सीएसआईआर
CSIR
भारत का नवाचार इंजन
The Innovation Engine of India

CSIR@100

(1942-2042)

A Pathway

July 2025

Council of Scientific and Industrial Research

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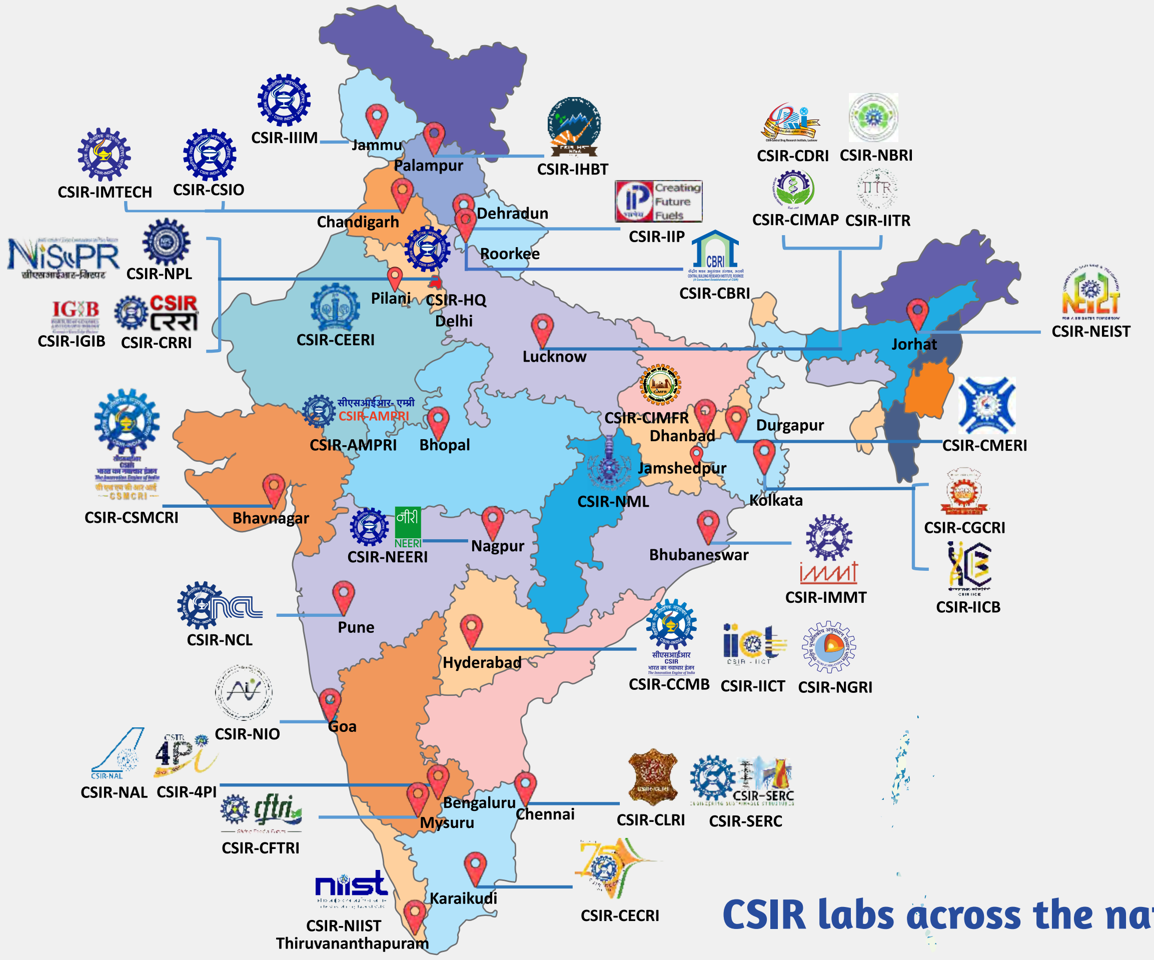
Introduction

The Council of Scientific and Industrial Research (CSIR) was established in 1942, in the midst of a global war and a rising Indian independence movement. During a time when colonial India had a limited scientific infrastructure to address industrial and supply chain needs, CSIR emerged as the country's first organized endeavour to establish a national ecosystem for galvanizing the country's scientific and technological prowess towards achieving industrial self-reliance. From modest beginnings, CSIR laid the foundation for industrial research in India with early successes in drugs, chemicals, leather, food processing and farming machinery.

Over the decades, CSIR has evolved as an industry-oriented, product-focused, technology-developing institution through its multidisciplinary R&D network of 37 laboratories across the nation, driving innovation in sectors ranging from agriculture to aerospace, genomics to geosciences, Labs to FABs, apart from nurturing Atal Tinkering Centres and Atal Incubation Centres. It pioneered India's first indigenous civilian aircraft, developed life-saving drugs and diagnostics, created sustainable farming solutions, advanced technologies in water purification, energy storage devices, e-mobility and climate-resilient infrastructure.

CSIR has always been a national institution with a societal mandate—supporting strategic sectors, empowering MSMEs, providing technology solutions through a Waste-to-Wealth approach, and creating employment through S&T-based enterprises. It has contributed to nation-building through import substitution, self-reliance, and inclusive innovation. As India strides towards *Viksit Bharat @ 2047*, CSIR remains committed to driving scientific excellence and technology-led development for a self-reliant and globally competitive nation.



CSIR labs across the nation

The Road to CSIR@100: A Vision for 2042

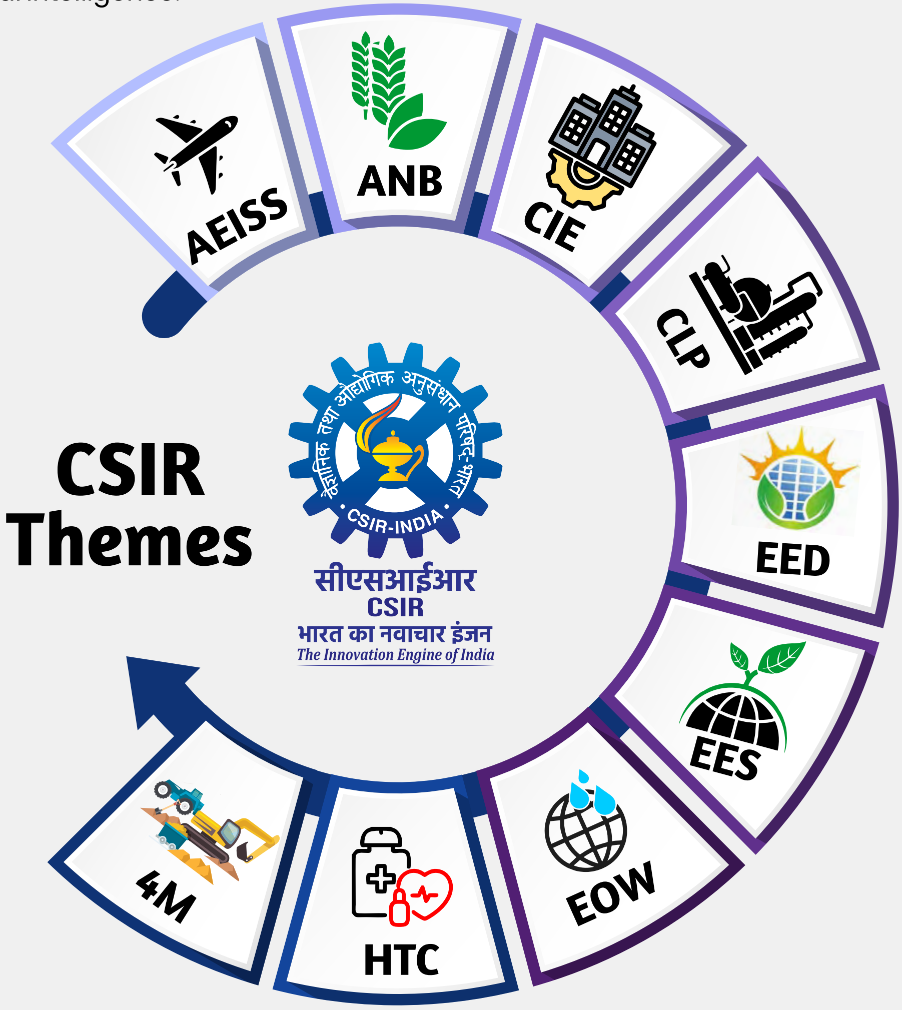
As CSIR approaches its centenary in 2042, it aspires to transform into a globally competitive, innovation-driven, mission-led organization that:

- Leads frontier science and deep-tech innovation in artificial intelligence (AI), clean energy, quantum technologies, synthetic biology, among others.
- Drives national missions in green manufacturing, bio-economy, strategic materials, and digital transformation.
- Becomes a hub of translational research, rapidly moving from lab to market with strong industry and startup partnerships.
- Promotes innovations inspired through validation of traditional knowledge across diverse areas such as health and wellness, food and agriculture, and metallurgy, drawing on the unique strengths of India.
- Nurtures next-generation S&T human resources through capacity building and strengthening skills and expertise.
- Harnesses and incentivizes intellectual property rights and technology commercialization for catalysing creativity, innovation and growth.
- Evolves into a talent magnet, attracting the brightest minds through flexible, interdisciplinary, and impact-driven research ecosystem.
- Shapes policy and society, contributing scientific insights to global challenges like climate change, food, waste, energy, health, strategic and data security, and circular economy and sustainable development.

Charting the Path to CSIR@100: A Dual-Stream Strategy

With an ambition to achieve global leadership, that is being effectively supplemented through structural reforms and strategic investments, CSIR is crafting its 2042 pathway towards catapulting the institution into the select group of players capable of transforming India and the world through cutting edge R&D interventions.

While preparing the CSIR@100 pathway, CSIR has adopted a structured and futuristic approach anchored in realism, strategic prioritization, and national relevance. Recognizing the importance of the 17-year window leading up to its centenary in 2042, CSIR undertook a visioning exercise to define its transformative role in making India self-reliant and globally competitive. The process began with a deep introspection of CSIR's historical contributions, current capabilities, and global positioning. A critical component of this approach was the identification of gaps in infrastructure, talent, and scientific readiness, particularly in high-impact domains such as self-reliant space and defence technologies, advanced materials, electronics, clean energy, and artificial intelligence.

