Pollution Control Boards.

According to the Material Recycling Association (MRAI), India's recycling rate stands at 30 per cent. Data associated with this recycling rate is largely dominated by highly recyclable materials such as ferrous and non-ferrous scrap, paper, rubber, and tyre.[54] The recycling of plastics in India is mostly handled by the informal sector. As per the Central Pollution Control Board, there are 896 registered plastic recyclers.

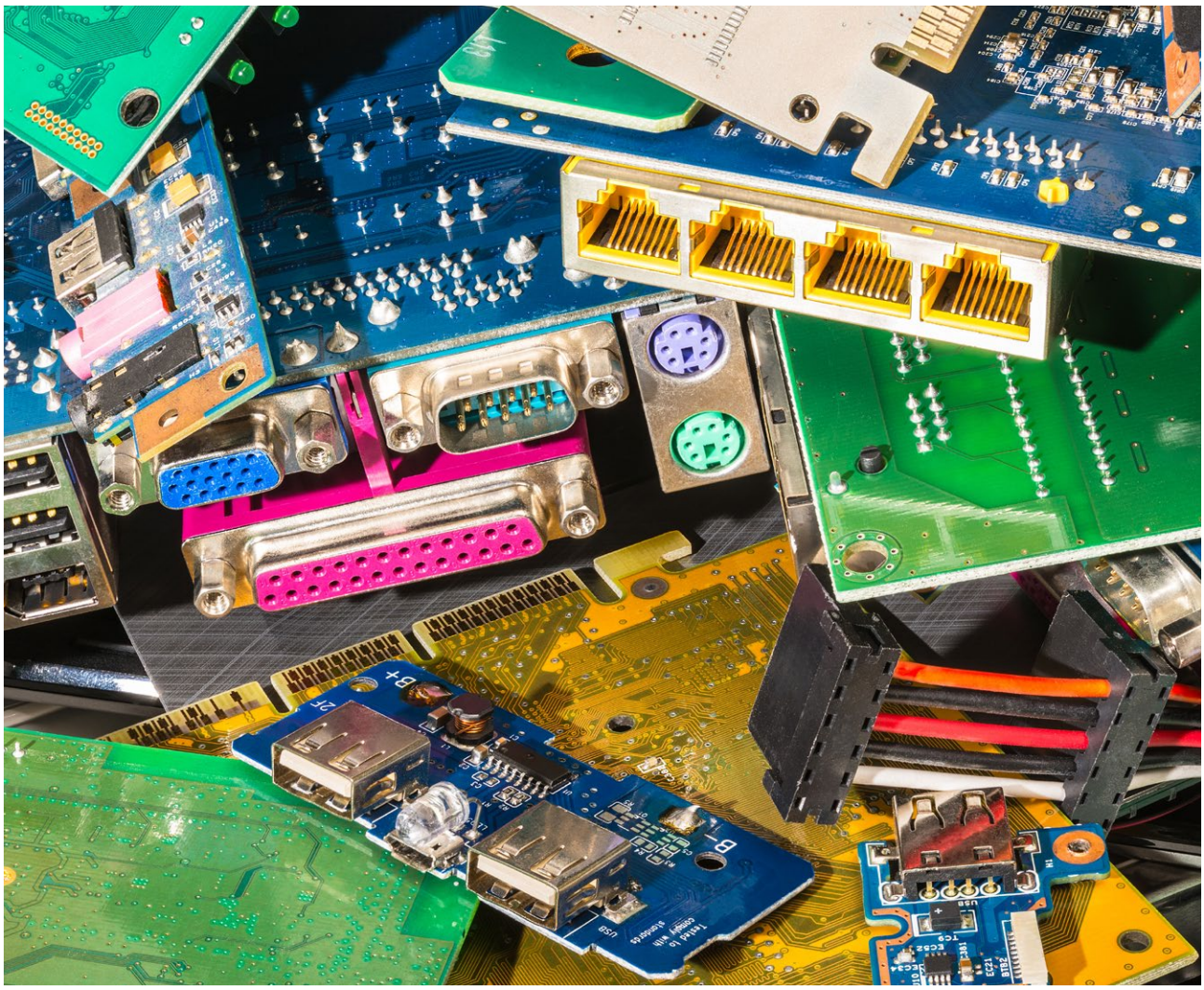
Research and Innovation Ecosystem

Financial risk for businesses to manage plastic waste will increase substantially as governments impose stringent curbs involving the transformation of the whole plastic value chain. A shift to the circular economy can be expected to reduce the volume of plastic waste ending up in oceans by more than 80 per cent by 2040. The sustainable approach can reduce the production of virgin plastic by 55 per cent and save nations £53 billion by 2040. It has a huge potential for reducing GHG emissions and creating new green jobs.

Some of the key innovation activities and stakeholders involved are:

- Circulate Capital and Closed Loop Partners are raising capital to support investments in sustainable plastic management and a circular economy. They are backed by multinationals such as Unilever, Procter & Gamble, and Coca-Cola. Circulate Capital invested £31 million in seven companies in India and Indonesia in 2020, with more to come.
- One of India's biggest diversified conglomerates, ITC, has collaborated with Invest India (the central government agency that promotes domestic investment) to crowdsource innovative ideas which can replace single-use plastic and automate waste segregation. This innovation challenge is expected to support start-up ideas on sustainable packaging. ITC's objective is to phase out single-use plastic by 2022.

- To bolster the entire polyester and polymer value chain and move towards the circular economy, Reliance Industries is doubling its PET recycling capacity by setting up a recycled polyester staple fibre (PSF) manufacturing facility in Andhra Pradesh. In 2021, it partnered with Srichakra Ecotex India to build and operate the new recycled PSF Recron GreenGold and PET flakes wash-line. PET bottles are collected before they reach and pollute the oceans to make R|Elan GreenGold Ecocean fabric. The method involves cleaning, crushing, and converting PET bottles into flakes before they are washed and converted into high-quality fibres, yarns, and fabrics. Reliance Industries converts more than two billion post-consumer PET bottles into fibres annually. With the addition of the new capacity in Andhra Pradesh, Reliance Industries will be instrumental in converting about five billion used PET bottles into value-added fibres.[55]
- Lucro, an Indian recycling start-up, has partnered with Dow to develop and manufacture film structures by employing a Plast-E-Cycle process (that converts plastic waste into granules) in combination with Dow's virgin resins to reduce plastic waste.[56]
- IIT Bombay has developed plastic-like film for the packaging industry that can degrade into hazardless components. It is made from a combination of non-toxic, edible sugar-based, or fat-based biopolymers, which are capable of degrading in about a week to a month. Biodegradable barrier films made from PLA (polylactic acid) are derived from a renewable monomer found in corn starch, tapioca roots, and sugarcane. It is also cost-effective, making it a better alternative for high-density polyethylene.[57]



