ANNUAL REPORT
2020/21

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Annual Report 2020/21

DIRECTOR **GENERAL'S MESSAGE**

The year 2020-21 has been unprecedented and immensely significant. Ever since the outbreak of COVID-19 in 2020, there has been a paradigm shift in our outlook. Worldwide, the virus has remained powerful, with its mutations emerging in several parts of the world. Despite obstacles and challenges, specifically in the context of COVID-19, The Energy and Resources Institute (TERI) in 2020-21 continued its ongoing activities and initiated many new programmes that are within its vision and mission. Through a synthesis of its Division-based areas—energy, natural resources and climate, integrated policy analysis, sustainable habitat, social transformation, environmental and industrial biotechnology, and sustainable agriculture—and Programme-driven research activities, the Institute continued in its effort towards achieving sustainable development. The information technology, services and spirited coordination made it possible for colleagues to work from home during the lockdowns and when COVID cases were on the rise. It enabled online meetings or collaborations and integrated people, contents, and tools. The support services fostered TERI's commitment to generate new knowledge and stay ahead in its research and other related activities. The support units—administrative services, human resources, and of course, information technology have proved to be important pillars to TERI's research efforts.

Human activities and the expansion of economic footprint have been expanding beyond the capacity of the Earth's ecosystems. Energy is the pillar of any country's socio-economic development, and over the years, the growth in the sector has been sustained through changes and variations in both the demand and supply sides. Beyond the COVID-19 outbreak, the adoption and promotion of clean-energy solutions remain the top-most priority of every nation. India, too, is trying to balance its increasing requirements for energy while simultaneously minimising the adverse environmental impacts that result from increased resource extraction, power generation, and energy usage.

The Energy Programme at TERI focuses on supporting the transformation of the nation's energy sector on both supply and demand sides by fostering development and deployment of adequate, dependable and affordable supply of clean and renewable energy (RE) as well as by promoting energy-efficient technological solutions and practices for end-users in diverse sectors of the economy. Through the Energy Transitions Commission (ETC) India work programme, the team at Energy Programme has developed a robust understanding of the factors that will drive the transition of the Indian energy sector towards cleaner technological solutions. TERI's focus under the ETC India work programme is on developing pathways for decarbonisation of the electricity sector and the harder-to-abate industry sectors.

During 2020-21, the Electricity and Fuels Division continued to work on smart distribution with storage, which was commenced in 2017. The collaborative project aims at addressing essential issues related to the adoption and deployment of smart grid concepts along with distributed energy resources (DERs), including storage in the distribution network, installation of grid-scale battery energy storage systems (BESS) on distribution feeders, catering to three categories of consumers—residential, institutional, and gated apartments—so as to demonstrate various use-cases of

energy storage. The Division pursued its research activities for various stakeholders in the country in order to support them in addressing various challenges. The Renewable Energy Technology (RET) Division has maintained its focus on research and development, project implementation, policy research, and consultancy services, besides select training and capacity-building activities. Over the years, the Industrial Energy Efficiency (IEE) Division has been working closely with the corporate sector and provides services to both large and small industries to improve their energy performance. During the year 2020-21, IEE provided consultancy services to international clients in Guyana, Mexico, and Pakistan. It also expanded its ongoing knowledge collation and dissemination activities under the SAMEEEKSHA (Small and Medium Enterprises Energy Efficiency Knowledge Sharing) platform.

During 2020-21, TERI worked on new solutions in remediation of contaminated environments, minimise the waste release and created pollution prevention alternatives by utilising living organisms. In partnership with various industries, the Environmental and Industrial Biotechnology (EIB) Programme has been finding out sustainable solutions to climate change-related problems by identifying bacteria for the production of cost-to-cost, cleaner energy forms, for carbon capture and storage that would displace the methane on coal seams with carbon dioxide, developing technological solutions to emerging micropollutants, extraction of essential oil, food-testing services, and promotion of organic cultivation, specifically in the tea sector. Oilzapper product was developed after seven years of extensive research work sponsored by the Department of Biotechnology, Government of India, for clean-up of oily sludge, oil spills, and treatment of hazardous hydrocarbon waste. The Bioremediation Technology area set up industrial-scale and industrial bioreactor facilities at Gual Pahari.

TERI in collaboration with Korea Maritime and Ocean University, South Korea, developed the hybrid system called 'up-flow anaerobic bioelectrochemical system' (UABE) for the enhanced methane production from distillery wastewater. The Microbial Biotechnology (MB) Area is actively engaged in exploring sustainable approaches for protection of environment, development of innovative technologies and alternate renewable energy production for commercial application. TERI has developed and demonstrated the microbial process for enhancement of gas in CBM well at Jharia. The microbial and stable gas isotope analysis data support the stimulation of microbial communities and in-situ biological gas production. The Biotechnology area at TERI-NE, Guwahati, installed anaerobic digesters in 100 days in schools and hostels in the eight north-eastern states for sustainable faecal sludge management in rural schools. The area conducted capacity-building workshops for elected representatives of Assam, Manipur, Tripura, Jamshedpur and Imphal. The Advanced Biofuels Programme is actively exploring to produce next-generation biofuels and high-value renewable raw materials in a sustainable manner, to achieve make these processes economically viable. The Advanced Biofuels Division is exploring to develop clean technologies for production of biofuel and renewable materials by using 2nd and 3rd generation feed (lignocellulose biomass, algae biomass, spent organic matter, livestock manure) as raw material. To achieve the goal this division's research thrust focused on the following thematic areas: microbial biofuels and biochemicals and pyrolytic biofuels, biochar, and green chemicals.

Resource efficiency, being the key agenda of TERI, continued to remain in focus. The Centre for Resource Efficiency and Governance (CREG) completed a study on 'Developing a Carbon Neutral Resource Efficient Strategy for Ladakh UT'. The study focused on developing a climate-resilient and resource-efficient green development strategy for the region. The Division also initiated a study on 'India-Australia Industry and Research Collaboration for Reducing Plastic Waste to Develop New Technologies and Business Models to Innovate Plastic Supply Chains'. The Division also organised several diginars, including the one on Blue Economy, Resource Efficiency, and Energy Security, a subject that is gaining importance in India. The Centre for Integrated Assessment and Modelling (CIAM) completed a study where the team was closely engaged in providing inputs to the MoEFCC, Government of India, through its study on long-term low-carbon development strategies for India.

TERI leads work on the various dimensions of climate change and cross-cutting themes. In the context of building climate resilience, its Natural Resources and Climate (NRC) Programme spearheads research in providing innovative and resource-efficient solutions for the management of water resources, waste resources, and bioresources, thereby aiming to become a global leader in providing scientific knowledge and solutions; and conducts on-field programmes to eradicate malnutrition from rural and urban areas of India. Earth Science and Climate Change, Land Resource, Environment and Waste Management, Water Resources, and Nutritional Security constitute the five divisions under the NRC Programme, leading work on various dimensions of climate change and cross-cutting themes.

The Centre for Global Environment Research (CGER) is working closely with the Ministry of Finance on various emerging discussions on climate finance under the UNFCCC and tracking climate finance flows from various sources. Further, as one of the key implementation partners of the SNAPFI project, the Centre has been working on exploring the role of international climate finance towards the implementation of NDCs in different geographies. The Centre in collaboration with the Union Territories of Chandigarh and Puducherry and the state of Uttarakhand, revised their State Action Plans for Climate Change. It has developed a flood early warning system for the cities of Guwahati and Jorhat in Assam besides contributing to the work on mainstreaming climate action and disaster risk reduction in the state of Uttarakhand. The Centre, as part of the Indo-German flagship project, Water Security and Climate Adaptation in Rural India (WASCA), is leading the efforts towards providing an evidence base for contextualising climate adaptation measures for enhancing water security in the designated project locations.

The Centre for Climate Modelling (CCM) has successfully provisioned multi-sectoral and multi-scale climate services products designed for various types of stakeholders, for example, first-of-its-kind TERI Climate Tool (TCT) and assisted deployment of flood early warning system at urban scale. It also launched a climate change and migration report for the state of Uttarakhand with its research partners at Potsdam.

The Centre for Environmental Studies has been involved in the pioneering source apportionment study for Bengaluru city and has also been working for many years on the use of state-of-the-art three-dimensional multi-grid air quality models (ISCST3, AERMOD, WRF, C-MAQ, etc.) to predict urban/regional scale pollution of criteria as well as emerging pollutants such as ozone. The Centre has assisted the Ministry of Environment, Forest and Climate Change (MoEFCC) in the preparation of the draft National Environment Policy and has also been recognised by the MoEFCC as one of the National Host Institutes for facilitating the development of State of Environment Reports at the state level.

TERI's Land Resources Division has been focussing on sustainable management of forest ecosystems, mitigation of land degradation, and conservation of biodiversity for over two decades. TERI conducted several studies with respect to the economic valuation of ecosystem services in 2020–21. Some of the notable ones include economic valuation of ecosystem services of National Zoological Park in Delhi, valuation of ecosystem services provided by Sardar Patel Statue of Unity in Gujarat and 35 other attractions within the complex, and the World Bank-supported economic valuation of mountain forests and mangroves in the Kingdom of Saudi Arabia.