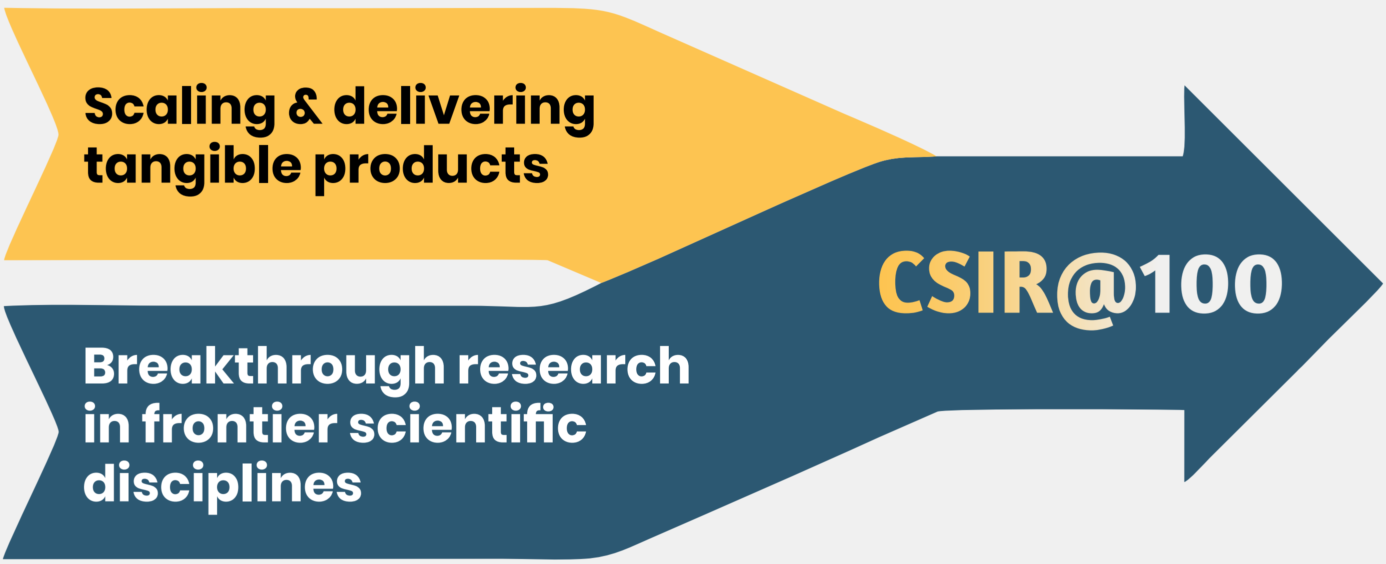


Aerospace, Electronics, Instrumentation & Strategic Sectors (AEISS); Agri, Nutrition & Biotech (ANB); Civil Infrastructure & Engineering (CIE); Chemicals (including Leather) and Petrochemicals (CLP); Energy (Conventional & Non-conventional) and Energy Devices (EED); Ecology, Environment and Sustainability (EES); Earth, Oceanography and Water (EOW); HealthCare (HTC); and Mining, Minerals, Metals and Materials (4M)

The roadmap being formulated rests on a dual-stream strategy. The first stream focuses on scaling and delivering tangible products in areas where CSIR already has a strong foundation. The second stream emphasizes breakthrough research in frontier scientific domains where India is beginning to engage, such as quantum computing and ocean mining. The CSIR thus aspires to support industrial R&D and manufacturing, including that of MSMEs and Start-ups, while also focusing on blue sky research. The document envisions to set clear targets, prioritize translational research up to Technology Readiness Levels (TRLs), and promote alignment of CSIR's R&D funding and institutional capacities with the sustainable development goals, national missions and industry needs. Each CSIR laboratory is expected to define its core deliverables and align them with emerging technological needs, ensuring that the CSIR@100 blueprint is both ambitious and grounded in scientific and operational feasibility.

To operationalize this dual-stream strategy, CSIR focussed on its current nine thematic areas that will drive India's future scientific and technological leadership - Aerospace, Electronics, Instrumentation & Strategic Sectors (AEISS); Agri, Nutrition & Biotech (ANB); Civil Infrastructure & Engineering (CIE); Chemicals (including Leather) and Petrochemicals (CLP); Energy (Conventional & Non-conventional) and Energy Devices (EED); Ecology, Environment and Sustainability (EES); Earth, Oceanography and Water (EOW); HealthCare (HTC); and Mining, Minerals, Metals and Materials (4M). These themes are cross-cutting, interdisciplinary, and aligned with both national missions and global opportunities. They are designed not only to leverage CSIR's current strengths but also to push the frontiers of knowledge and innovation in emerging and critical sectors.

Each theme underpins a forward-looking vision for 2042, complete with milestones, technologies, and implementation frameworks. From transforming food systems and regenerating soil health to reimagining mining and securing rare earths, these themes represent CSIR's commitment to solving real-world challenges at scale. The following sections present the thematic deep-dives, beginning with the aerospace sector.



Ascending India's Skies – Building Sovereignty and Supremacy in Aerospace and Instrumentation

AEISS

As India marches towards becoming a $10 trillion economy by 2047, aerospace and defence technologies stand at the epicentre of strategic self-reliance, economic expansion, and national security. Today, despite possessing the third-largest military in the world and a robust civil aviation market poised to reach $30 billion by 2030, India still heavily depends on imports for high-precision aerospace subsystems, advanced instrumentation, and flight-critical components. The Indian drone market alone, expected to grow to ₹50,000 crore by 2030, is largely dominated by foreign technologies and imported parts for propulsion, navigation, materials, and control systems.

CSIR envisions transforming this dependency into sovereignty. By its centenary year in 2042, CSIR will spearhead India's journey toward becoming a global leader in indigenous aerospace engineering, advanced instrumentation, drone systems, stealth technologies, and quantum applications, thereby aligning itself with the Government of India's *Atmanirbhar Bharat* and Make in India missions.

Civil & Military Aviation

CSIR intends to support the growing civil aviation market in coordination with the Ministry of Civil Aviation in the country by undertaking design of small and medium civil aircrafts. Towards this aim, CSIR will pioneer the use of highly efficient aerodynamics, light weight structures and fuel efficient and eco-friendly power plants. CSIR shall address the indigenization of aerospace electronics (i.e., avionics) and mechanical systems in order to reduce unit cost, tackle obsolescence and permit customization in the country. Many of these technologies are dual use and CSIR will leverage and strengthen the existing eco-system developed in the aerospace sector by CSIR, DRDO and ISRO.

Drones: From Import Dependence to Indigenous Excellence

Drones represent the next frontier in transportation, surveillance, logistics, agriculture, and disaster management. CSIR will lead the development of indigenous drones, offering scalable platforms for various verticals such as logistics, defence, agriculture, and emergency response. Recognizing that the bulk of drone subsystems—including propellers, airframes, motors, flight control units, and software—are currently imported, CSIR will take a mission-mode approach to build a national drone ecosystem. By 2030, CSIR will catalyse the establishment of dedicated drone component factories in India that produce small to large propellers, airframe structures, high-performance DC motors, and indigenous navigation systems. A comprehensive national framework will be put in place whereby CSIR develops core subsystems and networks them through validated platforms, which will then be transferred to Indian industries for mass production and export. These efforts will place India among the top five drone technology exporters by 2042.

Aerospace @ CSIR 2042

- Contribute to the robust growth of civil aviation.
- Build a national drone ecosystem and become an exporter by 2042.
- Leading role in building dual-use stealth platforms.
- Establish Centres of Excellence for the development of wide bandgap semiconductors and compound materials such as SiC (Silicon Carbide), GaN (Gallium Nitride), GaAs (Gallium Arsenide), and HgCdTe (Mercury Cadmium Telluride).
- To develop aerospace materials including aluminium, steel and titanium alloys, carbon fibres and pre-pegs as well as ceramic matrix composites.
- Leader in the application of quantum computing to solve problems.
- To provide National Testing Facilities and flying test-beds.
- To maintain National Standards in Aerospace.

To support this ecosystem, CSIR will establish state-of-the-art drone testing facilities across diverse geographies—deserts, coasts, hills, and urban environments. These centres will offer certification, safety validation, performance benchmarking, and pilot training, while creating a rich repository of data for regulatory and R&D purposes. CSIR shall use drones as flying test beds to demonstrate systems for manned and unmanned aircraft.

Enabling Stealth and Strategic Technologies

India's defence preparedness will get a significant boost as CSIR pivots toward stealth technologies—critical in radar-evading aircrafts, unmanned aerial vehicles (UAVs), and naval applications. A national initiative on stealth and aerospace materials, to be initiated by CSIR, will gather India's leading industry and strategic stakeholders to define a roadmap for indigenous development of stealth-enabling coatings, structures, and algorithms. CSIR will play a leading role in building dual-use stealth platforms—suitable for both military and high-value civilian applications such as surveillance in disaster zones or border monitoring.

Indigenous Semiconductor Chips, Materials, and allied Electronics

The need for indigenous semiconductor sensors and integrated circuits for driving, navigating, and communicating, along with the demand for electric motors, power electronics, and lightweight energy storage systems in the aerospace sector, is accelerating. CSIR will drive the development of high-efficiency electric propulsion systems, empowering next-generation UAVs, electric aircraft, and hybrid flying vehicles. India currently imports nearly 70% of its aviation-grade propulsion components; by 2042, CSIR aims to reduce this dependence by 90% through domestic innovation and manufacturing.

CSIR will establish Centres of Excellence for the design and development of wide bandgap semiconductor chips and compound materials such as SiC (Silicon Carbide), GaN (Gallium Nitride), GaAs (Gallium Arsenide), HgCdTe (Mercury Cadmium Telluride), and synthetic diamond. These materials are the backbone of advanced optoelectronics, aerospace sensors, and high-temperature electronics required for aerospace missions, missile systems, high-frequency RF communications, and deep-ocean instruments. The Centres of Excellence (CoE) will have the complete chip design, fabrication, assembly, and packaging facilities with aerospace compliance. For this purpose, CSIR will collaborate with Ministry of Electronics and Information Technology (MeitY) and Department of Energy (DoE).

Quantum Technologies & Algorithms

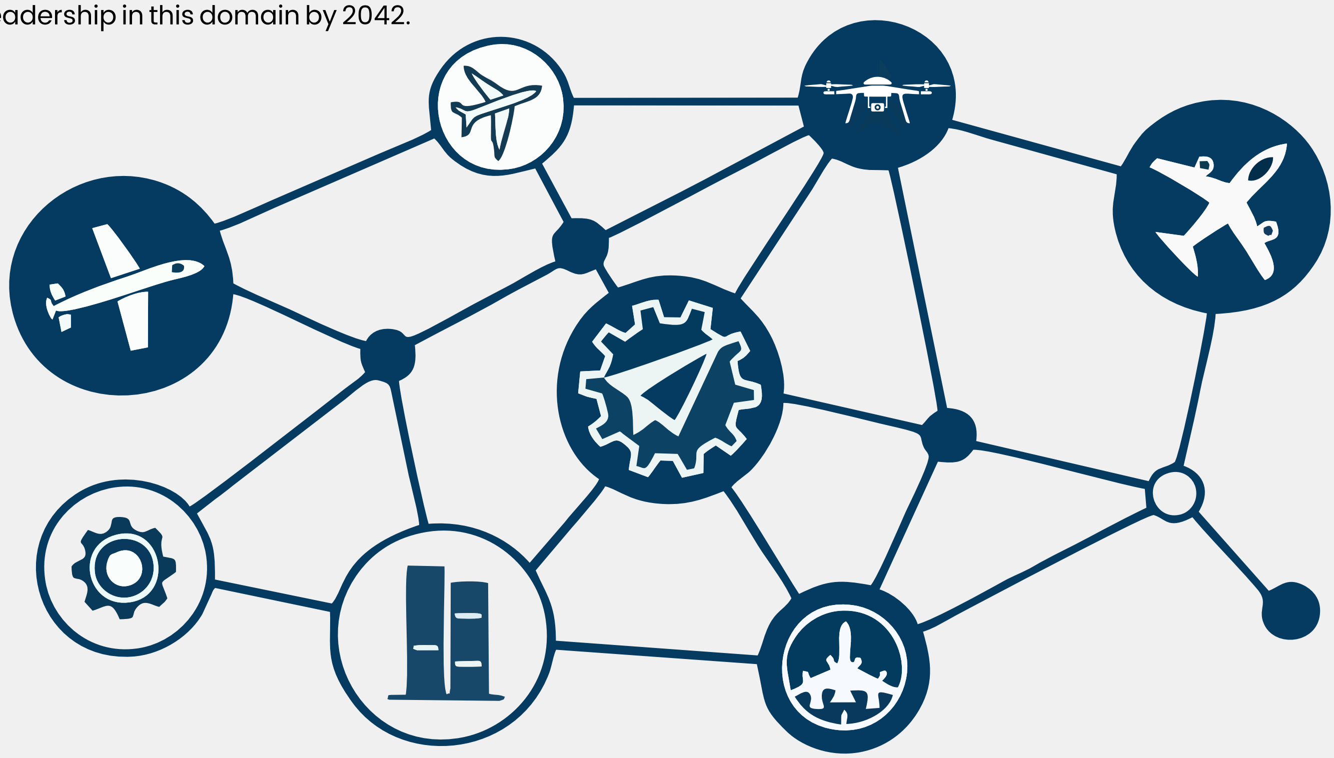
Quantum sensors are emerging to give sensitivities better than existing technologies. They are offering new applications including navigation in GPS-denied scenarios, geo-mapping for strategic as well as civilian uses, in big science projects like LIGO, Square Kilometre Array, among others. CSIR will be working with strategic sectors including DRDO to develop miniaturised high precision sensors for field deployment.
Quantum metrology standards are accepted as primary standards for the SI units. These form the backbone for high precision measurements and providing traceability to the quality infrastructure. Certification, calibration and testing of new quantum technologies require these standards. CSIR will be establishing these to facilitate much needed global acceptance for Indian products through quality infrastructure. Optical clocks are going to be the new primary standards for time keeping. Indigenous development of such clocks is need of the hour for self-reliance in space and strategic sectors. These will be developed with the support of the Ministry of Consumer Affairs, ISRO, and National Quantum Mission (NQM).