- Hi-Tech International is working on a plant-based polymer called Dr Bio which can replace single-use and multi-use plastic bottles, cups, straws, disposable cutlery, and poly bags with bio-compostable plastic. Different blends of biomass materials are used for different applications employing corn starch, lactic acid, PLA, and earth minerals for better tensile strength.[58]
- IndianOil is supporting a start-up, Sustainable Green Initiative Foundation, to develop a prototype of pavement blocks from plastic waste. IndianOil signed an MoU in November 2020 with NextChem, a subsidiary of Maire Tecnimont of Italy, to use green chemistries and technologies to foster a circular economy.[59]
- Procter & Gamble India, the leading personal care and hygiene products manufacturer, became a plastic waste-neutral company in 2021-22 and has recycled 100 per cent of post-consumer plastic packaging waste.
- The UK has partnered with India to deliver a circular plastics economy. India has become the first Asian country to develop a plastics pact, launching a ground-breaking new initiative to bring together leading businesses at a national level to commit to building a circular system for plastics. The India Plastics Pact (IPP) was launched in September 2021 as a collaboration between the World Wide Fund India and the Confederation of Indian Industry. The pact is supported by UKRI and WRAP (Waste & Resources Action Programme) and endorsed by the British High Commission in India. In Autumn 2020, UKRI committed £250,000 of funding to enable WRAP to establish the IPP, engage GoI and develop the appropriate targets and priority workstreams for India.[60]

Potential Areas for Collaboration

- Innovation in recycling aliphatic polyesters – PLA, a polymer that provides unique bioplastics.
- Reusable packaging system and compostable plastics for food packaging.
- Recycling technologies for single-use plastic in consumer products.
- Recycling technologies of plastic waste into chemical feedstock to be used by the petrochemical industry.
- Circular model of replacing existing plastic waste with sustainable raw materials in various industries.
- Sustainable chemical recycling of mixed plastic waste.

Construction and Cement

Introduction

India's construction sector was the second largest FDI recipient in 2020-21. It is the second-largest employer in India. The real estate industry in India is expected to reach £767 billion by 2030 and contribute 13 per cent to India's GDP.[61] India is expected to become the world's third-largest construction market by 2022. According to the India Brand Equity Foundation, India needs investment to the tune of £596 billion in the infrastructure sector for sustainable development. GoI's schemes, such as Smart City Mission[62] and AMRUT[63] are expected to provide further impetus to the sector.

The building sector accounted for emissions of more than ten gigatonnes, which was one-third of energy-related global carbon emissions in 2019.[64] Emissions from the sector showed a decline during the COVID-19 pandemic but are increasing as the economy shows signs of recovery. Globally, for nations to meet Paris Agreement goals[65] and achieve net zero targets by 2050, emissions from the building sector need to be reduced by half by 2030.[66] India's emissions from the building sector accounted for one-fifth of the country's total annual carbon emissions. According to the UN report, 2021 Global Status Report for Buildings and Construction, the building stock in Asia and Africa is expected to double over the next three decades, and the use of materials globally is set to more than double by 2060, with construction materials accounting for a third of that increase.[67]

The built environment sector across the world still operates mostly in a linear way. Voluntary action to redesign the building approach and make a transition toward the circular economy is gaining momentum. Green investments in the built environment sector can contribute to profitability and sustainability. Demand for green buildings in India is gradually rising, supported by national and sub-national policies. India is one of the largest and fastest-growing markets for green buildings around the world. According to the United States Green Building Council (USGBC), India ranks third globally when it comes to green buildings, only behind China and Canada. And as per their ranking on green building footprint, Maharashtra tops the list, amongst the Indian States, followed by Karnataka, Haryana, Tamil Nadu, and Uttar Pradesh. The Indian Green Building Council[68] expects to increase the country's green built-up space from 7.17 billion square feet in 2021 to 10 billion square feet by 2023.[69]

Addressing resource efficiency in building materials is fundamental to accelerating the pace of growth of green buildings in India. Cement is one of the most widely used building materials and contributes around 8 per cent of global carbon emissions. The cement industry is one of the fastest-growing industries in the world.[70] The Indian cement sector is the second largest in the world. Some of the leading players in the cement sector, such as UltraTech Cement and Dalmia Cement, are signing up for net zero commitments.[71,72] They are adopting the circular economy approach by recycling concrete waste to produce green cement, integrating renewable energy in plants, using cleaner fuel in logistics, and switching to sustainable manufacturing practices.

Progressive players are also adopting a cross-sectoral collaboration approach through circular supply chain management, where wastes and byproducts from other industrial sectors are being recycled to

replace natural materials needed for construction. Innovation in recycling construction and demolition wastes plays a major role in supporting circular economy strategy in the cement and construction sectors. These resource efficiency measures can substantially reduce carbon emissions and prevent large volumes of waste from reaching landfills.

Policy Landscape

The Construction & Demolition Waste Management Rules, 2016, from the MoEFCC, highlight the responsibilities of the generators of construction and demolition waste, such as building materials, debris, rubble waste resulting from construction, remodelling, and repair and demolition of any civil structure. It also mandates guidelines for processing and recycling facilities for construction and demolition (C&D) waste.[73]

Initiative to Promote Habitat Energy Efficiency: Following the launch of Mission Innovation, the Indian Department of Science and Technology announced the new Initiative to Promote Habitat Energy Efficiency (I-PHEE), originally launched in July 2016,[74] focusing on promoting R&D activities to improve the energy efficiency of buildings and cities. The initiative aims to enhance knowledge and introduce innovative solutions to reduce energy consumption in the design, construction, and operation of human habitats. The programme supports specific outcome-based research in energy-efficient building envelope technologies, low-energy cooling systems, day-lighting, electric lighting, and building automation and controls for energy savings.

The Guidelines on Environmental Management of Construction & Demolition Wastes issued by the Central Pollution Control Board and the IS 383: Coarse and Fine Aggregate for Concrete – Specification, 2016, standard, issued by the Bureau of India Standards encourage resource efficiency in the C&D sector.

Several state and city governments have issued advisories to departments and urban local bodies to use recycled C&D waste in building and road works.

Research and Innovation Ecosystem

Globally, the building and construction sector consumes 36 per cent of energy and produces 40 per cent of waste and approximately 40 per cent of carbon dioxide emissions (Global Alliance for Buildings and Construction 2017). The construction industry is also one of the largest consumers of raw materials. With unprecedented growth in real estate and infrastructure projects, the volume of construction and demolition waste is increasing manifold. However, less than one-third of construction and demolition waste is recycled or re-used.