TERI has been recognised as the Centre for Excellence and has been assigned the responsibility of developing governance models for the implementation of Community Forest Resource Rights under the Forest Rights Act, 2006. The Centre for Forest Management and Governance implemented the Pilot Forestry NAMA in Assam with a major focus on sustainable fuelwood management. TERI undertook two projects of Hindalco industries for reclamation/rehabilitation of red mud waste in Jharkhand and Uttar Pradesh. The primary objective of the research was to convert the inhospitable substrate of red mud into a favourable one by enhancing its Physico-chemical analysis, followed by standardising vegetation protocol through developing green cover at the project location. The Institute has also proposed to initiate a voluntary carbon market project for Sundarban

Tiger Reserve in West Bengal, India, to generate additional finance, which can be used for community welfare and biodiversity conservation. This strategy can be replicated in all tiger reserves and protected areas in India, which will help the country achieve its NDC target of 2.5–3 billion tonnes of CO_2 e. TERI's Coastal Ecology and Marine Resources Centre is working on a project on Deep-Sea Mining (DSM). It will further our understanding of DSM in the Indo-Pacific region. In addition, the Centre has been organising workshops, training programmes, and seminars regularly.

TERI's Western Regional Centre (WRC) located in Mumbai, has been dedicatedly working to provide pertinent, independent, and objective-oriented research in the broad fields of nutrition, energy, climate change, environment, bio-prospecting, sustainable communities, and livelihood. The Division initiated a project to improve the immunity and nutrition of tribal women and their families in Palghar district, Maharashtra. The project focused on the capacity building of self-help groups (SHGs) and the youth from the tribal areas.

The Environment and Waste Management Division successfully completed RECP implementation in 400 metal enterprises in Bangladesh, Nepal, and Sri Lanka. During 2020–21, under the NAMA project, it prepared baseline assessment reports and IEC awareness reports for Varanasi and Panaji. The Division also conducted independent audits for waste management services across East Delhi, South Delhi, and North Delhi Municipal Corporations to identify gaps, which helped the corporations in waste minimisation resource optimisation, and also made them aware of issues related to regulatory compliance. It focuses on building various forms of information tools and knowledge-sharing mechanisms to address health challenges linked to climate change in partnership with the National Health Mission.

The Environment and Health area has created a new index—Child Health Index, using principal component analysis of district-level data taken from NFHS-4, which include key health parameters such as stunting, wasting, underweight, anaemia, and diarrhoea in the most vulnerable age group (below five years). In the current pandemic scenario, TERI, along with associated partners, contributed to the development of Standard Operating Procedures for Wastewater-based epidemiology for SARS-CoV-2 testing, which can help in early detection of the virus, thereby improving the preparedness towards future outbreaks.

The TADOX® Technology Centre for Water Reuse (TTCWR) is a dedicated new area in the Water Resources Division of TERI. The area works towards R&D, technology development, and transfer and implementation of TERI's Advanced Oxidation Technology called TADOX®, training and capacity building, research leading to PhD, publications, policy interventions, and contributing to the missions of national importance such as 'Namami Gange', 'Self Reliant India', and others.

The Rural Energy and Livelihoods (REL) Division of TERI's Social Transformation Programme is active in a wide spectrum of fields, including technology design and customisation, skilling, action research, business model development for livelihood opportunities, pilot implementation of renewable energy-based solutions for quality and reliable power, livelihoods.

The Centre for Impact Evaluation and Energy Access (CIEEA), is engaged in assessing opportunities and challenges for social and gender inclusion and community participation in various renewable energy activities, including offshore wind energy, solar PV, water-energy-food nexus, and ecotourism for developing robust protocols and guidelines to develop just energy systems.

The Centre for Impact, Evaluation and Energy Access, Bangalore (CIEEAB) has been working with rural communities on aspects such as renewable energy, watershed development, women empowerment, social inclusion, livelihoods, and evaluation of corporate social responsibility interventions. CIEEAB completed an interesting and challenging evaluation of the Compensatory Afforestation Fund Management and Planning Authority Programme (CAMPA), 13th Finance Commission (TFC), National Afforestation Programme (NAP) and the National Bamboo Mission (NBM) schemes for Karnataka Forest Department. TERI's decade long programme 'Lighting a Billion Lives (LaBL)' programme has impacted more than 5.7 million lives in 24 States

of India and 13 countries worldwide through distributing over 170,000 solar lanterns, 100,000 indigenously developed improved cookstoves, 58,000 TERI-designed integrated domestic energy systems, 36,000 solar microgrid connections, and 7600 home lighting systems, among others, besides creating more than 3000 green jobs.

TERI's Sustainable Agriculture Programme has been recognised through national and international conference presentations, multiple awards to PhD students and faculty members. In the last decade, it has produced over 220 research publications in most reputed journals, eight granted patents and five new patent applications and 26 externally-funded projects to its credit and five IPRs.

Regarding enhancing livelihoods of marginal farmers using bio-innovations, TERI has been working at TRISHA (TERI's Research Initiative at Supi for Himalayan Advancement) at village Supi in the Nainital district of Uttarakhand since its establishment in 2003. Our efforts encompass a strategy for enhancing land productivity by using sustainable biotechnological approaches and harmonising modern technologies and traditional knowledge. As far as TERI-NE Centre is concerned, it has been working as the Implementation Support Agency (ISA) under the project titled 'Jal Jeevan Mission-2020' in four Public Health Engineering Departments (PHEDs) in Cachar, Karimganj, and Hailakandi districts of Assam. TERI's Southern Regional Centre (SRC) focus is mainly to support corporates and governments and accelerate energy use efficiency and more effective uptake of renewables to slash emission cuts.

The Sustainable Habitat Programme (SHP) of TERI has been envisioned to catalyse the 'Right to Sustainable Habitat' by mainstreaming principles of sustainability in the fields of buildings, transport, and cities. TERI contributed to the global urban discourse and curated sessions on the implementation of the New Urban Agenda and SDG 11 in South Asian cities at UN's HABITAT III in Quito, WUF 9 in Kuala Lumpur, and WUF 10 in Abu Dhabi. The United Nations Framework Convention on Climate Change, in their third biennial update report on India, recognised GRIHA Council work in the field of energy efficiency, site planning, conservation, and efficient utilisation of resources as the national green building rating system of India. At present, there are more than 2100 projects registered under the GRIHA rating with a green footprint (built-up area) of 650,000,000 sq. ft.

As always, TERI will continue its work on climate resilience, renewable energy technologies, participatory forest management, and knowledge generation. It seeks to retain its global position in pioneering 'smart' urban development solutions, environmental monitoring and modelling, sustainability in agricultural practices and water management, and application of modern biotechnology in daily life. In the past year, the Institute tried to acquire several new skills to stay motivated and relevant in this ever-changing world. We will continue to build strong collaborations with bilateral and multilateral agencies and like-minded bodies so that we are at par with the global knowledge base.

TERI is a premier think tank and research institute with state-of-the-infrastructure and specialisation in multi-disciplinary areas pertaining to Environment, Climate Change, Energy, Resources, and Sustainability. Its resilience and vibrancy are time-tested. All these points make TERI unique and one-of-its-kind.

TERI'S **GOVERNING COUNCIL**

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Chairman

Shri Vijai Sharma

Dr Shailesh Nayak

Shri Nawshir H Mirza

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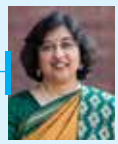

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Distinguished Fellow Emeritus

Mr Dipak Dasgupta
Distinguished Fellow, Earth Science and Climate Change

Dr Vibha Dhawan
Distinguished Fellow & Senior Director, TERI

Dr Prodipto Ghosh
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Air Commodore (Retd) M M Joshi
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Mr S Vijay Kumar
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Mr Ajai Malhotra
Distinguished Fellow and Senior Advisor (Climate Change), Project Management Unit