Quantum communication, especially, quantum key distribution is one of the proven applications of quantum technologies. Non-classical light sources, quantum random number generators, free space and fibre-based transmission, high secure and reliable transmission of time with high precision of down to nanoseconds, are some of the areas CSIR will work with ISRO, NQM, and other ministries.

CSIR shall undertake the development of hybrid classical-quantum computing along with associated algorithmic testing, Quantum-safe algorithms. For this purpose, CSIR will engage with the National Quantum Mission.

Data-centric Algorithms, Software Solutions and Networks

CSIR will develop Small and Medium Foundational Models, Urban Traffic management solutions, Indigenous cyberspace surveillance framework, AI enabled Cyber-Threat-Intelligence framework, AI standardization, Safe & Responsible AI, AI for automation, healthcare and inclusivity. Collaborations with India's leading IT and scientific institutions will result in application-specific quantum devices that ensure India's technological leadership in this domain by 2042.



Transforming Indian Agriculture, Nutrition, and Biotech through Science, Innovation, and Sustainability

India today holds significant promise in agriculture, yet faces evolving challenges in ensuring sustainable food and nutrition security. The agri-nutrition system is influenced by factors such as climate variability, soil health concerns, and the growing need for high-quality, nutritious produce. Additionally, improving supply chain efficiency and reducing reliance on synthetic inputs remain areas of focus.

CSIR envisions a forward-looking and transformative approach to address these complexities and position India as a global leader in agri-nutrition-biotech by 2042. As part of this vision, CSIR will work on futuristic areas such as synthetic biology, climate-resilient crops, certified reference materials, edible food sensors, small molecule discovery, and plant and soil microbiome research to drive innovation and impact across the agri-nutrition value chain.

Synthetic Biology

A central pillar of this transformation will be the creation of a comprehensive synthetic biology platform by 2042. CSIR will establish synthetic biology as a structured and vibrant discipline with distinct verticals in agriculture, bio-utilities, and pharmaceuticals. Today, the supply of many commercially valuable phytochemicals used as active pharmaceutical ingredients, food flavours, and cosmetic fragrances remains highly volatile, affected by environmental factors and limited plant yields. Through synthetic biology and biomanufacturing, CSIR will enable the efficient production of these phytochemicals using microbial systems such as yeast and bacteria, as well as plant-based platforms like cell and root cultures (Annexure I). These methods will ensure sustainability, consistency, and scalability—independent of traditional cultivation. This approach will secure India's access to critical bio-compounds and reduce dependency on natural variability and imports.

Agriculture, Nutrition, Biotechnology @ CSIR 2042

- Synthetic Biology approach to develop phytochemicals
- Development of Vital climate-resilient crops
- Develop 200 CRMs for phyto- and aroma-chemicals
- Edible food sensors and AI-enabled food safety

Climate-resilient crops

To combat the impacts of climate change and food insecurity, developing climate-resilient crops, specifically medicinal and aromatic plants will be a key focus. CSIR has already identified ten vital crops and key traits that will be targeted for development by 2042 (Annexure II). These crops will be engineered to withstand stressors such as drought, heat, and salinity, while also minimizing pre- and post-harvest losses. By integrating genomics, precision breeding, and AI-driven phenotyping, CSIR will ensure India's agricultural systems become more robust, productive, and adaptable.

Certified Reference Materials (CRMs)

CRMs play a critical role in ensuring product quality, global competitiveness, and regulatory compliance. Currently, the Indian Pharmacopoeia and Indian Systems of Medicine (ISM) Pharmacopoeia highlight a significant gap in the availability of herbal standard measures as well as phytochemical reference standards. CSIR will bridge this gap by developing 200 CRMs for phyto- and aroma-chemicals by 2042, thereby supporting the Ayush, essential oil, and functional food industries, and strengthening India's quality infrastructure. This will also support the vision of *Atmanirbhar Bharat* by reducing reliance on imports and enhancing India's global reputation in herbal and plant-based product standards.

Edible Food Sensors

In a future where consumers demand safety, transparency, and personalization, CSIR will lead India's efforts in edible food sensors and AI-enabled food safety mechanisms. These advanced systems-based on non-invasive, portable technologies integrating Near Infrared (NIR) spectroscopy and machine learning—will enable real-time detection of adulteration and quality issues without the need for laboratory infrastructure. CSIR is also pioneering edible biosensors from biodegradable and biocompatible materials that monitor pH, glucose, gut microbiota, and other markers. These nanosensors will dissolve safely within the body while transmitting data to mobile or wearable devices, thereby transforming food into a medium of continuous health surveillance and risk management. With these innovations, India will emerge as a global leader in smart and safe food systems, integrated with smart packaging options to serve a wide variety of sports to space food kit requirements.

Small Molecules

As the agriculture sector grapples with declining yields and chemical overload, CSIR sees small molecules such as peptides, small RNAs, and plant/microbial bio-actives as game changers for sustainable farming. These molecules can function as plant immunizers, growth stimulants, bio-stimulants, and alternatives to pesticides, offering a clean, effective, and scalable path to resilient crop management. Their ability to act as cross-kingdom gene regulators further opens new frontiers for modulating plant–microbe–environment interactions. CSIR's mission by 2042 is to drive discovery, characterization, formulation, and field deployment of these novel molecules through a multidisciplinary approach, advanced formulation

technologies, public-private partnerships, and field validation, thus ensuring wide-scale and cost-effective adoption. Bioreactors, germplasm, gene editing-cum-sequencing will be the approaches to popularise optimised agro-technologies as a part of ensuring sustainable agronomy.

Plant and Soil Microbiome Research

Plant and soil microbiome research will be central to revitalizing India's agricultural productivity and ensuring long-term soil health. Over 50% of Indian soils today are degraded due to overuse of chemical fertilizers, poor soil management, and unsustainable practices—posing a serious threat to smallholder farmers. CSIR's microbiome-centric vision will transition the country to regenerative and climate-smart farming. By harnessing native microbial communities to improve nutrient efficiency, stress tolerance, and soil structure, CSIR will introduce scalable solutions that reduce carbon emissions and increase productivity. These efforts will directly contribute to India's commitment towards Sustainable Development Goals (SDGs), making agriculture a pillar of environmental stewardship, economic resilience, and food sovereignty.

Together, these initiatives form a cohesive, visionary strategy leverages cutting-edge science to deliver systemic change. By 2042, CSIR will have catalysed a remarkable transformation of India's agri-nutrition-biotech sector, anchoring it in sustainability, innovation, and national self-reliance.

CIE

Engineering Tomorrow — Redefining India's Civil Infrastructure for a Resilient, Smart and Sustainable Future

India's rapid urbanization, climate vulnerabilities, infrastructure deficits, and ambitious national targets demand a transformative leap in how we build, live, and move. With over 1.4 billion citizens, 68% of whom reside in rural areas and an urban population projected to exceed 600 million by 2030, India's infrastructure needs are immense. At the same time, the country is witnessing increasingly frequent climate-induced disasters, ranging from heatwaves and floods to earthquakes and cyclones. Moreover, India's construction sector, which contributes 9% to the GDP, also accounts for nearly 25% of the total natural resource extraction and 40% of total energy consumption during the lifecycle of built structures. This reality underscores the urgent need for materials and systems that are smarter, safer, faster to deploy, and sustainable by design.

Top 10 Technologies from CIE at @CSIR 2042

- Implementation of CSIR Model Villages in all the districts in India.
- Cyber-physical systems for Structural Health Monitoring of critical infrastructure (IoT, ICT, Industrial Internet of Technology (IIoT) enabled predictive maintenance of crucial infrastructure including Digital twin)
- Smart roads with embedded sensors, IoT, and communication systems for Adaptive Traffic Management, Safety and Security.
- Commercialization of Non-toxic Radiation Shielding Materials for Medical and Strategic Sectors
- Intelligent Platform for Additive Manufacturing of large size component.
- Field implementation of fully integrated Climate Resilient Buildings in High Altitude and Extreme Weather conditions.
- Development of hybrid floating renewable energy system.
- Development of Designs for Waste-based materials for road construction.
- Commercialization of Eco-Friendly Geo-polymeric Construction Materials for Road, Infrastructural & Strategic Sectors.
- Multi Agent Systems/Swarm Robotics for wide area surveillance

CSIR envisions, by its centenary year in 2042, to be at the forefront of India's civil and infrastructure revolution, architecting a future where buildings, roads, shelters, and structural systems are climate-resilient, modular, recyclable, high-performing, and digitally integrated. Through the Civil and Infrastructure Engineering (CIE) Theme, CSIR will lead the nation in developing indigenous, cost-effective, and technologically superior infrastructure solutions for rural and urban India alike.

To address housing and shelter gaps, especially in disaster-prone and ecologically fragile areas, CSIR will develop and deploy prototype shelter structures optimized for extreme climates—ranging from high-altitude Himalayan terrains to flood-prone coastal belts. These structures will use innovative building materials that allow rapid assembly and disassembly, enabling emergency relief housing, military infrastructure, and resilient community centres.

A key innovation vector will be the development of high-performance construction chemicals tailored for India's diverse geographies. These include advanced waterproofing agents, thermal insulation compounds, and smart binders that reduce cement usage and carbon footprints. CSIR will also prioritize waste minimization by integrating recycled aggregates, fly ash, slag, and bio-waste into the construction materials stream—supporting India's mission of becoming a net-zero construction economy.

In the area of advanced materials, CSIR's roadmap begins with the development of smart and self-healing coatings, phase-changing materials for thermal efficiency, and graphene and carbon nanotube (CNT) reinforced composites for enhanced mechanical performance. Over the next five years, these materials will be tested and validated in controlled environments, with pilot-scale application in real systems in the medium term (10 years), culminating in commercial-scale deployment by 2042.

CSIR will also pioneer radiation shielding materials and geo-polymeric concretes, offering alternatives to conventional Portland cement and catering to strategic sectors like nuclear infrastructure and high-load military installations. Similarly, advanced concrete formulations using nano-additives and microbial agents will enhance strength, durability, and performance, making Indian roads and bridges more resilient and maintenance-free over longer cycles.

India's villages which are home to over 65% of the population will be transformed through the development of smart village materials that are locally sourced, low-cost, and climate-appropriate. These materials will be tailored for rural schools, health centers, homes, and community assets, contributing to rural prosperity while also enhancing resilience to climate shocks.

Pushing the boundaries of construction technology, CSIR will lead the development of 3D printed building components using recycled plastics, agricultural residues, and bio-based materials. By 2042, India will have fully functional 3D-printed housing ecosystems, enabling faster, cleaner, and more resource-efficient construction. Smart façades with energy-harvesting surfaces and dynamic thermal regulation properties will also become mainstream, radically improving energy efficiency in high-rise buildings and public infrastructure.