According to the Building Material Promotion Council, an estimated 150 MT of C&D waste is generated every year in India, but only one per cent is recycled.[75]

Some key stakeholders and their innovations are mentioned below:

UK company CDE Asia uses a patented technology to process C&D waste in India and recover high-quality M-sand, which can be used in a range of construction applications. The C&D waste recycling solution from CDE Asia ensures that the demand for sand and aggregates is satisfied from a sustainable source. This transformational technology helps to create a circular loop. CDE Asia's compact plant is energy efficient and recycles up to 95 per cent water. CDE Asia is a global leader in product innovation.[76]

At COP 26, Dalmia Cement (Bharat), a leading cement company in India, highlighted the importance of progressive cement companies in creating a roadmap for carbon pricing. Dalmia Cement has one of the lowest carbon footprints globally and has set an ambitious target to become carbon negative by 2040. It is one of the first cement companies to sign up to the global platform of The Climate Group – RE 100 (Renewable 100 per cent), EP 100, and EV 100 – thereby committing to resource efficiency across its manufacturing process, while also enhancing profitability.[77] The President of Dalmia Cement, Mr Mahendra Singhi, met COP 26 President, Mr Alok Sharma, during the latter's visit to India in 2021 and raised the importance of the reduction of carbon footprint and adoption of a circular economy by the cement sector. Dalmia Cement has announced its collaboration with UK company Carbon Clean Solutions to build a large-scale carbon capture facility at its cement plant in Tamil Nadu.[78]

In December 2019, Infosys became the first Indian company to receive the prestigious United Nations Global Climate Action Award in the Climate Neutral Now category at COP 25 in Madrid, Spain. Infosys is one of the first companies of its kind to commit to carbon neutrality. They have provided a circular model for climate action while setting a benchmark for integrating sustainable development and climate action. Infosys is in the process of building new energy-efficient buildings and upgrading its existing buildings toward transitioning to 100 per cent renewable energy. It has placed an internal price on carbon against which it assesses all projects and investments and runs an offset programme that works with communities to reduce emissions and contribute to sustainable development. All emissions are tracked using software applications and audited by a third-party verifier. Infosys' approach to achieving carbon neutrality is based on three pillars: reducing energy consumption through energy efficiency, transitioning to renewable energy, and offsetting emissions beyond its control. Infosys also promotes sustainable practices amongst its employees and vendors to reduce their carbon footprints (UNFCCC, 2019). [79]

Over 2,500 building products and materials manufactured by more than 150 leading manufacturers have achieved the GreenPro Ecolabel launched by the Indian Green Building Council (IGBC) under the guidance of the Confederation of Indian Industry (CII). The Ecolabel facilitates building products and material manufacturers to embrace green concepts. The CII and Government e-Market Place (GeM) are working together to facilitate the implementation of sustainable public procurement. GreenPro Ecolabelled products and materials enhance the performance of green buildings in terms of resource efficiency, indoor environment quality, and occupants' comfort, health, and wellbeing. These green products can cater to more than 90 per cent of the cost of construction and are available in the market at competitive prices when compared to conventional products.

Cost-effective plastic-embedded lightweight, sustainable bricks are manufactured by a start-up, Zerund Bricks, using fly-ash from thermal power plants, waste plastic, cement, etc. About 70 per cent of the bricks contain waste material that is manufactured using electrical machines instead of fired kilns. These are 10 per cent lighter and provide 10-12 per cent more thermal insulation than conventional bricks.

3D printing of bricks by using fly-ash, concrete, and plastic and manufacturing metal hybrid bricks by powder bonding and extrusion can be a sustainable solution to reducing material loss. Tvasta Manufacturing Solutions, a start-up by alumni of IIT Madras, is working on such 3D printed building materials, making India's first 3D printed house.

Opportunities for Collaboration

- Innovations in repurposing materials and equipment.
- Smart modular designing strategies that reduce carbon footprint and reduce waste.
- Digitisation and streamlining of construction equipment rental processes.
- Robotics to automate the manual sorting of construction waste e.g. asphalt, aluminium, concrete, stone.
- Low-temperature waste heat recovery in cement manufacturing units.
- Artificial intelligence and blockchain in the recycling sector.
- Technologies in areas such as scrap and slag utilisation.
- Metal recycling from e-waste and making products from C&D waste.
- Material efficiency to reduce the clinker-cement ratio.
- Carbon capture utilisation and storage in the cement sector to address emissions from limestone calcination.
- Alternative binding materials to reduce emissions from cement.

Electrical and Electronics Sector

Introduction

Electronics system design and manufacturing (ESDM) is the world's fastest-growing industry, with disruptive design technologies and innovation shaping and transforming the nation's social and economic pillars. The global electronic devices market was valued at £893 billion in 2020 and is expected to reach £1,239 billion in 2025 and £1,626 billion by 2030[80]. The Indian electronics manufacturing industry is projected to reach £399 billion by 2025. In the Union Budget 2021-22, the Ministry of Electronics and Information Technology (MeitY) has been allocated INR 97.2 billion (£972 million). In the allocated budget, revenue expenditure allocation is Rs. 9,274.66 crore (£927 million), and capital expenditure allocation is INR 4.46 billion (£44.6 million) for the sector.[81]

The GoI aims to generate £767 billion of economic value from the digital economy by 2025. The unprecedented growth of the sector has resulted in the generation of large volumes of e-waste, which causes severe health and environmental issues. In 2019, globally consumers discarded 53.6 MT worth of electronics, of which only 17.4 per cent was recycled sustainably. COVID-19 has driven the usage of electronics which means that the quantum of e-waste generated will only increase.

Approximately, 33 billion LiBs are used worldwide. A battery used in an electric vehicle can often contain as much lithium as 1,000 smartphones. The cathode material contains a variety of valuable and scarce metals, such as nickel (Ni), cobalt (Co), manganese (Mn), and lithium (Li). Recovering cobalt and lithium from end-of-life LiBs will contribute toward resource efficiency and the circular economy, reduce dependence on the import of these raw materials, reduce carbon emissions, and have a positive impact on the environment.[83]

According to MeitY's Annual Report 2020-21[84], India generated 3.2 MT of e-waste of which only 10 per cent was formally collected and recycled in 2019. India is the third-largest producer of e-waste after China and the United States. The informal dismantling and recycling units use crude ways (such as open-air burning) to extract and recover high-value materials resulting in health hazards and environmental damage.

Policy Landscape to Manage E-Waste

Resource efficiency strategy for the electrical and electronics sector is primarily focused on utilising secondary materials from end-of-life equipment and channelling the recovered materials into the production process. This is encouraged in India by the following policies and regulatory frameworks.

The E-waste Management Rules introduced by India in 2016 have mandated collection targets and extended producer responsibility (EPR). The targets were relaxed in 2018. The EPR also encourages manufacturers to adopt sustainable methods.

The draft NREP 2019 has identified key areas for promoting a circular economy. Some of these are:

- Formalisation, integration, and capacity building of the informal sector across the value chain while ensuring the protection of health and safety.
- Setting up the infrastructure for the collection of e-waste through local bodies.
- Introduce standardisation for the reuse and refurbishment of electronic products.
- Support R&D for efficient recycling of e-waste.
- Develop business models that can lead to a proliferation of recycling technologies.