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Mr K Ramanathan
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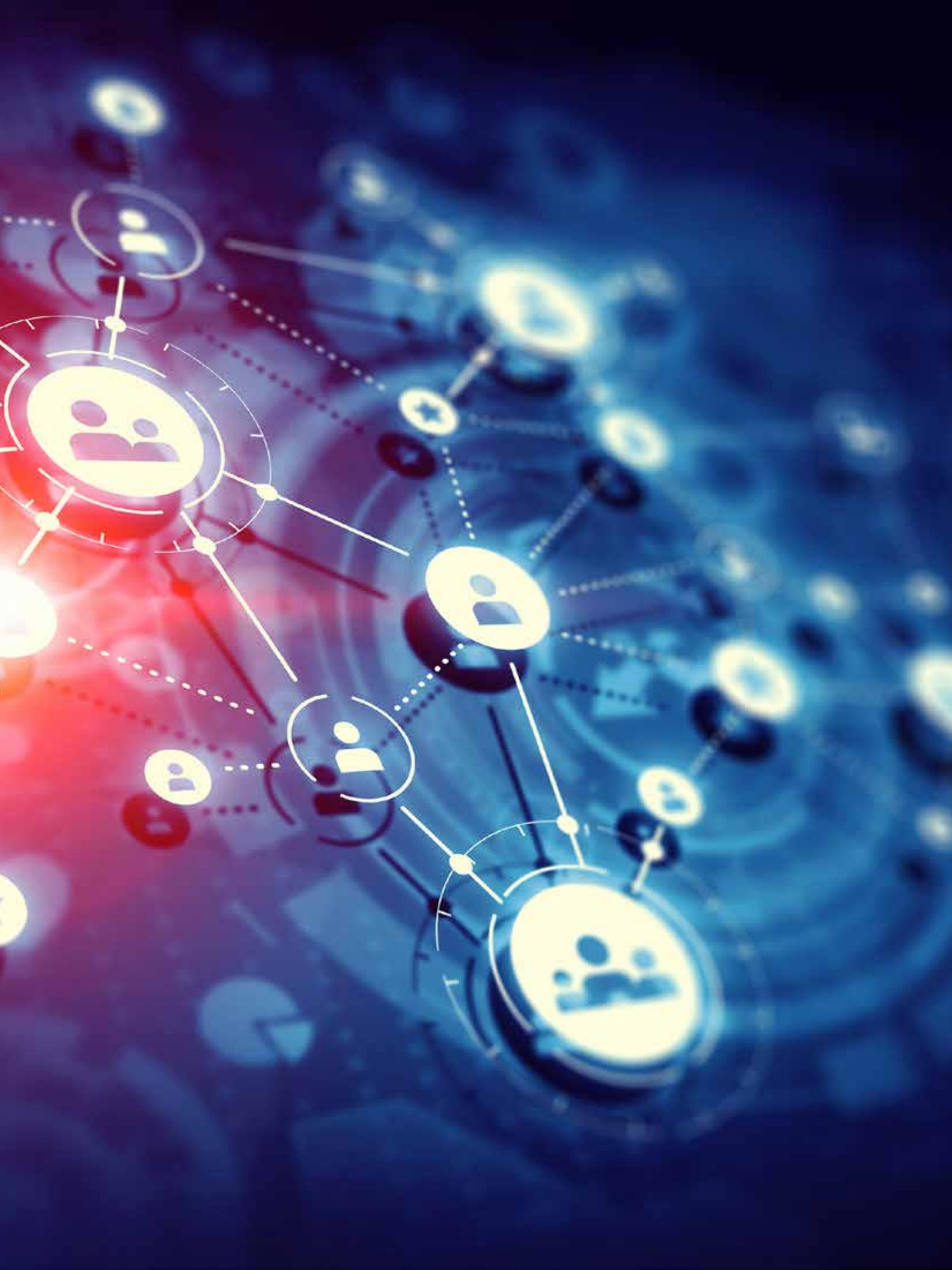
RESEARCH PROGRAMMES



Energy

Energy is a vital input for production and growth; it drives socio-economic development. As India continues on a path of rapid expansion and growth in every sector of its economy—industry, agriculture, residential, transport, etc.,—the challenge before the country is to meet the increasing requirements for energy while simultaneously minimizing the adverse environmental impacts that result from increased resource extraction, power generation, and energy usage.

The Energy Programme at TERI focuses on supporting the transformation of the nation's energy sector on both supply and demand sides: by fostering development and deployment of adequate, dependable, and affordable supply of clean and renewable energy (RE) as well as by promoting energy-efficient technological solutions and practices for end-users in diverse sectors of the economy. Through the Energy Transitions Commission (ETC) India work programme, the team at Energy Programme has developed a robust understanding of the factors that will drive the transition of the Indian energy sector towards cleaner technological solutions. TERI's focus under the ETC India work programme is on developing pathways for decarbonization of the electricity sector and the harder-to-abate industry sectors.

The Energy Programme has three broad divisions, which work in the domains enumerated herein: Electricity and Fuels Division (EFD) carries out policy and regulatory analysis related to the energy sector (electricity, coal, oil, and gas). The EFD primarily focuses on developing low-carbon pathways through detailed demand assessments and emerging supply mix, integrated demand–supply analysis in the medium and long term, integration of RE and smart grid solutions with storage, demand-side management (DSM) and other key issues and challenges in the electricity sector. EFD's efforts feed into technological and policy research, thereby, creating a virtuous cycle wherein supportive policies are framed to encourage and ensure large-scale adoption of clean energy solutions. The Division has considerable experience in regulatory and tariff issues and regularly works with regulatory bodies, public and private utilities, ministries, and government departments.

The Renewable Energy Technologies (RET) Division provides RE-based technological solutions for diverse user-groups in the industrial, commercial and residential sectors, besides working with municipalities/corporations and cities. It has developed and disseminated technologies for conversion of biomass into gaseous

forms for thermal, electrical, and cooling energy applications. The Division also focuses on research-oriented activities, policy research and consultancy projects, especially in the area of solar and biomass. The Division operates NABL-accredited test laboratories for certification as well as developmental testing of solar water pumps and solar lighting systems, besides undertaking training and capacity-building activities in the entire renewable energy space.

The Industrial Energy Efficiency (IEE) Division works closely with the corporate sector and provides energy audit services to clients in sectors such as cement, chemicals, pulp and paper, iron and steel, thermal power plants, food processing, hotels, commercial buildings, public works, etc. Additionally, it works with many energy-intensive MSME (micro, small, and medium enterprises) clusters and provides long-term hand-holding support in terms of adopting energy-efficient technologies and best operating practices. Over the past few years, the Division has also been focussing on assessing the technological pathways for decarbonizing the heavy industry sectors, such as iron and steel including the role of green hydrogen in India's energy transition plans in the long term. The Division works closely with ministries and government departments, multilateral and bilateral institutions, foundations, and other stakeholders in the field of energy efficiency.

Building on its four decades of experience in developing and promoting clean energy solutions, the Energy Programme shall continue to forge strong and synergetic partnerships/collaborations with multiple stakeholders at every level—policy, institutional, academia, industry, and community—in order to maximize the effectiveness of its initiatives and ensure their sustainability. Apart from its focus on India, the Energy Programme also works on promoting clean energy solutions in other parts of the world with a focus on developing countries in Africa and Asia.

Electricity and Fuels Division

Electricity is a critical input for economic growth and development. Over the years, the electricity sector has witnessed substantial growth; the growth in the last few years has been combined with changes in the demand profile as well as in the supply mix. The trend is likely to continue in the coming years. The Electricity and Fuels Division (EFD) of TERI works on cross-cutting themes of the electricity sector with allied focus on fuels such as coal and natural gas. Most of the research, consultancy, and capacity-building activities of the Division pertain to the demand and supply sides of the electricity sector. EFD's efforts feed into technical and policy research, thereby creating a virtuous cycle wherein supportive policy recommendations are made to encourage and facilitate large-scale adoption of clean energy solutions along with deployment of effective techniques and emerging technologies. The Division possesses rich and varied experience in the electricity/energy sector in India and abroad, and has been aiding public, corporate, and international clients on a range of activities. It offers expertise in the fields of power and coal, and has rich experience on regulatory and tariff, policy, and institutional issues. The Division has been closely working with utilities, regulatory commissions, central and state governments, bilateral and multilateral organizations/agencies, including the World Bank, European Union, IEA, MacArthur Foundation, CIFF, GIZ, ADB, JBIC, DFID, USAID, NEDO, IEEJ, ECCJ, SDC, Hewlett Foundation, Bloomberg Philanthropies, among others.

During 2020/21, the Division continued its core area of work on energy transitions, DSM and energy efficiency (EE), smart distribution grids, energy storage, just transitions, integration challenges of intermittent renewables, medium-term and long-term demand forecasting, integrated resource planning, and capacity-building programmes, and has embarked on the application of various emerging technologies such as peer-to-peer (P2P) trading using block-chain, use of artificial intelligence and machine learning, market transformation of electric vehicles (EVs), battery energy storage systems (BESS), etc. The Division's activities have been tailored to fall under the central theme of transition towards low-carbon and energy-efficient pathways and are structured to support and facilitate this transition.

The main thematic areas and important endeavours of the Division are as follows:

Energy Transition: Energy transition is a key focus area of the Division. Studies were carried out on a theme-based platform under the aegis of the Energy Transitions Commission (ETC) India, which was established with the objective to foster deployment of low-carbon pathways in the country. TERI hosted the secretariat of the ETC India and EFD, as the nodal division, in conjunction with other divisions of TERI, leading a diverse group of stakeholders to facilitate smooth transition towards low-carbon pathways in the energy sector through a collaborative approach. The activities started with funding support from Hewlett Foundation, Bloomberg Philanthropies, Oak Foundation, Growald Family Fund and Shakti Sustainable Energy Foundation (SSEF) with support from corporates including NTPC, Siemens, CLP India, BRPL, and Giriraj Renewables. Major new activities in this area include development

of modelling scenarios—current policy, current trajectory and high shares of renewables—in India's power sector to meet the anticipated demand profile for 2030 and 2050, and development of state-level models of high renewable penetration.