The theme will also deliver next-generation mobility and road infrastructure. Modular, pre-fabricated road panels incorporating recycled waste materials like plastics and demolition debris will be developed and tested for performance under Indian traffic and climate conditions. These will drastically reduce highway construction time and costs while improving durability and ease of maintenance.

In the domain of structural innovation, CSIR will design noise abatement materials for urban expressways and transport hubs, thus offering a much-needed solution to India's growing urban noise pollution. Metallic foams and sandwich panels, especially for defence infrastructure, will be engineered for blast resistance, thermal insulation, and lightweight deployment, thereby positioning CSIR as a strategic technology partner in national security.

Manufacturing for civil infrastructure will also undergo a revolution. CSIR will establish facilities for additive manufacturing (3D printing) of infrastructure components, enabling customization, rapid prototyping, and on-demand fabrication of bridges, culverts, and facades. A special thrust will be on green engineered materials, with synthesis processes that minimize environmental impact while maximizing performance.

By 2042, CSIR's CIE roadmap will enable India to design and build with intelligence and intention—from self-healing roads and climate-resilient villages to modular disaster shelters, smart urban buildings, and strategic defence structures. With scalability, sustainability, and sovereignty at its core, CSIR's civil and infrastructure engineering vision will redefine how India builds—not just for today, but for a safer, smarter, and more sustainable tomorrow (Annexure III).

CLP

Transforming India through Innovations in Chemicals, Leather, and Petrochemicals

India today stands at a critical juncture marked by escalating environmental challenges, a growing demand for sustainable materials, and shifting industrial priorities. As the world's third-largest emitter of carbon dioxide and a major hub for chemical manufacturing, India faces the twin imperatives of environmental stewardship and technological self-reliance. Against this backdrop, CSIR envisions a bold, forward-looking roadmap for the Chemicals, Leather and Petrochemicals (CLP) theme by 2042, marking the Council's 100 years of transformative scientific service to the nation.

CSIR Chemicals, Leather & Petrochemicals @CSIR 2042

- Optimize gigaton-scale storage infrastructure for CO_2 capture
- Commercialize 10 high-priority APIs
- Achieve 90% green API production
- Convert lignin into valuable chemicals
- Advance non-leather materials (Vegan leather)
- Biodegradable fluoropolymers
- Commercialize Nafion equivalent material
- Develop novel electrolyte systems
- World's largest salt producer

Carbon Capture Utilization and Storage (CCUS)

By 2042, CSIR will anchor a nationally coordinated mission on Carbon Capture and Storage (CCS) to help India meet its climate obligations. With India emitting over 2.8 billion tonnes of CO_2 annually and targeting net zero by 2070, the development of scalable CCS infrastructure is vital for hard-to-abate sectors like cement, steel, and chemicals. CSIR will initiate a pilot project in geologically promising sites such as Gujarat and Rajasthan, working in concert with industry partners like Oil and Natural Gas Corporation (ONGC) and Gas Authority of India Limited (GAIL). This will establish India's technological credibility in CCS and create viable roadmaps for industrial decarbonization.

The goal is to reduce energy demand for CO_2 capture by 25% by 2031 using phase change amines and reduce direct air capture (DAC) costs to \$110–120 per ton. By 2037, the aim is to demonstrate field-scale CO_2 capture (up to 0.3 million tonnes/year), enhance methanol conversion efficiency by 75%, and commercialize at least nine CO_2-derived value-added products. By 2042, CSIR aims to optimize gigaton-scale storage infrastructure and support industry-wide decarbonization. Futuristic R&D includes AI/ML-driven design of capture materials, carbon-negative cement, CO_2 refineries, and mineralization under engineered geomaterials and marine settings.

Active Pharmaceutical Ingredients (APIs) and Pharma Innovation

To strengthen pharmaceutical self-reliance, CSIR will identify and commercialize 10 high-priority APIs, particularly for drug-resistant tuberculosis, cancer, and autoimmune disorders. AI/ML-powered platforms will drive rapid lead generation and pre-clinical research. From 2026 onwards, 6–8 APIs/Key Starting Materials (KSMs) will be transferred to industry every five years, with 2–3 IND filings per phase targeting next-gen therapeutics. Future-ready strategies include 3D-printed APIs, microbiome-modulating compounds, flow chemistry, and RNA-based drugs. By 2042, CSIR aims to achieve 90% green API production, establish API innovation hubs, and simulate entire production pipelines digitally to optimize yields and minimize failures.

Valorization of Industrial Byproducts

In the petrochemical and specialty chemicals space, CSIR will redefine the global competitiveness of Indian R&D by focusing on the valorization of industrial byproducts. A key target will be lignin, a major residue from the paper and biofuel sectors—over 4 million tonnes of black liquor are generated in India annually. Instead of burning it for energy, CSIR will develop cutting-edge technologies to convert lignin into valuable chemicals such as aromatics, bio-based plastics, and fuel additives. These products will substitute petroleum-derived materials and align with India's waste-to-wealth, circular economy, and sustainable packaging goals.

Centre for Footwear Science and Innovation

Recognizing India's lack of a global-level institution dedicated to footwear innovation, CSIR will establish a Centre for Footwear Science and Innovation, a first-of-its-kind, interdisciplinary hub focused on both traditional leather and advanced non-leather (vegan and synthetic) materials. This will usher in a new era of durable, sustainable, and performance-oriented footwear materials that cater to evolving consumer preferences and export markets, while also addressing the need for eco-friendly production across the value chain. The centre will lead R&D in imported material substitution and aims to meet industrial needs through indigenous solutions and reach productivity leadership through innovations in comfort, quality, and sustainability.

Strategic Material Innovation

To meet global environmental norms and phase down HFC (Hydrofluorocarbons; asper the Kigali amendment), CSIR will develop eco-friendly fluorochemicals including HFOs (Hydrofluoroolefins), fire suppressants, and blowing agents. CSIR will make efforts to commercialize advanced fluoropolymers and refrigerants; expand to agro-pharma fluorinated organics and semiconductor etchants. By 2042, the focus will be on fully biodegradable fluoropolymers. CSIR will also take on strategic material innovation in the field of clean energy technologies. One of the pressing gaps in India's energy material ecosystem is the absence of indigenous substitutes for nafion, a critical membrane used in fuel cells. CSIR will develop and commercialize Nafion-equivalent materials tailored to Indian needs. Future R&D will explore green fluorination, AI-driven molecule discovery, and hybrid fluorinated platforms for medicine, electronics, and defense applications.

Development of Novel Electrolyte Systems

CSIR will also lead the development of novel electrolyte systems for advanced battery chemistries, enhancing India's energy storage capabilities, boosting grid resilience, and enabling the proliferation of electric vehicles under national missions like FAME and the National Green Hydrogen Mission.

Marine Chemicals

CSIR aims to make India the world's largest solar salt producer by 2042 through modernization, AI-based mechanization, and process optimization. Bittern valorization will be scaled up to recover potash, lithium, magnesium, and other critical elements like strontium, uranium, and rubidium from seawater using advanced selective materials.

Through this multifaceted vision, the CLP theme captures CSIR's resolve to reimagine the future of chemical synthesis, create sustainable materials, lead green industrial transitions, and enable India's emergence as a technology sovereign nation. By 2042, CSIR aims not only to innovate at the frontier of science but also to shape a more resilient, resource-efficient, and environmentally conscious future for India and the world.

EED

Pioneering India's Energy Future Through Innovation in Green Fuels and Advanced Devices

India, the third-largest energy consumer in the world, faces a defining energy challenge. With demand projected to double by 2040, and fossil fuels still contributing over 70% to the energy mix, the transition to clean and self-reliant energy solutions is both a national imperative and a global responsibility. CSIR, through its Energy including Energy Devices (EED) vertical, envisions a bold, structured transformation of India's energy landscape by 2042. This vision is anchored across five critical pillars namely Green Hydrogen, Energy Storage, Biofuels, Renewable Power and Alternate Fuels.

Green Hydrogen

Green Hydrogen will be a cornerstone of India's energy independence by 2042. CSIR targets to become the nodal agency for Green Hydrogen production by 2035, having developed cost-effective, globally benchmarked electrolysers (PEM, AEM, SOEC) by 2028. It will spearhead the indigenization of 700-bar hydrogen storage systems and advanced metal hydride and high entropy alloy-based systems, ensuring safe and efficient storage. On the utilization front, CSIR will lead the industrial scale-up of membrane and catalyst manufacturing for fuel cells, and drive innovations such as hydrogen internal combustion engine (ICE) technologies with selective catalytic reduction systems to cut NOx emissions.

Energy Storage

Energy storage is a critical enabler of renewable energy integration and electric mobility. Today, India relies heavily on imports for battery technology. By 2042, CSIR aims to change this paradigm. It will benchmark and transfer to industry lithium-ion batteries by 2028, and deliver sodium-ion, redox flow, and metal-air batteries by 2035. These batteries, along with new-generation supercapacitors, will be fully indigenous, meet global standards, and power India's clean energy future.

Energy (Conventional & Non-conventional) and Energy Devices @ CSIR 2042

- Green hydrogen ecosystem with indigenous electrolysers and storage systems
- Indigenous advanced energy storage systems (Li-ion, Na-ion, redox flow, metal-air batteries)
- Sustainable aviation fuel (SAF) and decentralized biofuel production technologies
- Net-zero energy buildings with agrivoltaics and smart energy systems
- Waste-to-fuel technologies including plastic-to-fuel and CO_2-to-fuel conversion

Biofuels

Biofuel represent a sustainable bridge to a carbon-neutral India. CSIR envisions becoming the nodal institution for Sustainable Aviation Fuel (SAF) by 2030, with HEFA-based SAF technologies commercialized by 2027. It will scale anaerobic gas lift systems to generate 100 TPD of biogas and purify it to CNG-grade using advanced vacuum pressure swing adsorption systems. CSIR's room-temperature biodiesel technology will be deployed across 100 decentralized units, ensuring grassroots energy access by 2030.

Renewable Power and Net-Zero Energy Buildings (NZEBs)

NZEBs are at the heart of CSIR's sustainability roadmap. CSIR will develop agrivoltaics that enable dual land use for crops and solar energy, and advance perovskite and dye-sensitized solar cells that meet international benchmarks. By 2035, India will benefit from building-integrated photovoltaics, smart glass technologies, thermoregulating roofing, energy-generating flooring, and waste-heat recovery systems, all developed and transferred to industry through CSIR's integrated R&D ecosystem.

EES

Ecology, Environment and Sustainability

India, with a population exceeding 1.4 billion and rapid urbanization and industrialization, generates over 62 million tonnes of solid waste annually, with urban areas contributing nearly 45 million tonnes alone. Additionally, approximately 38 billion litres of wastewater are produced each day, of which only a fraction is scientifically treated. Riverine ecosystems, urban drains, and rural nallahs are increasingly turning into hazardous channels of contamination, affecting agriculture, public health, and biodiversity. The environmental crisis we face today—ranging from waste mismanagement and air and water pollution to unsustainable consumption patterns—requires urgent, systemic, and scalable solutions rooted in science and innovation.

Municipal Solid Waste Management

India faces a growing challenge in managing municipal solid waste due to rapid urbanization, population growth, and limited infrastructure. The CSIR envision a robust, decentralized municipal solid waste management system focused on segregation at source, waste-to-energy solutions, and active citizen participation to achieve near zero-waste urban centers by 2030. By 2042, the goal is to establish a circular economy where over 95% of waste is recycled or repurposed using AI, biotechnology, and advanced automation, eliminating the need for landfills. Through continuous innovation, policy support, and global collaboration, CSIR aims to create sustainable, self-reliant urban ecosystems that lead the world in waste management practices.