Research and Innovation Ecosystem

Several innovation activities are taking place in this space. The start up sector in India is playing a catalytic role in introducing innovation and bringing about a circular economy in e-waste management. Some of the key activities, stakeholders, and case studies are mentioned below:

The MeitY introduced the Green Electronics for Sustainable Future Programme (GREENE) in March 2015 to generate awareness across various sectors to reduce the adverse impact on the environment and health arising from the polluting technologies used in recycling e-waste by the unorganised sector.[85] It also aims to bring together government and industries to encourage the adoption of sustainable measures in the manufacturing and use of electronics. MeitY has introduced a Centre of Excellence on E-waste Management, C-MET, to promote a self-sustaining ecosystem by boosting innovation, encouraging entrepreneurship, and building capacity.[86]

Opportunities for Collaboration

C-MET specialises in the recycling of printed circuit boards (PCB), LiBs, permanent magnets and solar cells. It acts as a knowledge hub and incubation centre for the development of affordable technologies for e-waste recycling to create a circular economy so that e-waste is safely dismantled, precious metals are recovered, process efficiency is enhanced, and end-of-life devices are safely disposed of. Some of the priorities are:

- Addressing the need to design and automate process equipment for environment-friendly recycling of PCBs.
- Separation of rare earth oxides from spent phosphorous, extracting Neodymium, Dysprosium and Praseodymium from discarded permanent magnets (used in wind turbines, electronic devices and electric drives) using hydrometallurgical processes.
- Recycling of spent photovoltaic systems to develop commercially sustainable recycling of silicon solar modules to recover both toxic and valuable materials to encourage circular economy in the solar energy sector.
- Refurbishing of e-scrap.
- Building capacity to empower the Indian electronics and electrical industries on the E-waste Management Rule (2016) through the RoHS (Restriction of Hazardous Substances) facility available at C-MET.[87]

Organisations are collaborating to innovate on recycling technologies for e-waste. Below are some of the examples:

- The Bhaba Atomic Research Centre (BARC), in collaboration with AGNii (Accelerating Growth of New India's Innovations Initiative) of the Prime Minister's Science, Technology and Innovation Advisory Council (PM-STIAC), offers technologies ranging from the recycling of rare earths from Nd-Fd-B (magnetic scrap) to novel separation techniques for Dysprosium (Dy) separation from Nd-Pr-Dy product obtained from magnetic scrap recycling, and other solutions such as the process for removal of mercury, and recovery of rare earth (Y, Eu, Tb) from end-of-life CFLs, production of Neodymium metal using metallothermicreduction technique, and Lanthanum, Praseodymium, and Cerium metal technologies. [88]
- Cerebra IT Technologies is emerging as one of India's top e-waste management start-ups. Cerebra IT assists companies and organisations in reducing waste production at source, as well as helping to reuse and recycle later. Its state-of-the-art facility provides several e-waste management services. This ranges from segregating and salvaging electronic parts to data destruction services that prevent any kind of data theft even after the disposal of the device. The start-up specialises in the socially responsible and environmentally safe disposal and dismantling of e-waste. All the waste sent to the company is 100 per cent recycled into three parts – metals, glass, and plastic – without any further disposal in landfill.[89]
- In November 2021, tech giant Xiaomi India partnered with waste management organisation, Saahas Zero Waste, to extend its support to an e-waste awareness drive, an initiative by the Karnataka State Pollution Control Board (KSPCB). KSPCB, along with Saahas, Xiaomi, and other brands, aims to spread awareness across all 31 districts of Karnataka, covering approximately five million citizens. The initiative includes developing awareness, managing the collection of e-waste, and channelling the same for recycling to authorised recyclers.[90]
- Popularly known as India's first e-waste recycler, E-Parisaraa in Karnataka has introduced a wide range of innovative and cost-effective recycling services.

C-MET Centre of Excellence on E-Waste

- Technology to extract rare earth elements from strong magnets used in wind turbines.
- Technology for recycling precious metals from PCBs and scaling up the capacity of process technology.
- Cost-effective recycling technologies to extract valuable materials such as lithium, nickel, and cobalt from LiBs used in electric vehicles, grid storage applications, mobiles, and other electronic devices.
- Innovation in hydrometallurgical and pyrometallurgical processes for recycling of LiBs.
- Recovery of the platinum group of metals from spent automotive catalysts.
- Recovery of precious metals from industrial waste streams.
- Smelters for complex and heterogeneous metallurgical and e-waste.
- Digital innovations to connect the stakeholders such as waste generators, collectors, processers, and recyclers to enhance geographical reach, enable full transparency and traceability of transactions, and offer automated compliance of EPR.

Steel

Introduction

India is the second largest producer of crude steel in the world. The steel industry enjoys the dual advantages of having access to high-grade iron ore and coal reserves, and a large domestic market. India's crude steel production rose by nearly 18 per cent to 118 MT in 2021, according to the World Steel Association. The public sector contributes about 20 per cent of production.

Presently steel contributes about 2 per cent to India's Gross Domestic Product (GDP) and employs some 600,000 people directly and 20,000 people indirectly. However, India's per capita steel consumption is much below the global average but rising continuously. The per capita steel consumption is likely to increase from around 74 kg to 160-180 kg by 2030-31.

Steelmaking in India follows two routes: 1) Blast Furnace-Basic Oxygen Furnace (BF-BOF) route, also known as the primary sector, comprising around 45 per cent of the country's steelmaking capacity, and 2) Electric Arc Furnace and/or Induction Furnace route, also known as the secondary steelmaking sector, accounting for the remaining 55 per cent of India's steel production capacity.

Policy Landscape

Production projection for 2030: The National Steel Policy 2017 (NSP-2017) addresses the needs of the continuously growing domestic demand for steel and ensures sustainable development of the Indian steel sector. This steel production capacity is expected to reach about 300 MT per annum by 2030-31.

The steel industry is covered by the Environment Protection Act and Environment Protection Rules and Regulations introduced by the Ministry of Environment, Forests, and Climate Change to address air, water, noise, and waste pollution. The industry is both energy and emission-intensive. Steel production has several impacts on the environment, including air emissions (CO, CO2, SOx, NOx, PM2.5, and PM10), wastewater release, and generation of solid and hazardous wastes. The major environmental impacts in integrated steel mills are from the coking and iron-making sections. According to the Steel Authority of India (SAIL), the industry accounts for about 6-7 per cent of the total GHG emissions in India. On average, a steel plant with an annual production capacity of 10 MT emits about 20-22 MT of carbon dioxide.

Research and Innovation Ecosystem

Steel products have high recyclability potential. According to Arcelor-Mittal, 85-90 per cent of steel products can be recovered at their end-of-life and recycled to produce new steel. There are huge reserves of obsolete steel scrap, which, if harnessed properly, will considerably enhance the growth of steel manufacturing through the Electric Arc Furnace and/or Induction Furnace route (secondary sector). However, due to the lack of an organised mechanism, India is forced to import nearly 6-7 MTPA of steel scrap, which leads to the drainage of large amounts of foreign exchange. Recycling 1 tonne of steel scrap saves 1.1 tonnes of iron ore, 0.6-0.7 tonne of coking coal, and around 0.2-0.3 tonne of fluxes. In addition, it leads to savings in energy of 16-17 per cent and reduces water consumption and GHG emission by 40 per cent and 58 per cent, respectively. Thus, using steel scrap in steelmaking enhances the sustainability of the steel sector and results in significant conservation of natural resources.