During 2020/21, funding support was provided by CIFF, Bloomberg Philanthropies and Stichting SED Fund. During this year, activities which commenced in 2017 were either carried forward or completed. EFD continued to participate in the work related to energy transition under the aegis of the International Energy Transition Commission for India's long-term strategy to decarbonize the energy sector. With the funding support of BEE, a project was initiated for providing assistance to the Ministry of Power in Global Energy Transition Index (GETI), National Energy Transition Index (NETI), Regulatory Indicators for Sustainable Energy Index (RISE), and State Energy Efficiency Index (SEEI) with an aim to improve the country's ranking and assistance in International Cooperation activities related to organizations such as CEM, BRICS, G20, etc.

Smart Distribution, Electric Vehicles, and Battery Energy Storage: The Division continued to work on Indo–US research project on smart distribution with storage which was commenced in 2017. The collaborative project aims at addressing essential issues related to the adoption and deployment of smart grid concepts along with distributed energy resources (DERs) including storage in the distribution network, installation of grid-scale battery energy storage systems (BESS) on distribution feeders, catering to three categories of consumers— residential, institutional, and gated apartments—so as to demonstrate various use-cases of energy storage in partnership with BSES Rajdhani Power Limited (BRPL). An important

objective of this project is to bridge the gap between smart grid, storage and renewable energy research and facilitate its subsequent adoption by distribution utilities in their systems through pilots with the joint efforts of the Indo–US consortium.

A study which initiated in 2018 with West Bengal State Electricity Distribution Company Limited (WBSEDCL) under MacArthur Foundation's grant continued its 3 years' journey focusing on assessment of techno-economic feasibility of BESS at distribution transformer (DT) and feeder levels that could potentially lead to the pilot-scale implementation. The study aims to assess the operational use-cases of BESS in the distribution network of WBSEDCL, developing battery sizing approach and operational control scheme for the BESS operation of the selected applications. A study was also undertaken for the Calcutta Electric Supply Corporation (CESC Limited) for conducting a techno-economic analysis of implementing BESS for overload management of a DT and managing load in critical facilities.

TERI assisted WBSEDCL, the nodal agency for the state of West Bengal for EV implementation, in working towards infrastructural development and EV tariff modelling. Work on EV charging infrastructure under funding from CIFF, as part of an overarching project on zero-carbon transition was carried out during this year. TERI undertook research activities to understand the perspective of national and state-level policies in respect to charging infrastructure deployment, global and Indian charging infrastructure standards, to estimate the impact of EV charging from various fleet on the overall system load through EV-load estimation models and thereby developing strategies to mitigate peak demand due to EV charging including coordinated charging control and its impact on load factor of the utility. A project for conceptualization, design and implementation of an EV cell to accelerate electric mobility adoption in West Bengal was also initiated. TERI also launched the India–UK E-mobility Accelerator Awareness Campaign with the support from Foreign and Commonwealth Development Office.

A study for preparation of road map for strengthening power distribution infrastructure in a Smart City with the support of MacArthur Foundation was taken up.

Demand-side Management and Energy-Efficiency: For over a decade, TERI has been working with various utilities and stakeholders across the country for DSM and energy-efficiency-related studies. The work encompassed development of load research methodology for preparation of DSM Action Plan for utilities as mandated by DSM regulations notified by the concerned State Electricity Regulatory Commission, development of utility or industry-specific DSM Action Plans and project implementation support. The Division continued to offer its expertise for DSM-related projects such as the preparation of DSM

Action Plan for Bangalore Electricity Supply Company Limited (BESCOM) with the support of MacArthur Foundation.

Under the BEE's flagship programme, capacity building of DISCOMs was continued in four DISCOMs in the north-eastern region of India—Manipur State Power Distribution Company Limited; Department of Power, Arunachal Pradesh; Department of Power, Nagaland; and Power Department, Government of Sikkim— for the load research, preparation of DSM Action Plan, capacity building of master trainers and circle-level officials as well as manpower support in technical and financial aspects. In the remaining four utilities, namely, Tripura State Electricity Corporation Limited; Meghalaya Energy Distribution Corporation Limited; Power and Electricity Department, Government of Mizoram; and Assam Power Distribution Company Limited, project management consultancy support for DSM activities was provided.

Implementation support was provided to Jamshedpur Utilities & Services Company Limited (JUSCO) for executing six DSM initiatives, namely, implementation of focussed EE programme in industries, employee awareness programme for industries, promotion of energy-efficient lighting programme for industrial and commercial consumers, promotion of energy-efficient appliances programme for domestic and commercial consumers, awareness campaigns, and mandatory use of energy-efficient appliances in JUSCO facilities.

Power Distribution Reforms and Utility Support Projects: The Division carries out research activities for various stakeholders in the country in order to support them in addressing various challenges. The Division continued its work on preparation of AT&C loss reduction road map for a distribution utility in the northeastern grid region, which involves preparation of circle-specific customized AT&C loss reduction action plan and provide facilitation support for piloting identified interventions. A one-of-a-kind study on gauging human capital challenges in Indian distribution utilities and identifying strategies for developing human capital through learning and development programmes, and other activities was being carried out with the support from MacArthur Foundation.

A study with the funding support of Sterlite Power Transmission Limited that aimed to ensure 24x7 reliable power supply to the people of Goa by developing strategies for greening the sector and improving the reliability of power supply by effective management of growing demand was initiated. Fuels, Transport, Environmental and Economic Studies: A study for International Energy Agency (IEA) for the assessment of multiple benefits of integrated policy response to clean-energy transition challenges for India in the FY 2020/21 with special focus on India in the context of the 'World Energy Outlook 2020' (the India Energy Outlook) was conducted.

TERI along with Nippon Steel Research Institute Corporation conducted a study to analyse the coal trends in India. TERI along with Green Technology Centre explored a South–South Collaboration opportunity for knowledge exchange on low-emission transportation in Asia-Pacific and African Regions.

Distribution Utilities Forum (DUF):
An independent discussion forum was launched in 2017/18 with the support of SSEF to provide the DISCOMs in the country a platform to share their views, perspective, and learnings, and come up with recommendations/way forward with regard to some of the critical challenges faced by the sector. This was a unique forum set up for the first time in India for distribution utilities in the country. During 2020/21, under the second phase of DUF, a study on energy storage at the distribution level—technologies, costs, and applications was carried out taking into consideration the DISCOMs and stakeholders' perspective through a consultative webinar (http://dufindia.com/).

Capacity Building and Stakeholder Interactions:
The Division imparts trainings to utility officials through tailor-made capacity-building programmes. Stakeholder interactions and dialogues were organized with a view to understand key concerns of the sector, promote sharing of learning, and dissemination of knowledge and expertise.

Under the BEE's capacity building of DISCOMs programme, Training of Trainers (ToT) programmes and Circle Level Training programmes were conducted in four DISCOMs in the northeastern region of India as mentioned earlier. EFD also extended expertise to other divisions in multi-disciplinary projects such as India's case study on Just Transition, India's industry sector transition in steel sector, and so on.

Renewable Energy Technology Division

India is moving steadily to achieve its renewable energy (RE) targets with wide-ranging policy initiatives at the level of central and state governments. The total installed RE capacity at the end of the financial year 2020/21 stands at 94.43 GW. In order to support the national vision of RE, the Renewable Energy Technology (RET) Division has maintained its focus on research and development, project implementation, policy research, and consultancy services, besides select training and capacity-building activities. The Division has developed partnerships with stakeholders, which included national and international institutions, bilateral and multilateral agencies, user and various manufacturing industries, and consumers. There is a strong team of more than 15 research professionals with a diverse group of experts in biomass, solar, wind, and hybrid technologies. The major projects and achievements under various segments of activities are given in the ensuing sections.

Key R&D projects pursued during the year are given below:

- Studies on thermal degradation of crop residues for kinetics, bio-polymeric transitions and value-added products. This activity was supported by the Indian Council of Agricultural Research.
- The Department of Science and Technology awarded a project under Clean Energy Research Initiative (CERI) programme for development and field demonstration of paddy straw-based briquetting plant.

During the year, the Division continued its implementation of field projects within the country as well as abroad. The marketing of the biogas (TEAM) technologies expanded through agreement between Blue Planet Environmental Solutions India Private Limited (BPES) for waste-to-energy plant. Some of the key projects pursued during the year are given below:

- Under Mission Innovation project sponsored by the Department of Science and Technology, biomass solar electricity and cooling system was developed and implemented in two villages of Odisha.
- Implementation of the UNIDO-sponsored project for setting up biomass power generation was continued.

Paddy straw procured and stored at site for field trials/R&D

Visiting India's first-of-its-kind paddy straw based briquetting plant in Punjab

Field visit for getting an overview of existing briquetting process

A bamboo waste-based gasifier of 200 kWe capacity in Thailand was successfully commissioned.