Biomedical Waste Management

Biomedical waste management is significantly challenging due to increasing healthcare demands, improper segregation, and inadequate treatment facilities. EES theme looks forward to a safe, technology-driven biomedical waste management system with real-time tracking, on-site disinfection, and strict compliance protocols to minimize health and environmental risks, where 30-35% of all pathogenic biomedical waste generated will be treated using CSIR technology by 2030. By 2042, the vision expands to a zero-hazard system powered by automation, AI-based waste classification, and eco-friendly disposal methods, ensuring full circularity and sustainability, with a worldwide implementation of CSIR technology for managing any biomedical waste generated across the globe. CSIR aims to lead innovation in this space through advanced R&D, regulatory support, and capacity-building across healthcare institutions.

Plastic Waste Management

India's escalating plastic waste problem, driven by rapid consumption and inadequate recycling infrastructure, poses serious environmental and health threats. A plastic waste management system centered on advanced segregation, chemical recycling, and the development of biodegradable alternatives to significantly reduce landfill and ocean-bound plastics is envisioned by 2030. The Theme's vision for 2042 circumvents achieving a fully circular plastic economy

Ecology, Environment and Sustainability @ CSIR 2042

- AI-enabled decentralized zero-waste systems
- Smart biomedical waste with real-time tracking
- Advanced plastic recycling & biodegradable alternatives
- IoT-based odour control solutions
- AI-driven air quality monitoring systems
- Carbon capture & sequestration technologies
- Integrated water body restoration systems

through AI-enabled collection systems, closed-loop recycling technologies, and industry-wide adoption of sustainable materials, positioning India as a global leader in plastic waste innovation and sustainability.

Odour Control

Foul smell from waste, industrial processes, and sewage systems is a growing concern in urban and peri-urban areas, and micro to large industrial zones, affecting public health and quality of life. By 2030, CSIR envisions the deployment of advanced odour control technologies such as biofiltration, activated carbon systems, and IoT-based monitoring to mitigate smells at source across 50% of the waste treatment and industrial facilities. As CSIR turns 100 in 2042, the goal is to achieve near-complete odour neutrality in urban environments through smart, self-regulating systems powered by AI, real-time air quality sensing, and green infrastructure integration.

Air Quality Monitoring

Persistent issues with air quality owing to serious air pollution from industrial emissions, vehicular traffic, and construction activities necessitate precise and real-time air quality monitoring. By 2030, a nationwide network of low-cost, AI-integrated self-powered air quality sensors that provide hyperlocal data, enabling timely interventions and informed policy decisions is envisioned as part of the thematic activities. By 2042, the vision expands to a predictive and preventive air quality management system using satellite data, advanced analytics, and community-driven monitoring to ensure clean and healthy air across all regions.

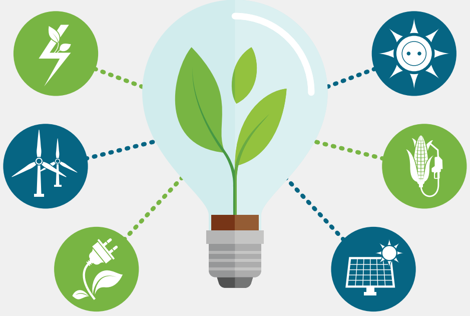
Co_2 Capture and Sequestration

Rising CO_2 emissions from industrial activities and fossil fuel use are major contributors to global warming and climate change, demanding urgent mitigation strategies. CSIR envisions scalable CO_2 capture technologies integrated with power plants and industries, alongside pilot projects for mineralization, bio-sequestration, and geological storage by 2030, leading to 30-40% reduction in national carbon footprint. By 2042, the vision is to establish a nationwide CO_2 circular economy with advanced direct air capture, utilization in value-added products, and permanent sequestration systems contributing significantly to India's net-zero goals.

Water Body Restoration

India’s water bodies are increasingly degraded due to pollution, encroachment, and unregulated urban development, threatening ecosystems and water security. An integrated water body restoration using bioremediation, real-time water quality monitoring, and community-led conservation to revive urban lakes, rivers, and wetlands envisages the action plan for 2030. A national resilient and self-sustaining aquatic ecosystem through nature-based solutions, AI-driven hydrological modelling, and long-term policy and stakeholder synergy is envisioned as part of the thematic activities converging in 2042.

With a strong foundation in interdisciplinary R&D and field-tested innovations, CSIR’s vision for EES by 2042 is to build a resilient, self-sufficient, and environmentally conscious India, where science not only restores ecological balance but also propels socio-economic growth. Timelines for accomplishing key initiatives are given in Annexure V.



Leading India's Blue Revolution—Harnessing Oceans, Water, and Earth Systems for National Prosperity and Sustainability

India, with its vast 7,500-kilometre-long coastline, 2.4 million square kilometres of Exclusive Economic Zone (EEZ), and one of the world's largest populations, faces mounting environmental and resource pressures. Today, India ranks among the top nations vulnerable to climate change-induced sea level rise, saltwater intrusion, and coastal habitat degradation. Simultaneously, freshwater scarcity is becoming a critical challenge: over 600 million Indians face high to extreme water stress, and nearly 200,000 die annually due to inadequate access to safe water. Despite being surrounded by oceans and endowed with marine biodiversity and mineral wealth, India has not fully unlocked the potential of its blue economy.

By 2042, when CSIR celebrates its centenary, it envisions playing a leading role in transforming India into a global ocean power, by pioneering sustainable exploration and utilization of marine resources, advancing earth system science, and ensuring water security for its people. CSIR's Earth, Oceanography, and Water (EOW) theme will serve as the backbone of this transformative journey.

A Blue Energy Revolution will be a cornerstone of this vision. With the global potential for wave and tidal energy estimated at over 500 GW, India's long coastline offers an immense opportunity. CSIR will establish dedicated pilot plants for both tidal and wave energy technologies in strategically selected coastal zones by 2030. These pilots will be used to demonstrate feasibility, validate designs, and enable partnerships with public and private industry players. Through rigorous R&D and technology adaptation, CSIR will work toward grid-scale deployment of ocean energy systems by 2042, reducing India's reliance on fossil fuels and boosting coastal energy resilience.

Recognizing the untapped mineral wealth of the deep sea, CSIR will lead India's deep-sea mining mission, developing robust capabilities for exploration and extraction of polymetallic nodules, rare earth elements, cobalt-rich crusts, and other critical minerals. These minerals are vital for electronics, clean energy systems, and defence applications. By 2042, CSIR will deploy indigenously developed Autonomous Underwater Vehicles (AUVs) capable of operating at depths up to 6000 meters, enabling real-time data collection, mapping, and mining operations in India's EEZ and international seabed zones.

Top Technologies from EOW Theme at @CSIR 2042

- Single-stage seawater desalination membrane & module fabrication with add-on rejuvenation technology - Demonstration and techno-economic analysis @ 1 MLD scale
- New generation Hollow Fiber membranes and scale-up using indigenous fluoropolymers for water purification
- One megawatt wave and tidal energy converter system
- Technology for the extraction of Co, Ni and Cu from Seawater
- Deep-Sea AUV capable of operating at 6000 m depth for high-resolution mapping of living and non-living resources
- Remotely Operated Vehicle (ROV) for real-time intervention and sample collection, forming a key framework between robotic platforms for resource assessment and sustainable utilisation
- Cysteine-Rich Type-II collagen from jellyfish offering enhanced bioactivity for biomedical and cosmetic applications.
- Low-cost decentralised system for fluoride removal
- Seismic Hazard Map of the Himalaya

To further unlock oceanic resources, CSIR will initiate targeted research on the extraction of valuable metals directly from seawater, including lithium, uranium, and magnesium. With technological breakthroughs in nanofiltration, ion-exchange, and bio-adsorption, CSIR aims to develop energy-efficient, cost-effective methods for metal recovery that could reduce India's import dependency and enhance its strategic mineral security.

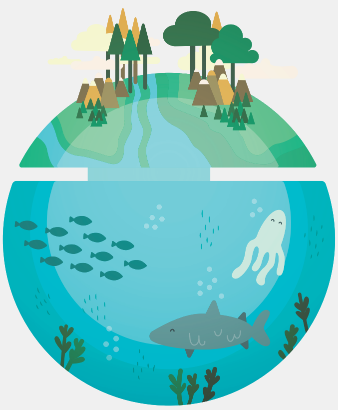
In parallel, CSIR will make pioneering strides in desalination and freshwater security. Given India's coastal communities' growing vulnerability to freshwater shortages and climate shocks, CSIR will deploy large-scale desalination plants along the 7,500 km coastline using state-of-the-art reverse osmosis (RO) and multi-stage flash distillation systems. These will be powered by renewable energy sources, enabling sustainable, off-grid solutions for drinking water, agriculture, and industrial use. This effort will directly support India's water security goals and significantly mitigate the impacts of groundwater depletion and salinity intrusion in coastal regions.

In response to the ecological and carbon imperatives of climate change, CSIR will spearhead mangrove ecosystem research and conservation, recognizing their critical role in shoreline protection, biodiversity, and carbon sequestration. India currently holds around 4,975 square kilometers of mangrove cover, but rising sea levels and development pressures threaten this vital resource. CSIR will develop predictive models, restoration protocols, and carbon accounting frameworks to expand and protect these ecosystems, enhancing India's commitment to climate mitigation and nature-based solutions.

Simultaneously, CSIR will lead the country's efforts in blue carbon sequestration. Oceans, estuaries, and coastal wetlands are significant carbon sinks, yet India lacks a comprehensive national framework to quantify, monitor, and utilize this capacity. CSIR will establish a national inventory of blue carbon ecosystems and provide technology platforms to monitor sequestration rates, enabling their inclusion in India's carbon credit mechanisms and international climate commitments.

Recognizing the enormous promise of marine bioresources, CSIR will launch strategic initiatives on seaweed cultivation and utilization. Seaweeds are a sustainable resource for food, fuel, pharmaceuticals, cosmetics, and biofertilizers. With an estimated global market exceeding $15 billion, seaweed farming can empower coastal communities, particularly women and youth. CSIR will build scalable models for cultivation, processing, and high-value product development, positioning India as a global seaweed innovation hub.

By 2042, CSIR's EOW mission will establish India as a blue innovation powerhouse, with integrated marine energy systems, deep-sea exploration, sustainable metal recovery, and ocean-driven climate resilience at its core. From ensuring drinking water for millions through desalination, to restoring mangrove forests and powering ports with wave energy, CSIR will deliver high-impact, science-based solutions that harmonize economic growth, environmental stewardship, and national self-reliance. Through this vision, CSIR will not only lead India's scientific engagement with the oceans but also place the country at the forefront of the global blue economy.



HTC

Redefining India's Health Innovation Landscape through Next-Generation Therapeutics, AI-driven Drug Discovery, and Precision Medicine

India, home to over 1.4 billion people, continues to grapple with a dual burden of disease. On one hand, communicable diseases persist due to varying socio-economic and environmental conditions. On the other, the incidence of non-communicable diseases (NCDs) like cancer, cardiovascular and neurological disorders has seen an alarming rise. Breast cancer, for instance, has become the most commonly diagnosed cancer in Indian women, with over 1.78 lakh new cases reported annually. Central nervous system (CNS) disorders, including neurodegenerative conditions and psychiatric illnesses, are growing silently and substantially affect quality of life. Meanwhile, rare bone disorders continue to be underdiagnosed and undertreated due to the lack of biological understanding and treatment frameworks. Despite being the world's largest provider of generic medicines, India lags in the discovery of original, high-impact therapeutics and biopharmaceutical innovation.

By 2042, the CSIR envisions reshaping India's health research ecosystem through a holistic and mission-driven approach under its Healthcare (HTC) theme. CSIR will embark on a flagship program to decode the fundamental biology of five critical diseases whose underlying mechanisms are still poorly understood—focusing initially on breast cancer, bone disorders, and CNS diseases. Using cutting-edge tools in genomics, proteomics, systems biology, and metabolomics, CSIR laboratories will develop comprehensive molecular maps of these diseases. This foundational knowledge will catalyse the discovery of new therapeutic targets and radically transform drug development in India.