A Few Case Studies in the Indian Steel Sector

- Tata Steel is investing heavily in the circular economy. It intends to achieve 100 per cent solid waste utilisation at its Jamshedpur Steel Works based on the foundations of reducing, reusing, and recycling waste. It is exploring the continuous injection of coal-bed methane gas at one of the Jamshedpur blast furnaces to reduce emissions. It has cut the use of coking coal in steel production by more than 100kg/t over the last few years. The use of carbon capture utilisation and storage with blast furnaces, upgrading the quality of raw materials, and using more scrap in steel production will lower the carbon footprint significantly. India's first carbon capture plant for a blast furnace has been successfully designed and commissioned for Tata Steel by the UK's Carbon Clean, a leader in cost-effective carbon dioxide capture and separation technology. Carbon Clean's technology is being demonstrated at Tata Steel's Jamshedpur steel plant in India, capturing 5 tonnes of CO2 per day. The modular skid-mounted unit captures CO2 directly from the blast furnace gas and makes it

available for onsite reuse in a variety of applications. The depleted CO2 gas is then sent back to the gas network with an increased calorific value. Tata Steel has utilised LD slag, a byproduct of steel production, for road construction and is supplying granules to several cement manufacturers.[92]

- India is working on green hydrogen as a fuel for reducing coal dependency in steel plants. Green hydrogen obtained from the splitting of water using solar and wind power offers cleaner alternatives for steel production. This can potentially reduce coking coal imports which contribute to a significant carbon footprint. JSW Energy is partnering with Australia-based Fortescue Future Industries on green hydrogen for steelmaking, green ammonia, and hydrogen mobility.
- A CoE on Industry 4.0 by Software Technology Parks of India (STPI) in Vizag Steel Plant will be one of the first 3D labs in the steel sector with participation from 12 leading technology players. It would involve disruptive technologies that include industrial Internet of Things, horizontal and vertical system integration, additive manufacturing involving 3D printing technology, augmented reality, autonomous robotics, cybersecurity, and big data and analytics.

Potential Areas for Collaboration

- Technologies for green manufacturing at the equipment level (coke oven, blast furnace iron making, sintering).
- Desulphurisation of coke oven gas, blast furnace top gas pressure recovery.
- Efficient steel scrapping.
- Green hydrogen in manufacturing green steel.
- Innovation in other uses of byproduct slag.
- Decarbonising technologies for carbon-neutral manufacturing of steel.
- Capturing carbon-rich waste gas from blast furnaces and converting the waste gas into recycled carbon chemicals.
- Innovation in low-temperature waste heat recovery technology.
- Reduction in use of water per tonne of steel production.

Green Hydrogen

Introduction

Green hydrogen is emerging as a game-changer in decarbonising economies and contributing to the circular economy. Electrolysers use electricity to split water into hydrogen and oxygen. It is a leading technology for synthesising zero-carbon hydrogen fuel using renewable energy such as solar and wind. It provides great opportunities for decarbonisation in different sectors, such as steel, refineries, fertilisers, transport, shipping, and aviation. Green hydrogen can help companies and countries in meeting their net-zero targets.

GoI welcomes partnerships with international funding agencies, industries, and governments to support large-scale hubs to build a green hydrogen economy and create domestic supply chains. NITI Aayog stated in March 2022 that the government aims to reduce the cost of green hydrogen to £1.92/kg by 2025 and £0.77/kg by 2030. This can be ensured by scaling up hydrogen manufacturing and taking advantage of India's rapidly declining costs of renewable energy.

Voluntary initiatives to scale-up hydrogen production by collaborating with international agencies are gaining momentum. For example, the India Hydrogen Alliance (IH2A) is an industry-led coalition of global and Indian companies committed to the creation of a hydrogen value chain and economy in India. IH2A works with private sector partners, the government, and the public to ensure that costs of hydrogen production are brought down, and a local supply chain for hydrogen and demand is created in the industrial, power, and transport sectors. Lead members include Reliance Industries, JSW Steel and Chart Industries.

IH2A estimates that India will need investments of about £19.17 billion from the public and private sectors to create a domestic green hydrogen supply chain with a national installed electrolyser capacity of 25 GW producing 5 MT of green hydrogen by 2030.

Policy Landscape

National Hydrogen Energy Mission 2021

The Indian Prime Minister launched the National Hydrogen Energy Mission on 15 August 2021 to make India a green hydrogen hub. The mission has a target of producing 5 MT of green hydrogen by 2030 and building a supportive renewable energy capacity to facilitate the transition from fossil fuel to green hydrogen and green ammonia and meet India's commitments to renewable energy. About £80 million is expected to be invested over the next three years for infrastructure development and R&D on green hydrogen generation.

In line with the National Hydrogen Mission, India's Long Term Low Emission Development Strategy, presented at the COP27, mentioned that India will work on the rapid expansion of green hydrogen production and increase electrolyser manufacturing capacity in the country.[94]

The key policy highlights are: [95]

- Green hydrogen/ammonia manufacturers may purchase renewable power from the power exchange or set up renewable energy capacity themselves or through any other developer anywhere, and open access will be granted within 15 days of receipt of application.
- Distribution licensees can also procure and supply renewable energy to the manufacturers of green hydrogen/green ammonia in their states at concessional prices, which will only include the cost of procurement, wheeling charges, and a small margin as determined by the respective State Commission.
- Waiver of inter-state transmission charges for 25 years will be allowed to the manufacturers of green hydrogen and green ammonia for the projects commissioned before 30 June 2025.
- The manufacturers of green hydrogen/green ammonia and the renewable energy plant shall be given connectivity to the grid on a priority basis to avoid any procedural delays.
- The benefit of renewable purchase obligation (RPO) will be granted as an incentive to the green hydrogen/green ammonia manufacturer and the distribution licensee for the consumption of renewable power.
- To ensure ease of doing business, a single portal for carrying out all the activities, including statutory clearances in a time-bound manner, will be set up by the Ministry of New and Renewable Energy (MNRE).
- Connectivity, at the generation end and the green hydrogen/green ammonia manufacturing end, to

the ISTS for renewable energy capacity set up for manufacturing green hydrogen/green ammonia shall be granted on priority.
- Manufacturers of green hydrogen/green ammonia shall be allowed to set up bunkers near ports for storage of green ammonia for exports/use by the shipping sector. The land shall be provided by the respective port authorities at applicable charges.

Commercialising Green Hydrogen and Proposed Creation of Public–Private H2Bharat Taskforce for National Hydrogen Hubs

On 3 March 2022, NITI Aayog recommended seven steps to commercialise green hydrogen at scale in India with global funding agencies, industry, and government bodies. These recommendations were made at a workshop, along with the industry body India Hydrogen Alliance (IH2A), attended by the European Investment Bank (EIB), the World Bank, the Organisation for Economic Co-operation and Development (OECD), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), CDC, the Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden NV(FMO), GoI, the government of Kerala and industry players from across the hydrogen value chain.

The seven recommended steps from the NITI Aayog-IH2A workshop are:

1. India to replicate the global best practice of GW-scale green hydrogen hubs with co-located green hydrogen production and consumption, across different use cases, in a single regional cluster or hub, to commercialise green hydrogen.
2. The first green hydrogen hubs to be designated national projects or Special Projects of National Importance and be supported with special incentives and public funding.
3. Formation of public-private consortiums for the development of national green hydrogen hubs and project clusters to pool public and private resources and de-risk early project development.
4. Sovereign green bonds and global climate finance commitments can provide the necessary funding for GW-scale green hydrogen hubs in India. Multilateral and government agencies can play a catalysing role in early market development by part-funding design and pre-feasibility studies for the national hubs.
5. India needs a pipeline of national hydrogen hubs that can be evaluated before public and low-cost funding can be extended to them. Funding agencies are keen to see the synergies across the green hydrogen value chain in project plans rather than standalone green hydrogen projects.
6. Pre-feasibility studies for the first set of GW-scale green hydrogen hubs should start immediately, with at least five national green hydrogen hubs identified in the next 18 months.
7. Formation of a public-private H2Bharat commercialisation taskforce, with a focus on green hydrogen hub or cluster development, with the target to conduct pre-feasibility studies for the first five GW green hydrogen clusters/hubs in India in the next 12 months. The proposed task force is expected to bring down the cost of green hydrogen manufacturing.