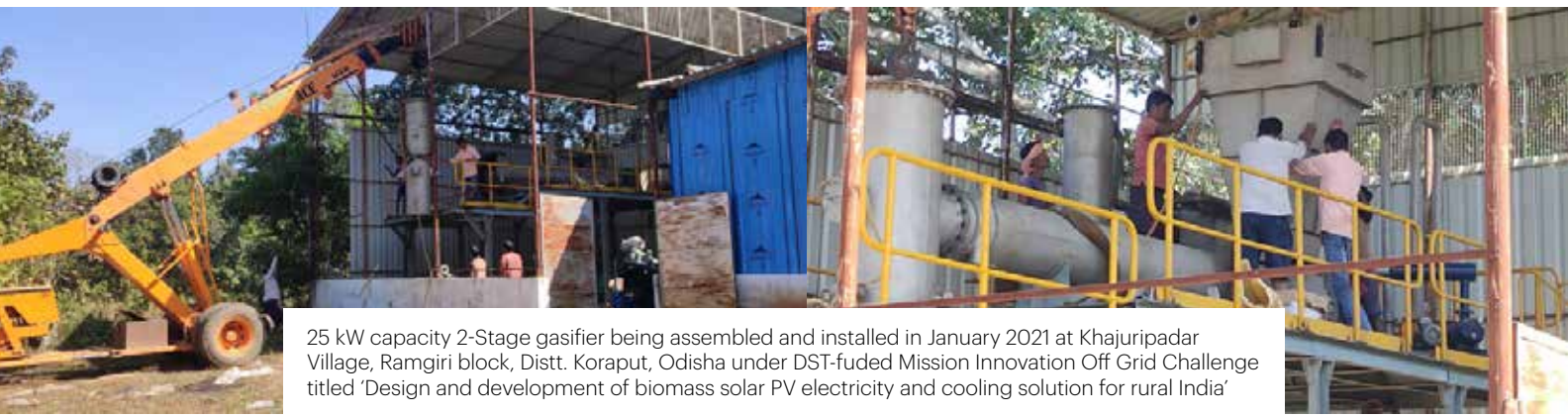
- Innovate UK awarded a contract to TERI titled, CORES: Collaboration to Optimise Renewable Energy Systems: Introducing affordable, reliable, portable energy solutions to remote communities in India and Africa.
- Under Indo–US Science and Technology Forum for innovative concept, i.e., solar dryer-based self-employment model for rural tribal communities, women and differently-abled persons.
- Under a project by National Thermal Power Corporation Limited (NTPC), TERI implemented a-100 kg per day biomethanation plant in NTPC Farakka.

Interaction with farmers during field survey in Arunachal Pradesh

The RET team also undertook the following specialized studies during the year:

- Study and Evaluate Price of Fuel to be used in Biomass and Bagasse-based Power Plants in Maharashtra sponsored by Maharashtra Electricity Regulatory Commission.
- Engagement of consultancy service to carry out assessment study of biofuel (biodiesel, ethanol, and CBG) in Northeast Region of India by Oil India Limited.
- Study for measuring biofuels potential in India sponsored by the Organization for Economic Co-operation and Development.
- TERI in association with the United Nations Development Programme is implementing a project titled 'Consultancy for Provisions of Technical Services for Development of Investments in Climate Resilience and Access to Renewable Energy Technologies'. The objective of this consultancy is to support sustainable and inclusive economic development of rural areas in Papua New Guinea by increasing the use of renewable energy for selected end users in East and West Sepik provinces.

- A study supported by MacArthur to support implementation of PM KUSUM scheme for power sector utilities in India, technical assistance to SNAs in the states of Punjab and Madhya Pradesh for implementation of PM KUSUM scheme has been initiated.
- TERI in partnership with EDF is developing a long-term vision, implementation plan, road map and institutional framework for implementing 'One Sun One World One Grid' (OSOWOG).
- MOA: Concurrent Monitoring, Evaluation and Impact Assessment of Promotion of Agricultural Mechanization for In-situ Management of Crop Residue in the states of Punjab, Haryana, Uttar Pradesh and Delhi under the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.



25 kW capacity 2-Stage gasifier being assembled and installed in January 2021 at Khajuripadar Village, Ramgiri block, Distt. Koraput, Odisha under DST-fuded Mission Innovation Off Grid Challenge titled 'Design and development of biomass solar PV electricity and cooling solution for rural India'

Industrial Energy Efficiency Division

The industry sector is a crucial component of the Indian economy in terms of its contribution to economic growth, trade, and as a provider of employment. The sector is also the largest consumer of commercial energy, accounting for nearly half of the total energy consumed in the country. The industry sector is a mixture of large as well as micro, small, and medium enterprises (MSMEs). India's growth story and the government's ambitious 'Make in India' campaign are dependent on the prosperity of this sector. The challenge, however, is to grow in a manner that is resource efficient and addresses sustainability considerations from all perspectives—social, economic, and environmental. In this context, the Industrial Energy Efficiency (IEE) Division works closely with the corporate sector and provides services to both large and small industries to improve their energy performance. In order to maximize the reach of its specialist teams and synergize their capabilities and activities, both within and outside India, IEE functions from two hubs: Industrial Energy Efficiency and Sustainable Technologies (IEEST) area, located at TERI, New Delhi and Industrial Energy Group (IEG), located at TERI's Southern Regional Centre, Bengaluru (TERI-SRC).

The pool of engineers in the Division, many of who are accredited and certified energy auditors with the Bureau of Energy Efficiency (BEE), Government of India, regularly conduct energy audits in

industries to identify options for energy conservation at the plant level. With expertise and in-depth knowledge of applicable technologies, TERI is able to offer the corporate sector high-quality technical advice on ways to reduce their carbon footprint. TERI is a leading name in promoting energy efficiency and facilitating deployment of energy-efficient technologies in the MSME sector, courtesy the IEE Division's continuous engagement with the sector for the past 25 years.

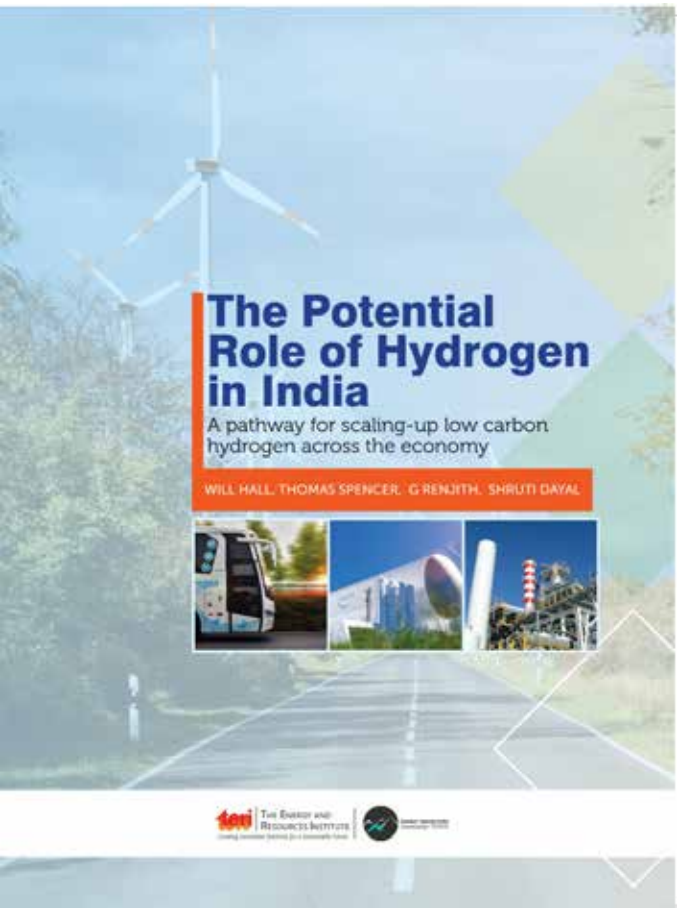
During the year, the Division undertook energy audits in different kinds of industries in India in sectors such as cement, power, chemicals, laminates, steel, pulp and paper, food processing, public utilities, etc. A few prominent groups where IEE rendered services included Jhabua Power, Prism Cement, Saurashtra Cements, Karnataka Milk Federation, Tata Power, Sesa Goa, Karnataka Electricity Regulatory Commission (KERC), Timken, Syngene International, Jindal Steel, Merino, and Gopal Glass. The Division continued to provide support under the Perform, Achieve, and Trade (PAT) scheme of BEE to various designated consumers (DCs) with regard to Mandatory Energy Audit, Monitoring and Verification (M&V) services and check verification.