A cornerstone of this transformation will be the establishment of a National Centre for Synthetic Biology Research. This Centre will serve as a multidisciplinary hub integrating biology, chemistry, engineering, and data science to design and synthesize biological parts, systems, and organisms for specific medical applications. The Centre will focus on creating designer enzymes for targeted biochemical functions and biosimilars that are critical for accessible, affordable biologic therapies. At present, India imports a significant percentage of high-value biologics, and CSIR aims to change that by driving indigenous development and scalable production.

Recognizing the accelerating impact of artificial intelligence in global biomedical innovation, CSIR will partner with premier information technology institutions to develop AI-powered drug design platforms. These tools will enable structure-based drug discovery, de novo molecule design, and predictive modeling of drug efficacy and safety. In a country where traditional drug discovery pipelines take years and cost millions, CSIR will pioneer a faster, data-driven, and cost-effective alternative.

Furthermore, CSIR envisions creating a comprehensive, end-to-end personalized medicine ecosystem. By 2042, healthcare delivery in India must move away from the "one-size-fits-all" approach to truly individualized treatment strategies. CSIR's framework for personalized drug treatment—targeted to be operational in the next five years—will integrate AI algorithms, patient genomic data, and precision diagnostics to design tailor-made therapies. This framework will support the development of India's own pharmacogenomic libraries, ensuring that drugs are optimized not only for specific diseases but also for the unique genetic makeup of Indian populations.

To bring this vision to reality, CSIR will adopt a mission-mode strategy, establishing long-term research clusters, clinical validation pipelines, and translational centres in collaboration with hospitals, academia, and industry. These initiatives will not only generate a rich portfolio of therapeutic interventions but also catalyse India's transition from a volume-based generic producer to a globally respected innovation-driven health science leader.

By the time CSIR celebrates its centenary in 2042, the HTC theme will have transformed the biomedical innovation landscape in India, ushering in an era of deep disease understanding, AI-integrated drug development, world-class biosimilar manufacturing, and truly personalized medicine. Through this, CSIR will help realize the national dream of affordable, equitable, and world-class healthcare for all Indians.

By 2042, CSIR will establish itself as a national leader in precision drug innovation by focusing strategically on the development of high-value, low-volume drugs that address critical, unmet medical needs. India's current pharmaceutical ecosystem, while globally prominent in generic drug production, lags in the discovery of novel therapeutics. To bridge this gap, CSIR will identify and advance at least ten promising candidate molecules for accelerated development—spanning orphan diseases, rare cancers, neurodegenerative disorders, and other complex conditions—through targeted translational pipelines. These drugs, though limited in volume, possess immense therapeutic and economic value, and can place India at the forefront of cutting-edge medical innovation.

In pursuit of frontier science, CSIR will position itself at the helm of global efforts to tackle the "undruggable genome"—regions of the genome and biological pathways that have remained inaccessible to conventional drug design. These include protein-protein interactions, intrinsically disordered proteins, and gene regulation networks, which are increasingly recognized as central to diseases such as cancer, autoimmune disorders, and neurological degeneration. By leveraging advances in structural biology, machine learning, chemical biology, and genomics, CSIR will aim to transform these formerly "undruggable" targets into actionable therapeutic opportunities, redefining what is possible in drug development.

Recognizing the immense potential of India's biodiversity, CSIR will integrate plant biology and traditional knowledge systems into mainstream drug discovery efforts. The country's rich heritage in Ayush, combined with its vast reservoir of terrestrial and marine biological diversity, offers a largely untapped source of novel bioactive compounds. CSIR will establish interdisciplinary programmes to systematically explore this treasure trove, identifying, characterizing, and validating herbal formulations, phytochemicals, and marine-derived compounds that can serve as leads for the treatment of diverse diseases—particularly those with high unmet medical need or widespread prevalence.
By combining ethnobotanical wisdom with cutting-edge molecular and pharmacological research, CSIR aims to build a powerful discovery engine rooted in India's ecological wealth.

To achieve this, CSIR will set up dedicated centres of excellence and national consortia focused on botanically-derived therapeutics. These centres will house high-throughput screening platforms, omics-based profiling tools, and AI-powered compound mapping systems to rapidly identify plant-based bioactives with therapeutic potential. By 2042, CSIR aims to mainstream India's botanical heritage into the global drug development pipeline, creating a unique niche where ancient knowledge meets futuristic science, an approach that is both deeply Indian and globally competitive.

- **Next Generation Diagnostics and Biomarkers for Cancer**

Point-of-care diagnostics, including regular, CRISPR-based, and next-generation sequencing methods, can be used to determine a patient's drug resistance profile before treatment is developed. All bacterial infections, including tuberculosis, will be the focus. CSIR will achieve this through a combination of antimicrobial resistance (AMR) surveillance and next-generation sequencing of both clinical and wastewater samples. Artificial intelligence and machine learning algorithms will be employed to identify key determinants of resistance, and kits or methods will be developed based on this information.
CSIR already has a mission on Triple Negative Breast cancer (TNBC), wherein sequencing of 1000 TNBC genomes and transcriptomes is in progress. CSIR will focus on TNBC and Pancreatic cancer to identify novel biomarkers that would enable early diagnosis.

- **Discovery of Novel Cell and Gene-Based Therapies**

Targeted Enzyme Replacement Therapy (ERT) for treating Lysosomal Storage Diseases (LSDs), other metabolic deficiencies, and pancreatic insufficiency. Indigenous methods will be developed and the process will be standardised up to a 1000-litre scale and transferred to industry for GMP/GLP production.
Advanced Chimeric Antigen Receptor (CAR–T) Therapy for Cancers and Inflammatory Disorders. This will be a Comprehensive Indian Initiative and CSIR will develop novel CAR-NK and CRISPR-guided immunotherapeutic screening for haematological cancers and CAR-T constructs for Ovarian adenocarcinoma, lung fibrosis and rheumatoid arthritis.

- **Developing Platform Technologies**

CSIR will develop platform technologies. CSIR is working on creating an indigenous end-to-end mRNA vaccine platform that can be used to develop vaccines against any viral or bacterial diseases. The current focus is on viral diseases such as chikungunya, JEV, and bacterial diseases like TB. However, the technology can also be utilised for other emerging and reemerging diseases, depending on the nation's needs.
Another platform technology that CSIR will develop is three-dimensional self-organizing structures that mimic the specific organs (organoids). They will be derived from induced human pluripotent stem cells (iPSCs). These models can be used for testing the efficacy of drugs, gene therapy and to investigate disease mechanism.

- **Bioremediation and Synthetic Biology**

CSIR has successfully performed bioremediation to decontaminate perchlorate, used as rocket propellant. CSIR will work on bioremediation processes for plastic and other environmental pollutant degradation.
Synthetic biology involves engineering bacterial cells to produce useful chemicals and materials via fermentation. CSIR will focus on this approach to develop active pharmaceutical ingredients through fermentation. CSIR plans to establish a Synthetic Biology Centre and recruit faculty with the necessary expertise.

- **Drug Development**

CSIR has the necessary expertise to undertake drug development, which involves new chemical entities (NCEs), phytopharmaceuticals, repurposing existing drugs, and generating biosimilars. Furthermore, computational tools will be used to develop and repurpose selective inhibitors against validated targets.
CSIR will utilize all four paths mentioned above to tackle antimicrobial resistance (AMR). Targets such as COVID, AMR, and Dengue are well-known threats. However, CSIR also needs to prepare to apply this expertise to other emerging and reemerging diseases. This involves nurturing the existing capacity and building upon it.

4M

Transforming India through Intelligent Mining, Sustainable Materials, Critical Minerals and Metals

India stands at a pivotal juncture where its aspirations for industrial growth must be balanced with sustainability, safety, and strategic autonomy. With a growing population exceeding 1.4 billion and increasing infrastructure, energy and material demands, India's mining, metals and materials sectors are under immense pressure to modernize, decarbonize, and diversify. Yet, many core capabilities such as the ability to apply the AI-enabled exploration and low carbon mining, utilization of lean/low-grade resources of iron ore, reduction in ash content of the coal, ways & means to reduce the carbon emission in steel production, beneficiation/enrichment/separation of critical minerals for clean energy, electric vehicles & technological advancements, holistic & sustainable utilization of industrial wastes, the reuse and recovery of critical minerals from electronic and clean energy equipment waste, ability to manufacture advanced & strategic materials including high purity semiconductors needs to be developed for our country's goal for Atmanirbhar and VIKSIT BHARAT .

The CSIR through its 4M theme, envisions a bold leap forward by 2042 to reimagine how India mines, manufactures, and builds. By leveraging the power of AI, Machine Learning (ML), automation, innovative & economically viable processing and materials science, CSIR aims to lead India into an era of technologically advanced intelligent and sustainable industrialization.

Intelligent Mining System & Underground Coal Mining Solutions

One of the cornerstone missions under CSIR@100 is the development of a fully integrated Intelligent Mining System. This system will harness AI/ML algorithms to enable predictive maintenance of equipment, real-time hazard detection, resource mapping, and automated operations—ushering in a new age of safety and efficiency in India's mines. With over 600 coal mines and more than 1 million people working in the Indian mining sector, the transformation will impact millions of lives and significantly reduce mining related fatalities, which currently average more than 100 per year.

In the short term, by 2027, CSIR will deliver a comprehensive underground coal mining solution, integrating indigenous equipment, process designs, and world-class safety protocols. This will form the foundation for broader deployment across both public and private mining operations, reducing import dependence and modernizing India's underground mining sector.

Clean Coal & Coal Dust Utilization Systems

Recognizing that coal will continue to be a critical part of India's energy mix for the foreseeable future, CSIR is committed to decarbonizing the extractive industries. CSIR will develop clean coal & non-Coking to coking coal from Indian resources which will help in decarbonization of steel production in tune with the National Steel Policy,2017. To introduce circularity CSIR will develop nitridebased fertilizers from coal ash, coal washery rejects and coal gasification.

CSIR will develop and deploy Coal Dust Utilization Systems that convert coal by-products and chemical wastes into building materials, chemicals, and carbon-based additives. This will be aligned with national missions on clean energy and circular economy, and also tie in with CSIR's Construction Industry Ecosystem (CIE) to ensure industrial symbiosis.

Next-generation Mining Equipment

In parallel, CSIR will drive the development of next generation mining equipment that is sensor-integrated, remotely operable, and AI-powered. These machines will not only increase operational efficiency but also ensure the safety and dignity of miners. Robotics, real-time data analytics, and sustainable battery-powered drive trains will be the hallmarks of CSIR's mining equipment of the future.