A PLI scheme is being developed to support the indigenisation of electrolysers and target the establishment of 10 GW of domestic manufacturing capacity green hydrogen. Regulatory frameworks are being evaluated to make it mandatory for refineries to meet 10 per cent of their hydrogen demand through green hydrogen.

Research and Innovation Ecosystem

Transformational technologies to produce green hydrogen are being researched in India. Several businesses, including oil and gas players, steel industries, fertiliser industries, research institutions, and government, are playing a major role in advancing innovation on green hydrogen. Some key examples and leading stakeholders are mentioned below:

- IndianOil is pioneering the development of hydrogen technologies for refineries to use hydrogen as feedstock for petrochemical units. IndianOil has set up a pilot four-tonne/day compact reformer-based hydrogen-enriched compressed natural gas production plant in collaboration with the Delhi Transport Department. IndianOil is trialling 50 cluster buses of the Delhi Transport Department to run on hydrogen-based fuel. Hydrogen-enriched compressed natural gas is predicted to be one of the first steps to a hydrogen economy. In addition, the surplus hydrogen at IndianOil's Gujarat Refinery would serve dispensing facilities of fuel cell electric vehicles.
- IndianOil has signed a statement of intent (SoI) with the Norwegian company, Grenstat, for setting up a Centre of Excellence on Hydrogen (CoE-H), which includes hydrogen storage and fuel cell-related technology sharing, know-how, and experience. IndianOil's R&D Centre is also working on using concentrated solar power technology to generate electricity which can be used to produce hydrogen. IndianOil, in collaboration with IIT Kharagpur, is also developing and indigenising the Type-3 and Type-4 high-pressure hydrogen cylinder technology.
- India's engineering giant, Mumbai-headquartered Larsen & Toubro (L&T), signed an agreement with Norway's HydrogenPro to enter the green hydrogen business in January 2022. Under this agreement, L&T and HydrogenPro will work towards setting up a joint venture in India for gigawatt-scale manufacturing of alkaline water electrolysers based on HydrogenPro technology for the Indian market and other select geographies.[96]
- JSW Future Energy, part of power producer JSW Energy, has recently partnered with Australia-based Fortescue Future Industries (FFI) to explore green hydrogen development. Under their agreement, FFI and JSW Energy will collaborate and conduct scoping work on potential projects in green hydrogen production. They will also explore opportunities to use green hydrogen for steelmaking, hydrogen mobility, ammonia, and other mutually agreed industrial applications.[97]
- Adani Group and Canadian PEM (polymer electrolyte membrane) fuel cell producer Ballard Power Systems signed a memorandum of understanding in February 2022 to consider joint investment in the commercialisation of hydrogen fuel cells for the mobility sector and industrial applications. Under the agreement, the partners will examine various cooperative opportunities including fuel cell manufacture in India. Green hydrogen could be a logical move for Adani, given its experience in large-scale renewables and electricity transmission and distribution infrastructure. The group sees itself as well-positioned to become a big green hydrogen producer. Adani's efforts under the deal signed with Ballard will be led by the newly formed green hydrogen subsidiary, Adani New Industries, which is focused on the production of the energy carrier and downstream products, such as green electricity generation and the manufacture of electrolysers and wind turbines. Adani Group will deploy innovative use cases across its businesses with fuel cell trucks, mining equipment, marine vessels, off-road vehicles, and critical industrial power.[98]

- MNRE's Research Development and Demonstration programme on hydrogen energy and fuel provides support across industrial sectors in collaboration with research institutions to harness the production of hydrogen from renewable energy sources, ensure safe and efficient storage, and use in the transportation sector through fuel cells. Mahindra & Mahindra, Banaras Hindu University, and IIT Delhi have partnered to pilot vehicles that run on hydrogen fuel. Hydrogen refuelling stations are being set up by IndianOil R&D Centre, Faridabad, and the National Institute of Solar Energy, Gurugram.
- Fusion Fuel Green, with offices in Portugal and Ireland, has signed an agreement with BGR Energy Systems, an engineering procurement and construction company based in Chennai, to install green hydrogen production facilities in Tamil Nadu.[99]
- The Indian Railway's organisation for alternative fuels is exploring the development of hydrogen fuel cell-based hybrid powertrains for retrofitting 700 HP diesel-hydraulic locomotives running on the Kalka-Shimla narrow gauge section in Himachal Pradesh.[100]

Potential Areas for Collaboration

- Hydrogen production and electrolyser/fuel cell manufacturing.
- Hydrogen storage and application in heavy-duty vehicles and four-wheelers.
- Advanced electrolysis technologies.
- Application of hydrogen in green steel and storage.
- Development of offshore wind turbines to power electrolysers.

Biofuel

Introduction

Using biofuel to decarbonise various fossil-fuel-based/carbon-intensive industries is fast emerging as an area for sustainable manufacturing. According to the International Energy Agency (IEA), bio-energy accounts for approximately one-tenth of the total primary energy supply in the world today. India is an active member of Mission Innovation and the co-lead of three Innovation Challenges: Smart Grid, Off-Grid Access, and Sustainable Biofuels.[101] India has developed a roadmap to set up second-generation biorefineries.

Policy Landscape

The MNRE introduced the National Policy on Biofuels in 2018 primarily to reduce carbon emissions and lessen the country's dependency on imports in the oil and gas sector. This mandates a blending of biofuels (ethanol) of approximately 20 per cent in transport fuels and a five per cent blending of biodiesel in diesel by 2030. Several steps are being taken to broaden the feedstock base for biofuel production and drive R&D of new technologies to support this ambition.

The Indian Department of Biotechnology (DBT) has established five bioenergy centres to integrate basic and translational science capabilities for biofuel development and to scale production. The primary focus has been fermentation technology and enzymes for cellulosic ethanol, algal biofuel, and waste-to-energy conversion. Based on the encouraging results of these centres, demonstration scale technologies for cellulosic ethanol have been set up. Emphasis is also being given to the development of advanced biofuels such as bio-CNG, bio-methanol, bio-hydrogen, bio-jet fuel, and dimethyl ether derived from bio-methanol.

Research and Innovation Ecosystem

The DBT Bioenergy Centres are working with international bodies and oil companies in India on innovative biofuel technologies. Top oil and gas companies such as IndianOil and Reliance Industries are working with multiple stakeholders on advanced biofuel research. Some of the key activities are mentioned below.