The IEE Division also promotes accelerated development and transfer of climate technologies across the developing countries for energy-efficient, low-carbon and climate-resilient development. With the rising costs of energy and concerns about global warming, it is imperative that countries adopt efficient energy conservation measures and technologies. IEE provided consultancy services to international clients in Guyana, Mexico, and Pakistan during the year 2020/21:

- The World Bank engaged IEE to carry out an assessment of the Cutzamala integrated water system, Mexico City in terms of energy efficiency, load management, and renewable energy options. This is one of the world's largest water supply scheme in terms of energy consumption (170 MW).
- TERI completed the technical assistance project for the National Designated Entity (NDE) of Pakistan. The project provided assistance in developing the national certification scheme for energy auditors, including preparation of draft rules and regulations for the scheme as well as conducting a first-of-its-kind Training of Trainers' programme in Pakistan.
- The Government of Guyana (GoG) signed a new Memorandum of Understanding (MoU) with TERI to promote clean energy technologies in Guyana.

COVID-19 pandemic situation kept the entire nation under lockdown and forced everyone to stay at home. At this hour, like many other organizations, IEE also started providing online services to various stakeholder groups. For example, a webinar on 'Home Electricity Footprint' was successfully conducted with a group of students and teachers by the IEE team. Also, an In-house Energy Management training programme was conducted for Haldia Petrochemicals staff in online mode.

During the year 2020/21, the IEE Division continued its activities in the field of industry decarbonization, particularly in the steel sector, which is globally perceived to be a 'harder-to-abate' sector. A multi-disciplinary team led by the IEE Division also undertook in-depth analytical work on the role that green hydrogen can play in India's future energy transition plans. A detailed report titled 'The Potential Role of Hydrogen in India—A pathway for scaling-up low carbon hydrogen across the economy' was published during the year.
It was launched by Dr Rajeev Kumar, Vice Chairman, NITI Aayog on December 16, 2020. It was an online event titled 'The Potential Role of Hydrogen in India – Harnessing the Hype'. TERI's analysis clearly brought out that green hydrogen (produced from renewable electricity) has huge potential in India's energy transition. In transport, this can be used to fuel longer-range vehicles and heavier-duty



trucks, in industry largely as a chemical feedstock, and in the power sector, to provide longer-term energy storage. The work on steel sector and hydrogen was undertaken under the aegis of the Energy Transitions Commission (ETC) India work programme and was primarily supported by Shakti Sustainable Energy Foundation (SSEF) and Children's Investment Fund Foundation (CIFF). Researchers from IEE were also actively involved in organizing various outreach events and workshops around the theme of decarbonization and energy efficiency. Some of these were:

- Thematic track on 'Low Carbon Industry Transition' in partnership with European Commission during TERI's flagship event World Sustainable Development Summit 2021 (February 12, 2021)
- The Potential Role of Hydrogen in India, organized under the CIFF supported project on NDC Enhancement (September 21, 2020)
- Webinar on Producing Green Steel: A Case Study in Hydrogen-based Steelmaking with the Hybrit Project (August 20, 2020)

The activities in the MSME sector were primarily supported by BEE, United Nations Development Programme (UNDP), and Shakti Sustainable Energy Foundation (SSEF). TERI continued to expand the knowledge collation and dissemination activities under the SAMEEEKSHA (Small and Medium Enterprises Energy Efficiency Knowledge Sharing) platform. Due to COVID-19 pandemic, two meetings of this platform were held in online format in October 2020 and February 2021. The discussions in the October 2020 meeting focused on the increasing relevance of energy efficiency when the units are struggling to recover from the shutdown forced due to lockdown—because energy efficiency can bring significant improvements in productivity and profits as well as help reduce emissions. The February edition focused on the energy conservation guidelines prepared by BEE for MSMEs and the actions required to implement them in different clusters. Other projects/activities undertaken during the year in the MSME sector included:

- Initiated two new projects in the 'Chemical' and 'Glass and Refractory' sectors on Energy and Resource Mapping of MSME Clusters. These projects are supported by the BEE. The projects involved conducting detailed energy audits in five clusters in the two sectors. Based on the audit and sectoral studies, a road map would be prepared for technological interventions to promote energy efficiency in the sectors at national level.
- Undertook Investment Grade Energy Audits (IGEA) and prepared Detailed Project Report for 60 MSMEs in the State of Manipur under a project supported by UNDP India.
- Completed a detailed study on switch to electrification in industrial processes under a project supported by SSEF.
- A new project 'Facilitating Green Economic Recovery: Improving the uptake of cleaner technologies among MSMEs in Eastern India' has been started with support from SSEF.

The IEE Division also expanded its relationship with Japanese expert institutes in the field of energy and environment, such as the Institute for Global Environmental Strategies (IGES), Energy Conservation Center Japan (ECCJ), and New Energy and Industrial Technology Development Organization (NEDO). Activities with ECCJ were aimed at increasing the awareness of DCs on the Energy Conservation Guidelines (ECG) and to help DCs prepare Energy Management Manual for major energy intensive equipment/appliances installed in their respective units. Many online events were also organized involving experts from the Japanese organizations on different themes.

TERI Council for Business Sustainability

TERI Council for Business Sustainability (CBS) serves as the interface for TERI's research work to be connected to the corporate world. The Council is a network of Indian business leaders working on a shared commitment to mainstream sustainability in business strategies and practices. Set up in 2001, the Council recognizes and promotes sustainability leadership practices. Member companies of the Council include public and private sectors, including MNCs—representing various industry sectors, sizes, and geographies. Activities of the Council are governed by an Executive Committee from amongst member companies.

TERI CBS engages with the core issue of 'what businesses must do to shape and lead in sustainability'. The Council co-creates business solutions with member companies to address national sustainability challenges; curates common interest forums of member companies with the participation of board members and Chief Sustainability Officers; undertakes policy advocacy through Thought Leadership reports and industry dialogues; and builds capacity through trainings, learning visits, webinars, conferences, etc. With individual member companies, the Council provides a range of tailor-made advisory services. These comprise sustainability strategy development, performance assessment and improvements, capacity building and facilitates showcasing best practices in national and international forums.

The year 2020/21 witnessed an unprecedented situation of the growing concerns over the coronavirus (COVID-19). Owing to restrictions and safeguards from the COVID pandemic, virtual platforms were extensively used for the Council's engagements and convenings.

The engagements with the businesses and member companies of our Council ranged from diverse webinar sessions, sustainability assessments and the India Sustainability Leadership Summit. During this period we witnessed enthused participation of our national and global partners as well as diverse government stakeholders at the state and central levels. We indeed are thankful to the support from all our partners and the companies in the Council's network in these unprecedented times.

Undoubtedly, the COVID-19 crisis calls for urgent actions by individuals, governments and businesses to shape a better, resilient, and sustainable world in the future. Amidst the varied response strategies to the pandemic, a Statement to promote policies that can stimulate green growth and create a resilient India was unveiled that outlines a set of 8 priorities for repurposing future business actions. This Statement is a shout-out by 24 Indian CEOs to lend predictability to India's future development pathways. The Statement intends to enable businesses, civil society and government come together to garner support and accelerate actions.

The potential for significant and sophisticated policy advocacy is strong, and TERI's partnership with the We Mean Business Coalition, supported by CIFF funding, offered the resources needed to super-charge these efforts. The foundational goal of this partnership was to accelerate the ambition loop in India and contribute to India strengthening its Nationally Determined Contributions (NDC), putting forward an ambitious long-term strategy, and strengthening domestic policies in key sectors to accelerate emissions reductions. The work programme during 2020/21 was designed to ensure that influential policymakers take cognizance of the climate action taken by businesses and that there is a strong business case for doing so. Thus, creating

an enabling policy environment to achieve ambitious climate targets would provide economic and competitive advantage to India. During 2020/21, the WMB-TERI collaboration synergized the work of existing WMB India coalition—namely The Climate Group, CDP, and World Business Council for Sustainable Development.

Building on from TERI's assessments for electricity sector transition in India, we are excited to take forward the industry transition agenda. A coalition of leading market players from the Indian industry has been put in place under an 'Industry Charter for Near Zero Emissions Ambition by 2050'. This Charter emerged as an important step from Indian industry to voluntarily commit themselves to decarbonization measures and to work together in key thematic areas that can make a 'zero carbon' future, a reality for India. The existing Charter Signatories unanimously expressed their intent to make their companies exemplars of low- or zero-carbon technology solutions within their sectors, and gradually bring more heavy industry sectors into the fold of the Charter.

During this year, we redefined the ways and means of interactions and assessments for the 2020 edition of the F&S-TERI Sustainability 4.0 Awards. We—along with our partner Frost & Sullivan—aspire to assist organizations unearth the environmental, social and governance risks, leverage onto the opportunities, enable them to benchmark their performance, and reward them for their accomplishments in embedding sustainability in their business model. To ensure safety for all, we leveraged digital platforms as the medium and means of interactions and assessment. Through this approach we ensured not to compromise the objectivity and completeness of the process as well as the quality and standards of evaluation. The winners were announced at a virtual ceremony on August 28, 2020.