Decarbonization & Green Steel

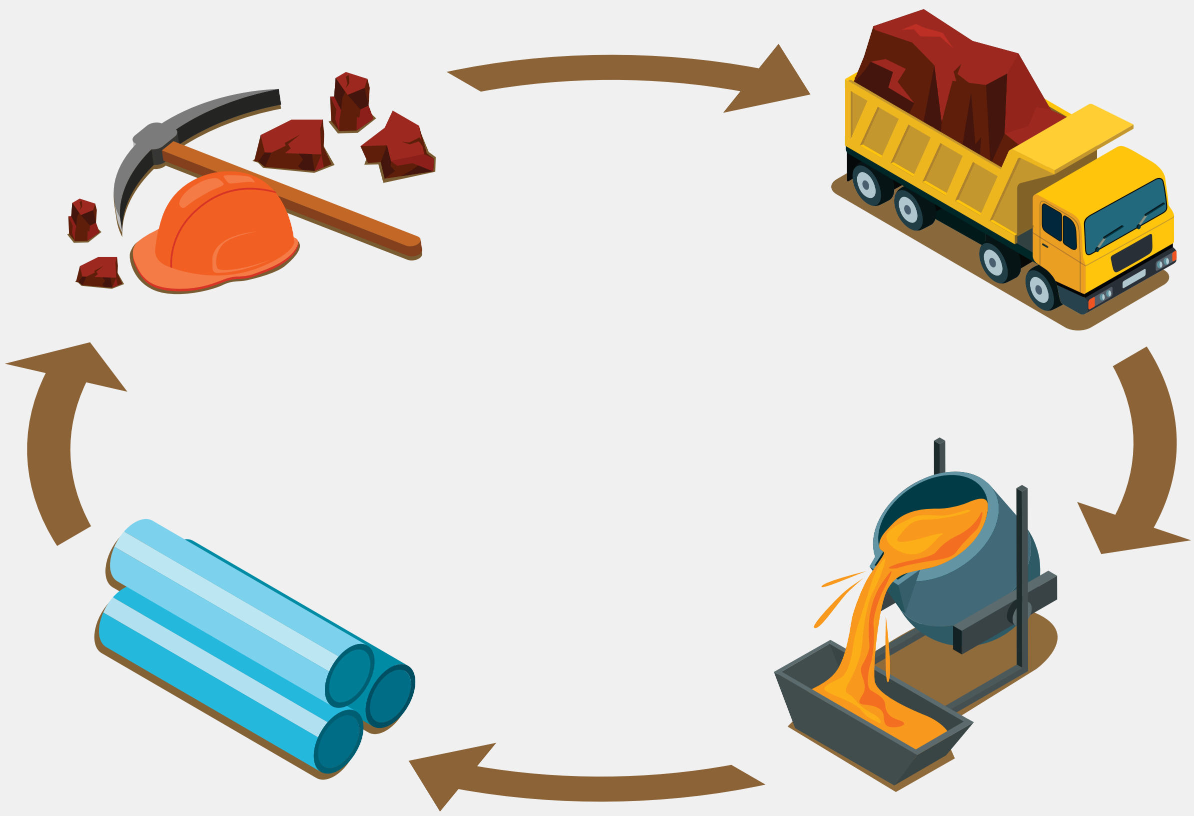
India is the second largest crude steel producer in the world, with a capacity to produce 179.5 million tonnes of crude steel and the largest production capacity of sponge iron in the world at 55 million tonnes in FY 2023 -24. Emissions from current steel manufacturing technologies are high, but there is a clear effort to explore avenues for producing green steel. Steel industry has a net zero target by 2070, with green hydrogen-based routes accounting for 71% of the total production among others while completely phasing out the coal-based routes. The major challenge for the production of green steel is due to the increase of lean and low grade of ores in India. Therefore, the present focus of CSIR is to develop technologies for lean and low-grade ore processing of Iron, Coal and others for the decarbonization and production of green steel. CSIR is working closely with Ministry of Steel and invested for the creation of infrastructure like Coal Gasification Pilot Plant, Pilot scale Coke Making Tunnel Furnace, Straight Grate Pelletization Pilot Plant, Pilot scale Rotary Klin, Vertical shaft Pilot plant with special funding and all would be operational by 2026. CSIR will developing technologies for the decarbonization & green steel in phase wise manner. The Enrichment /Beneficiation of low-grade Iron resources, Dry beneficiation of Iron Ore/Coal Biochar for DRI, Syngas based DRI by 2030 -32, Natural Gas based DRI, Electrowinning Process, Plasma Processing & Molten salt electrolysis by 2035-37 and Hydrogen based DRI and Electrowinning/electrochemical Processes & Plasma Processing & Molten Salt electrolysis by 2042-44.

Mining, Materials, Minerals Metal @ CSIR 2042

- Intelligent Mining System
- Coal Dust Utilization Systems
- Underground Coal Mining Solution
- Semiconductor-grade Silica
- Next-generation Mining Equipment

Critical Minerals and Materials

India aims to become a global leader in sustainable mining and critical mineral value chains and has announced National Critical Mineral Mission (NCMM) in 2023 by Ministry of Mines wherein they identified 30 critical minerals which is central for our country's programs on energy transitions, electric vehicle and other high-end technologies. CSIR is working very closely with Ministry of Mines & NITI AYOG. CSIR is running Mission programs on Lithium from Indian Deposits, Battery to Battery and Mapping & Tapping of Critical Minerals and a new mission will be launched very soon on Solar Panels, Electronics & Solar Cells to Sustainable Materials (SEAS). The focus is on to developing process technologies for Ti, REEs, (Significant Reserves), Cu, Zn, Pb, Mn, Cr, Mg, Sn,



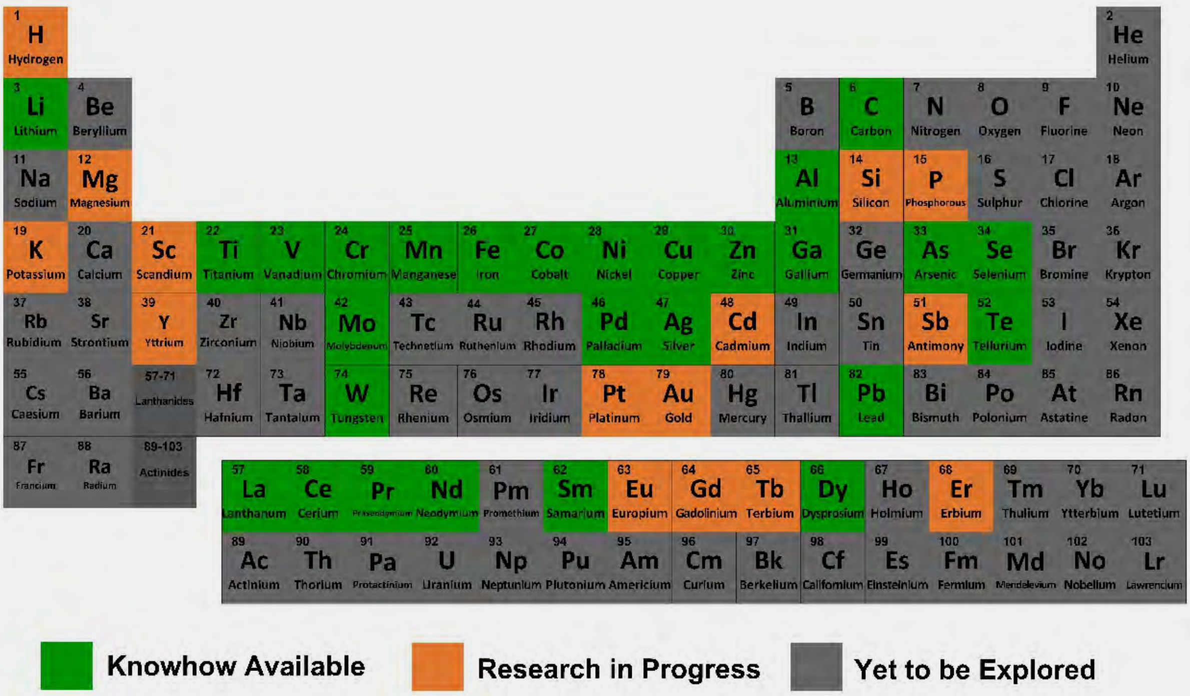
Nb, Ta, (Limited reserve) Co, Ni, W, Mo, Sc, Li, Se, Te, V, Ga, In, PGE (Au, Pd, Pt, Rh, Rd) from both primary & secondary sources. The secondary resources include Red Mud, Fly ash, Overburden, Tailings etc. The goal of the focussed R&D is to develop critical mineral beneficiation, enrichment, separation and process technologies. Pilot Scale Molten Salt Electrowinning of Light Metal and Rare Earths, Pilot Retort Process (Pidgeon) for Mg metal extraction and Solvent Extraction (SX) Pilot Plant for REE Separation are being installed at CSIR for Critical Minerals. By 2042 CSIR will aim to develop pilot processes for at least 8 Critical minerals while build capacity in all the identified critical minerals of the country. CSIR is also partnering with GSI, KABIL, other nonferrous industries and Start ups to make India Atmanirbhar in critical minerals value chain.

Advanced, Strategic Materials & Semiconductor-grade Silica

The advanced materials market in India was valued at US$5 billion in 2021 and is expected to grow at a CAGR of about 10-12% owing to India's focus on sustainable development and cost-effective solutions and emphasis on the manufacturing sector. To become self-reliant in advanced, strategic & functional materials and device development and also to emerge as a major manufacturing hub of the world, the R&D focus must be on advanced material research especially materials for Semiconductor & electronics, renewable energy & quantum technologies. CSIR is developing FIBER LASER Broadband Source BASED OCT, Phase change material, Materials for Optoelectronics & Energy, Functional Coatings deposits, Graphene & derivates, Mxene & 2D Materials, Sensors for defense /steel/ pellets, electronics sorting, Graphene nano platelets, Bio composites, stealth materials, Aluminium Alloy, High Strength Steel, Metal Foam & multifunctional glasses towards self-reliance.

Another critical dimension of the 4M theme is materials—particularly semiconductor-grade silica, a sector where India is rich in raw materials but poor in high-purity production capabilities. Despite India having some of the largest silica reserves globally, the country currently imports nearly 100% of its semiconductor grade wafers, with purity levels such as G9 and G10 (99.9999999%) being essential for electronics, defence, and space applications. CSIR will take up the national challenge to establish indigenous capability for producing high-purity silica. This aligns with India's Semiconductor Mission and is critical for Atmanirbhar Bharat in high-tech manufacturing.

By 2042, CSIR aims to build a resilient ecosystem where India is no longer just a raw material exporter but a technology creator, product developer, and strategic supplier of advanced materials and machinery to the world. The transformation will be powered by CSIR through a fusion of science, engineering and innovation, ushering in a new era of prosperity, sustainability, and global leadership for India.



Conclusion

As CSIR approaches its centenary in 2042, its vision is not just about keeping pace with global science and technology, but about shaping the future India deserves—resilient, inclusive, sustainable, and sovereign. Through the strategies and thematic roadmaps outlined in this document, CSIR aims to deliver tangible, high-impact outcomes for India's citizens, industry, and environment. This vision is rooted in our scientific legacy, yet boldly reoriented toward the challenges and possibilities of the coming decades. The CSIR@100 roadmap is more than a plan—it is a collective call to action. It invites every CSIR laboratory, every scientist and partner institution, to align their strengths and aspirations with the nation's grand objectives. With structured investments, policy alignment, and institutional agility, CSIR is confident of transforming from a great scientific organization into a global leader in innovation, technology, and nation-building. Together, we will build a future where India not only solves its own challenges through science, but also leads the world by example.