International Centre for Genetic Engineering and Biotechnology

The biotechnology laboratories of the International Centre for Genetic Engineering and Biotechnology (ICGEB)[102] in Delhi are running several projects that could lead to the development of commercially viable technologies for producing biofuel and greener chemicals from biomass such as lignocellulosic material. Five groups in ICGEB develop technologies for the production of clean energy from biological sources. They isolate novel enzymes (cellulases, xylanases) with higher specificity towards cellulosic biomass and engineer bacteria with enzymes capable of producing biofuel. The groups also use metabolic engineering and synthetic biology approaches to produce high-density fuels and green chemicals. They are working on a project with the UK's University of York, in which lignocellulosic waste of sugarcane from a factory in India is treated through biotechnology to produce citric acid. The Yeast Biofuel Group of ICGEB aims to develop a cost-effective lignocellulosic material-based technology for fuels and chemical production.[103]

DBT-ICT Centre of Energy Biosciences in Mumbai: Collaboration with Joint BioEnergy Institute, USA and University of Nottingham, UK

Major areas of focus include cost-effective technology for bioethanol production from biomass, bio-refinery approach for selected biomass, and other biofuel technologies such as bio-diesel, bio-hydrogen, and bio-methane. The research at the centre covers synthetic biology, fermentation technologies, separation technologies, enzyme technology, and algal biotechnology. This centre has developed an economically viable and scalable technology for cellulosic ethanol from all types of

agricultural residues and energy crops. This technology has been successfully scaled up at 10TPD levels and is now building two large-scale commercial plants of 400TPD capacity. A state-of-the-art laboratory for algal biotechnology has been set up at the centre with a sunlit environmental chamber and raceway ponds of 1,000-litre and 5,000-litre capacities with novel designs as well as controlled photobioreactors, all equipped with microprocessor-based SCADA controlled systems. The centre has active collaborations with the Joint BioEnergy Institute, USA, and the University of Nottingham, UK. More information on DBT-ICT can be found at www.dbt-ceb.org.[104]

DBT-IOC Centre for Advanced Bio-Energy Research, Faridabad

GoI's DBT has set up this centre with the largest Indian petroleum company, IndianOil, in equal partnership. The main focus areas are lignocellulosic-based biofuels, algal research, gas fermentation, and lifecycle analysis. The centre has worked on the development of new and economical pre-treatment processes, feedstock selection/development and characterisation, process optimisation for saccharification/fermentation and scale-up, bio-assisted/chemical lignin de-polymerisation and lignin value addition, and commercial-scale enzyme development.

Based on the centre's R&D efforts, a 10TPD cellulosic ethanol plant is under construction. A pilot plant for waste gas fermentation has been established, and developed enzymes have been successfully scaled up to a 5000-litre fermentor. More information on DBT IOC can be found at www.dbtiocberc.org.[105]

Reliance Aviation is a leading supplier of aviation turbine fuel. Reliance is working on sustainable aviation fuel. This integration of biofuel with aviation fuel can contribute to cleaner skies, create new jobs, and catalyse resource efficiency.

IndianOil is setting up the world's first refinery of the gas-to-bioethanol production facility at Panipat, Haryana, with US company Lanza Tech. The team has developed a novel 2G enzyme to replace the imported options and enable the production of 2G ethanol from lignocellulosic biomass. A pilot plant of 10TPD is being constructed to showcase the technology. The company is planning to set up bio-refineries in Odisha and Chhattisgarh to convert rice stocks available with the Food Corporation of India to 1G ethanol and blend it with petrol.

Potential Areas for Collaboration

- Biofuel technologies for sustainable aviation fuel.
- Engineering algae to produce affordable, carbon-neutral biofuels.
- Biochemical, thermochemical, and electrochemical conversion technologies.

Financial Landscape

Mobilising clean growth and climate finance and forging technology partnerships are keys to enabling all economies to successfully transition to a circular economy-based development.

At the 11th Economic and Finance Dialogue (EFD) between India and the UK held on 2 September 2021, the Finance Ministers of India and the UK met to enhance cooperation on the flow of technology to address climate change and highlighted the shared vision of the two countries of economic growth, sustainability and investment. The UK welcomed a substantial package of public and private finance mobilisation which represented a major step forward: [106]

- Public finance: £756 million investment by British International Investment, formerly CDC Group, the UK's Development Finance Institution, into climate-related projects in India over 2022-2026. This builds on its £1.5 billion existing portfolios in India and its commitment to invest in businesses that mitigate and build resilience to the impact of climate change. In May 2021, the Central Board of Direct Taxation recognised CDC Group as a sovereign wealth fund, enabling it to receive the full benefits of investing in Indian infrastructure.
- Public finance attracting private finance: The Green Growth Equity Fund (GGEF) is scaling up with a new commitment of £151 million from a range of international investors. The GGEF was announced at the 9th EFD, with the governments of the UK and India investing £120 million of seed capital each, through India's National Investment and Infrastructure Fund (NIIF). It has since attracted additional public and private investment, demonstrating the attractiveness of India's green infrastructure projects, including renewables, energy storage, and electric mobility. It is on course to reach its target of £500 million by the year-end, making this the largest single-country emerging market climate fund in the world. GGEF's success reinforces the view that public finance participating in an investment fund that is designed to deliver commercial returns has a strong potential to attract private capital at scale.
- Public finance attracting private finance: Joint UK and Indian investments of up to £23 million in venture capital funds to support early-stage companies and start-ups to create innovative tech solutions at scale in majorly climate-related sectors such as clean energy, sustainable agriculture, and manufacturing. Investments will be made from the UK-India Fast Track Start-Up Fund and the Innovative Ventures and Technologies for Development (INVENT) programmes and will be channelled via the new UK-India Development Cooperation Fund, building on the UK-India Neev Fund, which has attracted an additional £130 million from institutional investors in projects addressing climate and development, including bioenergy, solar and wind energy.
- The Climate Finance Leadership Initiative (CFLI) India Partnership aims to work with financial institutions, corporates, and existing sustainable finance initiatives, to accelerate efforts to mobilise private capital into India. The partnership will be led by the CFLI, a group of leading financial institutions responsible for £4.75 trillion of assets, chaired by Michael Bloomberg, and supported by the UK government, the GoI, the Global Infrastructure Facility, and the City of London.
- The India-UK Global Innovation Partnership under the Trilateral Development Cooperation Framework, where India and the UK will co-finance a fund equally over 14 years to support the transfer and scale-up of climate-smart inclusive innovations from India to third countries and accelerate the delivery of SDGs and climate-related goals in recipient developing countries.

- The UK and India agree to continue working together to mobilise finance via multilateral and private means, and share relevant experience, including the UK's upcoming sovereign green bond issuance. This collaboration is facilitated by UK-India Sustainable Finance Forum. The work by the UK India Sustainable Finance Working Group, led by the City of London Corporation and Federation of Indian Chambers of Commerce and Industry, aims to scale the flow of finance to support India's ambitious SDGs. The group will amplify its efforts to provide advice and recommendations to green the financial system, including appropriate disclosures and taxonomy.
- The UK-India Infrastructure Partnership includes plans for the UK Infrastructure Projects Authority to provide technical expertise to support India's Centre of Excellence for Public-Private Partnerships. The UK and India will continue to work together to support India's National Infrastructure Pipeline, including raising investment via the City of London.