By means of various policy products such as 'Think Pieces', 'Policy Briefs' and 'Discussion Papers', TERI provides high quality multidisciplinary insights on SDGs towards strengthening its engagement with stakeholders in the government and business sectors to promote integrated thinking on sectoral and multi-sectoral national policies in the context of the SDGs. Through its ongoing partnership with the National Foundation for Corporate Governance (NFCG), the Ministry of Corporate Affairs, Government of India, TERI aims to augment and accelerate business action on SDGs in India. In 2020/21, the CBS Division completed the research study on 'Enhancing the role of businesses towards achieving the SDGs in India' as part of grant by the National Foundation of Corporate Governance (NFCG). The report underscores the need and relevance of SDGs to enhance and accelerate business action on sustainability in today's time. The report highlighted the need to apply the SDG lens while evaluating business strategy and actions; illustrated how the SDGs can be used by businesses to design focused sustainability actions; and demonstrated the results that may be achieved when

companies embrace and fully integrate the SDGs into their business strategy and actions.

The annual convening by the Division for the businesses– 'India Sustainability Leadership Summit' was held virtually on August 28, 2020, in partnership with Frost & Sullivan. The India Sustainability Leadership Summit is a platform to enhance awareness on business models, tools, technologies, solutions and approaches followed by industry leaders towards building sustainable economies. Every year the Summit witnesses participation—comprising CXOs, Unit Heads/Functional Heads and Managers/ Executives from our Council's member companies and other Indian companies. The year 2020 marked the beginning of the Decade of Action to deliver the Sustainable Development Goals (SDGs) by 2030. The global pandemic—COVID-19 also set in this year. The world continues to reel under the impacts of COVID-19, with great uncertainty even to this day on the exact, actual impacts of the crisis on the global economy. The unprecedented health, economic and social impacts of the pandemic are undermining the progress made by the nations since 2015, making the achievement of the SDGs even more challenging in the times to come. The 2020 edition of the Summit raised the most pertinent question—'Given COVID-19 how to we jump-start the Decade of Action?' The Summit explored the imperatives of innovative solutions and business models for addressing sustainability challenges in emerging economies, in the context of the Sustainable Development Goals and the 2030 Agenda for Sustainable Development. The deliberations of the Summit comprised a Thought Leadership Panel and a CEO Panel.

Our convenings with CEOs and CXOs at TERI's annual World Sustainable Development Summit 2021 revealed the urgency of actions on sustainable development. The discussions pointed out that it is time now that we exhibit our intentions through putting together the business plans, investment plans and design lighthouse projects that articulate a narrative on how the future India would be. The recently concluded UN annual conference on climate change (COP26) would give us an appropriate platform to showcase our strengths and ask questions of relevance to the global community.

Environmental and Industrial Biotechnology

The Environmental and Industrial Biotechnology (EIB) Division is committed towards protecting the environment, finding new solutions, and developing innovative sustainable technologies in a fast-growing economy for large-scale applications.

EIB has two areas namely Microbial Biotechnology Area (MB) and Bioremediation Area (BR). Bioremediation Area is working on large-scale implementation of technologies, particular on bioremediation of oil spills in oil fields, treatment of organic carbon, pesticides contaminated and other organic polluted sites and production of biopolymer as a drilling mud for oil companies. Further commercialization is take care by ONGC TERI Biotech Ltd (a joint venture of ONGC and TERI, www.otbl.co.in).

MB area mainly focusses on basic and industrial application research and exploring innovative solutions, particularly in the area of oil and gas sector. The Area is working on conversion of coal into methane, conversion of CO_2 into useful product through anaerobic fermentation process, control of souring of oil reservoir, microbial enhanced oil recovery, prevention of paraffin deposition in oil well tubings, and control of microbial induced corrosion. The Area has NABL accredited Laboratory for testing of water and hydrocarbon contaminated samples.

Bioremediation Technology Area

Fermentation Technology Research Centre

Fermentation Research Center has state-of-the-art bioreactor facility with 3.2, 30, 100, 200, 1500 and 13,000 litre bioreactors to carry out research and large-scale biofermentation production. The Centre has successfully developed best-selling technologies—'Oilzapper' at a large scale. Oilzapper is globally acknowledged for its broad-scale implication in cleaning of oil spills and treatment of oily sludge generated by refineries. The Oilzapper technology not only helped several petroleum industries (ONGC, IOCL, HPCL, BPCL, Oil India Limited, Tata Power, BG Exploration Limited, and Reliance Petroleum) across India in providing a sustainable solution for

bioremediation of oil spills and oily sludge-contaminated sites in a cost-effective manner but it also spread its roots in the international arena which helped grab a major project of Kuwait Oil Company (KOC) through a global competitive bid, for the bioremediation of 2.8 million tonnes of oil-contaminated soil. After the successful completion of bioremediation work in this project, the Oilzapper technology has bid for a second-phase mega tender (KERP Bioremediation at South Kuwait) for remediation of total petroleum hydrocarbon (TPH)-contaminated soil in KOC oilfield and for clean-up of oil-contaminated sites.

Oilzapper product was developed after 7 years of extensive research work sponsored by Department of Biotechnology, Government of India, for clean-up of oily sludge, oil spills, and treatment of hazardous hydrocarbon waste. Industrial-scale and industrial bioreactor facilities were set up by TERI at Gual Pahari. At present, there are bioreactors and utilities at Fermentation Technology Research Centre, as mentioned below.

Research Activities of

Bioreactors

3.2 litre and **100** litre photo bioreactors

10 litre, **30** litre, **100** litre, **200** litre, **1500** litre, and **13,000** litre bioreactors

Bioremediation Technology Area

Development of hexachloro-cyclohexane (HCH) degrading bacterial formulation

Biostimulation and bioaugmentation are two methods that are efficient for remediation of persistent organic pollutants. Our studies have reported these methods are practically viable approaches for decontamination of HCH from the HCH dumpsite located at Umari Village of Barabanki district in Uttar Pradesh. Microbial communities present in the HCH dumpsite harbour robust catabolic activities for degradation of various HCH isomers as reported in previous genomics and metagenomic studies. In light of this background work and serious problems posed by HCH muck at the HCH dumpsite, biostimulation and bioaugmentation were proposed to remediate Umari land. In the present project, teams at University of Delhi, TERI, CSIR-NBRI, CSIR-IITR and Ramjas College, Delhi joined hand together with complementary expertise are involved to undertake demonstration of the remediation of large HCH dumpsite. TERI produced large volume of HCH degrading Sphingobium B90A bacterial culture in 13 KL bioreactor which was discovered, identified, and developed by University of Delhi. TERI has conducted bioaugmentation and biostimulation field demonstration at site. The bacterial formulation and specially designed nutrient mixture developed by TERI were applied into the field. Field trial assessment is continuing over a period of last two years and progress is satisfactory. Once the project is successful, demonstration of the technology for HCH decontamination can be used worldwide. Present study will also generate new-of-its-kind technical skill in bioremediation sector.

HCH dumpsite located at Umari village at Barabanki District, Uttar Pradesh

Bioremediation activity is under progress

Production of D(-) Lactic acid production using membrane integrated bioreactor

D-Lactic is a green platform chemical used in various industrial spheres like biodegradable plastics, biomedical equipments, textiles, etc. Growing demand for poly-lactic acid (PLA) is expected to reach 1,960,100 metric tonnes in near feature. Interest is more focused on Poly DL-Lactic acid (PDLLA), a hetero-polymer cross-linking between alternate D and L monomers. For this reason there is a significant demand for optically pure D (-) Lactic acid in last decade. TERI team has collaboration with IIT, Guwahati for the integrated biofermentative production of D (-) Lactic acid at low cost. For the green product production, the novel Lactobacillus strains were isolated and the process control variables optimized. This research study aims to develop a techo-economic strategy for effective valorization of whey to D (-) Lactic acid, which would open the avenue for value addition to Indian dairy industry in terms of additional revenue generation and mitigate the environmental pollution. TERI's state-of-the-art fermentation facility has been utilized to produce optically 98% pure D(-)Lactic acid.

Consultancy services in the area of Environmental Monitoring and Assessment

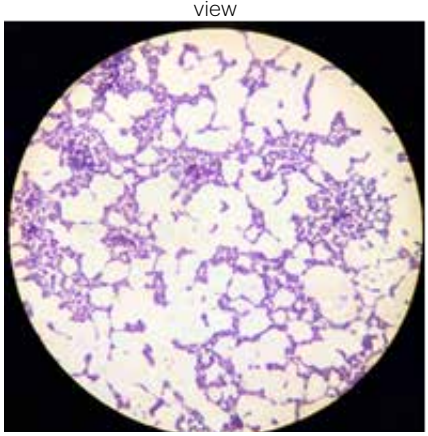
The team also had undertaken the study to ascertain the agricultural soil fertility of ONGC oilfields of Ankleshwar, Gujarat. In this study, the soil fertility loss caused by ONGC exploration and exploitation of hydrocarbons was assessed through field investigation, soil sample collection, and analysis. The samples were analysed for physico-chemical and microbiological characteristics, including microbial enzymes. The analysis data were compared with the soil quality of unpolluted agricultural fields from the same region. The nutrient index revealed no significant difference among soil samples of contaminated and uncontaminated reference sites.