Annexure I

List of Phytochemicals for the production through Synthetic Biology and Biomanufacturing platform		
Sl. No.	**Compounds**	**Uses**
1.	γ-Decalactone	Flavor and fragrance industry
2.	Santalol	Aroma and fragrance industry
3.	β-amyrin	Chicken feed, immunity booster
4.	valencene	Flavour and fragrance industry
5.	Silymarin	Anti-oxidant and hepatoprotective agent
6.	Morphine	Analgesics
7.	Scopolamine	Anticholinergic agent
8.	Reserpine	Adrenergic blocking agent
9.	Hyoscyamine	Treatment for gastrointestinal (GI) tract disorders
10.	Betalains	Antioxidant used in food and nutraceuticals

Annexure II

List of crops envisaged for improvement of traits associated with climate resilience		
Sl. No.	**Name of the crop**	**Traits**
1.	Mint species	Water & nutrient use efficient, drought tolerant, low water required, short duration, high yielding verities/technology
2.	Tulsi (*Ocimum* species)	Cold stress, salinity stress, water & nutrient efficient, high moisture tolerant, short duration, high yielding varieties
3.	Ashwagandha (*Withania somnifera*)	Rain fed, drought, all season growing, quality & high root yielding verities/technology
4.	Vetiver (*Chrysopogon zizanioides*)	Rain fed, drought, salinity, flood, heat, short duration, energy and time efficient processing, high root and oil yielding verities/technology
5.	Saffron (*Crocus sativus*):	Temperature sensitivity for adaptation to warmer temperatures
6.	Tulip (*Tulipa gesneriana*)	Temperature sensitivity for adaptation to warmer temperatures
7.	Amaranth (*Amaranthus hypochondriacus*)	Cold stress resilience
8.	Milkweed (*Asclepias syriaca* L.)	Indigenous enhance fiber production; Pan-India production in all climate
9.	Lotus (*Nelumbo nucifera*)	Year-long flowering, fragrance
10.	Rice (*Oryza sativa*)	Biotic and abiotic stress tolerance
11.	Apple	Low chilling, virus rot free
12.	Lemon grass	All terrain

Annexure III

Civil and Infrastructure Engineering Roadmap			
Focus Area	**Short Term (5 years)**	**Medium Term (10 years)**	**Long Term (17 years)**
Advanced Materials	Development of Smart & Self Healing coating	Pilot scale application in real systems	Commercialization of indigenous coatings
	Phase Changing Material (PCM) development	Real field testing, Validation and Simulation	Industry transfer & Commercialization
	Development of Graphene & CNT reinforced Composites material	Property evaluation & development of component as per design/performance requirement	Evaluation under real condition and its commercialization
	Development of Radiation Shielding and Geo-polymeric construction materials	Property evaluation and pilot scale production and prototype demonstration	Up-scaling, testing in real condition and its commercialization
	Development of Advanced concrete materials	Property evaluation, up-scaling & development of infrastructure component	Testing in real condition and its commercialization
Buildings	Material development for smart villages	Pilot scale production & its property evaluation based on its application	Evaluating performance in real condition and its commercialization
	3D printed building component with recycled & bio-based materials	Upscaling of the process for pilot scale 3D printing of building and its performance evaluation	Real condition evaluation & further commercialization

	Development of smart material for Smart Facade application	Design of material/prototype component and its response time evaluation	Modifications in the design based on the feed back and its commercialization
Mobility & Road Infrastructure	Development of modular road panels for rapid installation with using waste materials	Property evaluation, up-scaling & development of road panels	Testing in real condition and its commercialization
Structures	Design of Material for Noise Abetment & establishment of testing facility	Performance evaluation of its acoustic properties and design change based on the feedback	Performance in actual condition and know-how transfer
	Development of metallic foam material for Defense Infra-structure	Characterization of metallic foam, development of sandwich panel & its characterization	Development of prototype structure, its evaluation and know how transfer
Manufacturing and Robotics	Development of Additive manufactured Infrastructural component & establishment of facility	Demonstration of 3D printed component at pilot scale, evaluation of its strength & Design modification	Performance evaluation & up-scaling of process and know-how transfer
	Development of green engineered materials & its synthesis process	Property evaluation and pilot scale production	Up-scaling, testing in real condition and its commercialization

Annexure IV

CSIR's Energy Roadmap			
Theme	**Sub-Theme**	**Target/Action**	**Timeline**
Green Hydrogen	Hydrogen Production	Develop low-cost electrolytes and prototypes of PEM, AEM & SOEC	2028
		Capex & Opex comparison and industry commercialization commitment	2030
		CSIR as nodal agency for Green Hydrogen	2035
	Hydrogen Storage	700 bar Type IV cylinder with 5.5 wt% capacity	2028
		Industry commercialization of 700 bar Type IV cylinder	2030
		Metal hydride-based storage with ~5 wt% capacity	2030
		High entropy alloy storage with 3 wt% capacity	2035
	Hydrogen Utilization	Fuel cell component scaling with industry	2030
		Prototype fuel cell meeting global benchmarks	2035
		Selective catalytic reduction of NOx in hydrogen ICE	2028
		Commercialization of indigenous SEC tech	2035
Energy Storage	Batteries	Benchmark CSIR LiB and ToT for commercial production	2028
		Develop indigenous SiB and ToT for commercial production	2035
		Develop Redox batteries (Vanadium & Zn Br) and ToT	2035
		Develop metal air batteries (Al-air, Zn-air) and ToT	2035
		New generation supercapacitors to global benchmarks	2030
Bio Fuels	SAF	HEFA-based SAF commercialization	2027
		CSIR-IIP nodal institute for SAF	2030
	Bio-Gas	Anaerobic Gas Lift tech producing 100 TPD biogas	2030
		Advanced VPS tech to purify 100 TPD biogas	2030
	Bio-Diesel	Room temperature bio-diesel tech in 100 plants	2030

Renewable Power	Solar	Agri-photovoltaics demo and implementation	2030
		Perovskite-based solar cells to global benchmark	2035
		Dye-sensitized solar cells and ToT	2035
	NZEB	Building-integrated photovoltaics incl. indoor PV	2030
		Commercialization of energy-saving smart glass	2028
		Thermoregulating tiles and roofing	2035
		Smart flooring for energy generation	2035
		Indigenous energy-efficient lighting tech	2030
		Thermoelectric waste heat recovery and ToT	2030
Alternate Fuels	Waste to Fuel	Commercialization of plastic to fuel (10 TPD x10 plants)	2026–2030
	CO_2 Utilization	CO_2 to SAF technology	2030
	Methanol/DME	MeOH to DME commercialization (100 TPD)	2035
		CO_2 to MeOH commercialization (100 TPD)	2035

Annexure V

CSIR's Ecology, Environment & Sustainability Timeline	
Timeline	**Key Initiatives**
2025	• End-to-end integrated solid waste management solutions • Compact sewage and faecal waste treatment units • Biomedical waste management • Bio-mining of legacy waste • Mechanized drain cleaning system • Utilization of construction and demolition waste
2030	• Odour control technologies • Separation of pollutants/CO_2 and valorisation • Integrated demonstration plant for zero-discharge system • Carbon neutral leather • Development of India-specific GHG emission factors (EFs) for MSW
2035	• Waste to energy and plastic waste valorization • AI enabled sensor network for surveillance • Wastewater management in polluted water bodies like rivers, drains, and nallahs in urban and rural areas • Integrated WTE hubs in smart cities
2040	• Pollution control methods for Urban regions • Direct air carbon capture system • Chemical and biological processing of organic waste • Waste-linked carbon credit systems • Human exposure analysis and health risk assessment including fugitive emissions
2042	• Indigenous self-reliance in waste-to-resource • Conversion of MSW organics to biochar, biohydrogen, biofertilizer • Habitat restoration and ecological connectivity • Low-carbon and nature-positive infrastructure planning

	NZEB	Building-integrated photovoltaics incl. indoor PV	2030
		Commercialization of energy-saving smart glass	2028
		Thermoregulating tiles and roofing	2035
		Smart flooring for energy generation	2035
		Indigenous energy-efficient lighting tech	2030
		Thermoelectric waste heat recovery and ToT	2030
Alternate Fuels	Waste to Fuel	Commercialization of plastic to fuel (10 TPD x10 plants)	2026–2030
	CO_2 Utilization	CO_2 to SAF technology	2030
	Methanol/DME	MeOH to DME commercialization (100 TPD)	2035
		CO_2 to MeOH commercialization (100 TPD)	2035

Annexure VI

Mining, Minerals, Metals and Materials Roadmap			
Research Domain	**Short Term, 2030**	**Medium Term 2036**	**Long Term 2042 & beyond**
Intelligent Mining System	Classification and analysis of ore lumps and fines using computer vision and machine learning. (Online)	Cloud-based software to optimize the instrumentation plan, analyze multiscale ground monitoring data and and suggest ground control measures	Big Data Analysis based Machine Learning algorithm to continuously optimize blast design parameters Physics-Informed Machine Learning (PIML) technique for predicting ground failures in underground mining
Next-generation Mining Equipment	Capacity Sensor-integrated, remotely operable, and AI-powered	Pilot: Capacity Sensor-integrated, remotely operable, and AI-powered	Robotics, real-time data analytics, and sustainable battery-powered drive trains
Underground Coal Mining Solutions	Underground coal pillars Mapping of inaccessible old abandoned underground mine Post-mining accelerated reclamation Pipeline Transport for decarbonization	Sustainable & Environment friendly Mining Sustainable potash fertilizers from mine waste and glauconite. Post-mining accelerated reclamation in coal mining Pipeline Transport Rock Excavation Engineering	Autonomous longwall and pillarless underground mining system for more than 90% recovery CCUS Intelligent Mining Systems / Paste Backfilling in Mines
Clean Coal & Coal Dust Utilization Systems	Clean Coal Coal Dust into building materials, chemicals, and carbon-based additives	Clean Coal Coal Dust into building materials, chemicals, and carbon-based additives	Non-Coking to coking coal Coal Dust into building materials, chemicals, and carbon-based additives
Decarbonization & Green Steel	Enrichment /Beneficiation of low grade Iron resources Dry beneficiation of Iron Ore/Coal Biochar for DRI Syngas based DRI	Dry Beneficiation of iron ore Coal Syngas based DRI Natural Gas based DRI Non Coking coal to coke Electrowinning Process Plasma Processing & Molten salt electrolysis	Hydrogen based DRI Non Coking Coal to coke (scale up) Electrowinning/electrochemical Processes Plasma Processing & Molten Salt electrolysis
Critical Minerals and Materials	Li, PGE, REEs, Cu, Se, Co,	Li PGE REEs Cu Se Co Ni, Nd, Si, Mg, phosphate	Other Critical Minerals as per value chain

form Primary Sources	Ni, Nd, Si, Mg, phosphate Flow sheet /Extraction Additives & Chemicals for extraction, separation Equipment & Instruments	Flow sheet /Extraction /Scale up Additives & Chemicals for extraction, separation Equipment & Instruments	
Critical Minerals and Materials From Secondary	Holistic utilization of mine waste tailings rejects electronics home appliances waste Geopolymer Red Mud Values Pilot Plant Critical from Flyash	Holistic utilization of mine waste tailings dumps slims washery Recovery of value from spent graphite electrode Fused magnesia from kimberlite tailings Critical from Flyash Red Mud Values Pilot Plant	Recovery of REEs & Other valuables from Other Indian Resources Holistic utilization of mine waste tailings dumps slims washery Pilot Process for Utilization of carbonaceous waste for metallurgical applications
Advanced, Strategic Materials & Semiconductor-grade Silica	Phase change material Materials for Optoelectronics Functional Coatings deposits Graphene & derivates, Mxene & 2D Materials Sensors for defense /steel/ pellets Graphene nano platelets Mxenes Parali and other hybrid composites Multifunctional glasses with tailored properties High performance fiber laser pushing the boundary of (i) high CW power (5kW) for defense (ii) Narrow-linewidth (~1 kHz) for precision metrology (iii) Ultrafast fiber laser (<60 fs) for THz spectroscopy Indigenous visible-near IR Optical Coherence Tomographic (OCT)	Phase change material Materials for Optoelectronics Functional Coatings deposits Additive Manufacturing of high performance alloys & composites Superhydrophobic/self healing & stealth coatings Fiber reinforced composites, Biocomoisites Graphene & derivates, Mxene & 2D Materials Sensors for defense /steel/ pellets Graphene nano platelets Mxenes Visible-near IR portable OCT system for medical imaging and diagnostics	Powder for Additive manufacturing Specialty Coatings Materials for sensors, energy devices 2D devices and appliances Laser for Surgery, Diagnostics 3D terrain mapping for Agriculture and earth health, Quantum Technology Mid-IR supercontinuum-based OCT system for medical imaging and diagnostics

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