The Joint Statement released at the Economic and Financial Dialogue highlighted the role of the financial sector, which plays a central role in galvanising climate action by directing capital flows and providing necessary finance for sustainable growth. The UK welcomed India's work to establish a Business Responsibility and Sustainability Reporting (BRSR) regime. The UK and India agree to continue working together, in line with their domestic regulatory frameworks, to promote globally consistent, comparable, and decision-useful climate-related financial disclosures. Both countries welcomed global coordination efforts through the International Financial Reporting Standards Foundation (IFRS) to develop a global corporate reporting standard for sustainability, building on the the Task Force on Climate-Related Financial Disclosures (TCFD) recommendations to foster global best practices.

Also, the UK welcomed the Reserve Bank of India's recent membership of the Network for Greening the Financial System (NGFS). The assessment of climate-related risks being an evolving area, the Reserve Bank of India is looking forward to learning from the experience of the Bank of England and other leading central banks through its membership of the NGFS, as it considers ways to assess the resilience of the financial system through climate stress testing using NGFS scenarios, and issuing supervisory expectations, as well as how climate can be integrated into its own central bank operations through publishing its own climate risk disclosures. The Reserve Bank of India is also looking forward to accessing the Climate Risk Portal on the FSI Connect and related training programmes offered by the Bank of England and other leading central banks under the Climate Training Alliance (CTA).

The City of London's role in financing India's growth has continued to strengthen. The London Stock Exchange is the largest global centre for masala bonds, having raised over 50 per cent of the total aggregate amount originated globally. Over the last five years, Indian firms have raised £13.41 billion in masala, dollar, and green bonds listed on the London Stock Exchange.

During the visit by the UK Prime Minister, Boris Johnson, to India in April 2022, the UK and India released a Joint Statement. The statement highlighted a $200 million guarantee by GuarantCo for Axis Bank to accelerate India's transition to electric vehicles. The two leaders reinforced their commitments to cooperate closely on COVID-19 recovery, climate finance, services trade, and multilateral engagement, including intensifying cooperation in financial services, banking, insurance, fintech, green bonds, sustainable finance, and capital market sectors and promoting collaboration between regulators and stakeholders.

British International Investment, formerly CDC Group, has invested £70.8 million to scale-up renewable energy projects in India. This investment comprises a £3.5 million commitment to Fourth Partner Energy and a £3.15 million project finance debt investment to Thar Surya, an Indian subsidiary of Enel SpA, Italy (Enel).

GoI supports research and innovation activities through a range of government programmes, budgetary support to a network of research laboratories and autonomous bodies, and research grants. The central government held the largest share at 45 per cent of the total R&D expenditure in 2017-18, and the state governments accounted for 6.4 per cent. The business sector accounts for 41 per cent of the total share in R&D expenditure, led by the private sector at 37 per cent and public sector industries at 4 per cent. The business sector's contribution to India's gross domestic expenditure (GERD) on R&D and the total number of personnel and researchers are among the lowest compared to the top ten economies in the world. India's Economic Survey 2021 has called for an increase in the private sector's investment in R&D.

In the financial year 2021-22, the Ministry of Science and Technology (MoST) was allocated INR 147.94 billion (£1.479 billion) which included an allocation of INR 60.67 billion (£606.7 billion) to DST, INR 52.24 billion (£522.24 million) the Department of Scientific and Industrial Research and INR 35.02 billion (£350.2 million) to DBT. The MoST supports a range of programmes including science and technology institutional and capacity development programmes, statutory and regulatory bodies (such as the Science and Engineering Research Board and Technology Development Board), and over 25 autonomous bodies.

Aside from the above support, GoI launched a variety of government programmes and incentives such as Make In India, Start-up India, and Skills India, in the last decade aimed at boosting the domestic manufacturing sector, building a robust start-up ecosystem, and supporting Indian youths with vocational and market-relevant training programmes.

Large companies have their R&D budgets, commission-sponsored research programmes at universities, and various R&I bodies, and support promising start-ups. India's start-up ecosystem is currently the third largest in the world. It has a well-established network of angel investors, venture capital funds, and private equity players who have supported many start-ups in the early stages of their journey with seed capital and other assistance.

Recommendations and Next Steps

This report provides insights into the emerging trends and opportunities in the resource efficiency and sustainable manufacturing landscape of Indian industries. It captures key initiatives in the area of sustainable manufacturing of some of the main Indian players in some key sectors and highlights the policy ecosystem that is encouraging the shift from a linear model to a circular model of production.

The report indicates the strategic focus of these progressive organisations in India on adopting a circular economy model, an approach that is emanating from a host of factors: response to climate change, India's global commitments, growing regulatory frameworks, rising customer demand for sustainable products, enhancing competitiveness, greening the supply chain, achieving less dependence on import of raw materials, organisation's sustainable aspirations, and reaching the net zero goals. COP 26 has also played a positive role in raising corporate sustainability ambitions and driving change.

Sustainable manufacturing is receiving impetus from the GoI's PLI schemes in various priority sectors, private investment, venture capital funds, and bilateral and multilateral funding mechanisms. New funding mechanisms and fresh investments are flowing into companies, start-ups, and research organisations to work collaboratively to address resource extraction, environmental degradation, and waste generation. Cross-sectoral collaboration, between industrial sectors, is also under consideration as a high-potential area to deliver resource efficiency goals. While several best practices are emerging in the new frontier of circular supply chain management, there are still unmapped and unexplored areas that need to be identified and addressed to enhance resource utilisation at the optimum level. Analysis of gaps in cross-sectoral collaborations and interdependencies in highly resource-intensive sectors is crucial in closing the supply chain loop. Identification of barriers and innovative practices of cross-sectoral collaboration will help formulate progressive policy frameworks.

Huge potential to enhance resource efficiency lies in the areas of electrification of transportation, plastic, electrical and electronic equipment, steel, construction and cement, green hydrogen, and biofuel, to name a few. Opportunities, such as infusing innovation in industrial networks, need to be addressed. Sectoral analysis to identify potential areas of strategic alternatives need to be carried out in view of evolving policy ecosystem and net-zero commitments.

The UK and India have areas of common interest and demands in innovations related to resource efficiency across multiple sectors. Some of the research has reached commercial scale, and some promising innovations need the necessary push to materialise into technologies whose applications can be widespread. Innovative collaborations, access to finance, business models, and technology partnerships building on recent successes and bilateral announcements will take forward the UK-India Roadmap 2030. These would be mutually beneficial and contribute toward the SDGs and climate commitments of both the UK and India. The following steps might help India and the UK establish a deeper and closer engagement in the sector and lead to win-win research and business successes in the coming years.

1. Map specific R&I programmes of the top ten Indian companies and research bodies in each sub-sector along with their focus areas, size and trajectory of the research projects, budget, and gap in technology and research inputs.
2. Identify UK stakeholders who are well-placed to collaborate on bilateral R&I opportunities.
3. Design a supporting mechanism comprising India-UK events, workshops, missions, and creation of virtual groups for easy exchange of information with inputs from both GoI and the UK government, and participation of other stakeholders, including industry bodies, large companies, and innovation/incubation centres in the two countries, and network of select venture capital funds and other potential investors.

In the medium-to-longer term, it will be worth exploring options of twining institutions between India and the UK. Subject to analysis and evidenced mutual benefit, there is an opportunity for joint demonstration centres/centres of excellence on key themes in resource-efficient/sustainable manufacturing may be considered to support the ongoing India-UK links and identify and foster new collaborations.

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