International collaborative projects

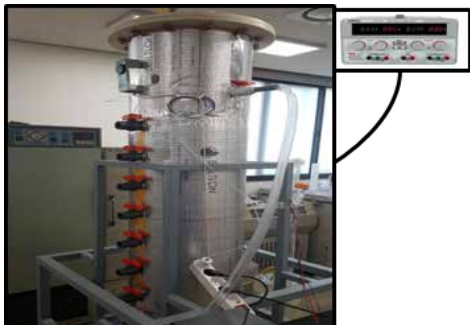
A collaborative study on the novel high-rate bioelectrochemical anaerobic digestion process for renewable energy recovery from distillery waste water

TERI in collaboration with Korea Maritime and Ocean University, South Korea developed the hybrid system called 'up-flow anaerobic bioelectrochemical system' (UABE) for the enhanced methane production from

Lactobacillus MCW3 under microscopic view



D-Lactic acid production in Bioreactor



100 Litre BEAD Systems

distillery wastewater. The UABE system is superior in methane production and chemical oxygen demand (COD) reduction in comparison to conventional anaerobic digester.

Enzymatic degradation of antibiotics and phenolic residues waste components at low concentration in surface waters and industrial wastewater using modified membrane bioreactor

The area recently completely Indo–Hungary bilateral project which demonstrated the advanced wastewater fluid standards. The feasibility studies of the developed product has been analyzed and further tested at the Institute of Drilling Technology (IDT), ONGC Dehradun, and Chemical Laboratory, Oil India Limited, Duliajan. As the product is ready for commercialization, all industrial applications will be done by ONGC TERI Biotech Limited (OTBL), a joint venture of TERI and ONGC which will open up new opportunities.

Development of eco-friendly oil well drilling fluid: XC polymer (xanthan gum)

In 2015, TERI initiated research in the area on development of XC polymer with a view to provide an eco-friendly technology to oil industry to be used for drilling fluid/viscosifier. XC polymer is produced by bacterial fermentation along with the addition of selective chemical additives to achieve the drilling fluid standards. The feasibility studies of the developed product has been analyzed and further tested at the Institute of Drilling Technology (IDT), ONGC Dehradun, and Chemical Laboratory, Oil India Limited, Duliajan. As the product is ready for commercialization, all industrial applications will be done by ONGC TERI Biotech Limited (OTBL), a joint venture of TERI and ONGC which will open up new opportunities.

Microbial Biotechnology Area

Microbial Biotechnology (MB) Area is actively engaged in exploring sustainable approaches for protection of environment, development of innovative technologies and alternate renewable energy production for commercial application. The Area mainly focusses on basic and applied research for exploring microbes towards development of sustainable solution for industry.

Focus areas

- Demonstration of bioconversion of carbon dioxide to methane using hydrogentrophic methanogens in coal seams

- Demonstration of microbial methane generation/enhancement from poor to marginal producing coal bed methane (CBM) wells (fields).
- MEOR for enhanced oil recovery from oil reservoirs for tackling the problem of oil well stripping.
- Environmental protection for safeguarding the natural gas pipelines/ LPG pipelines for microbial induced corrosion (MIC) in oil/gas pipelines
- Prevention of paraffin deposition in oil well tubing.
- Sequestration of carbon dioxide with simultaneous production of commodity chemicals.
- Metabolically engineering for industrial-scale production of commodity chemicals.
- Development of potential probiotics from novel sources.
- Developing green corridor (plantation) on highways and greening of schools for environment sustainability.
- Application of recombinant strain for industrial-scale production of a commercial enzyme.
- Detection of bacterial drug resistance, (AMR) phenotypes through targeted nucleic acid via CRISPER CAS system.

Microbial enhanced oil recovery

A technology for enhancing oil recovery in dead or abundant oil wells was jointly developed with Institute of Reservoir Studies, ONGC. This technology is currently commercialized by the joint venture OTBL ONGC TERI Biotech Limited formed by TERI and ONGC. Another customized thermophilic bacterial consortium was also developed for US oilfields for joint venture, Glori Oil, and is being implemented in oil wells in Texas, USA. Currently carrying forward MEOR activities, the area has developed highly effective bio-based technology for tackling viscosity reduction of heavy oil in flow line. The MB Area is exploring the potential of biopolymer and adjuvants (electron acceptors-like nitrate) which can increase oil production in economical and sustainable way and develop a new recovery method to be known as BcEOR (Biochemical Enhanced Oil Recovery). The biopolymer under investigation has better rheological properties and sweep efficiency. Thus, BcEOR process holds tremendous potential to be developed as full-fledged technology for production of residual oil in economical, environment friendly, and sustainable approach.

Biological enhanced methane production from coal

India is world's third largest producer of coal. The reserves in India are estimated at around 298.94 billion tonnes, as on March 31, 2013. As per Directorate General of Hydrocarbons (DGH) database, India has estimated 92 trillion cubic feet of CBM gas reserves, however commercial production of CBM is still at a very nascent stage in the country. ONGC is currently operating in four CBM Blocks, located in Jharia, Bokaro, North Karanpura, and Raniganj. It is estimated that on an average only 15%–20% of the coal is recoverable and rest of it lies unexploited. The utilization of biotechnological processes can be one of the promising approaches to convert low rank or unrecoverable coal into methane. It is recognized that methane-generating bacteria can act on coal seams to produce biogas, comprising mainly methane and carbon dioxide.

TERI in association with OEC has developed and demonstrated the microbial process for enhancement of gas in CBM well at Jharia. The microbial and stable gas isotope analysis data support the stimulation of microbial communities and in-situ biological gas production. The field experiments have demonstrated that there is manyfold increase in gas production and the enhanced activity of methanogens leads to additional/enhanced methane generation in coal seams.

Therefore, microbial stimulated CBM can increase the longevity and productivity of the CBM fields. The experimental wells in Jharia are producing gas at enhanced levels for more than 36 months. TERI and OEC are continuing with various field experiments to enhance the gas production from different CBM wells. Currently TERI and OEC are exploring the Raniganj CBM block for enhanced biological methanation.

- Bioconversion of carbon dioxide to methane using hydrogentrophic methanogens in coal seams

Installation of online monitoring system at BK#11 well site Bokaro

Installation of online monitoring system at BK#10 well site Bokaro

In view of the benefits of microbial process for conversion of carbon dioxide to methane, OEC and TERI are jointly working, on development and demonstration of microbial process for generation/enhancement of methane from underground coal seams. Proof of concept for bioconversion of carbon dioxide to biomethane in anaerobic fermentation has been tested under laboratory conditions and detailed studies are in progress to understand the mechanism using electrolytic hydrogen. In the microbial culture of hydrogenotrophic methanogens catalyzing the reduction of carbon dioxide to methane, the method of energy conservation and electron fluxes has been recently specified and basic differences between two metabolic types of methanogens—hydrogenotrophic and methylotrophic—are identified. These findings helped to elucidate the metabolic versatility of methanogenic cultures and bring the potential for engineering use of methanogens in new technologies. Utilizing the metabolic potential of hydrogentrophic methanogenic cultures for processing and upgrading other gases such as syngas to biomethane is a promising prospect for increasing energy utilization from non-traditional sources.

Carrying forward these research explorations, MB Area is exploring on development of a microbial biosensor for the detection of oil and oil-derived compounds in the environment. And also on disposable polymeric cryogel bioreactor for medical application and biotechnological production and Industrial-scale production of enzymes (Alkaline Protease) and commodity chemicals (succinic acid, poly lactic acid, poly glutamic acid, etc.).

Currently, in partnership with the government and various industries, the MB Area is keen on finding a sustainable solution to climate change-related problems by identifying bacteria for the production cleaner energy forms, for carbon capture and storage that would displace the methane on coal seams with carbon dioxide, bio-remediation of mine water treatments.

Microbial Biotechnology Area has also started some corporate social responsibility (CSR) initiatives/projects such as green corridor development with awareness programmes where engaging schools, community, government and other stakeholders for and environment awareness which will be mass movement towards sustainability.

TERI North Eastern Regional Centre

The research and development activities of the Centre include treatment of wastewater using potential algal strains and phototrophic biofilm-facilitated adaptation conditioning of algal and bacterial association leading to easier harvest of biomass; wastewater treatment; water quality improvement; waste management; production of quality planting materials and demonstration; sericulture; medicinal plants; improvement of livelihood through adoption of location-specific sustainable land-based and off-farm activities; rural development and extension-oriented activities and implementation of projects related to development of agriculture, horticulture, natural resource management, medicinal plants and watershed development activities.

In its efforts to promote horticulture in the region and improve the productivity, the Centre continues to produce quality planting materials of horticultural crops such as black pepper, Assam lemon, and Khasi mandarin, which have significant economic value for the region in boosting its economy. Also an essential oil extraction unit has been set us at Byrnihat for extraction of plant-based essential oil.

In the capacity-building initiative of the Centre, TERI-NE organized various training programmes for the key stakeholders of the projects to equip them with skills in executing the project activities for ensuring their livelihood in a sustainable way.

Biotechnology Area

Biopesticide is a formulation made from naturally occurring substances that control pests by non-toxic mechanisms and in an eco-friendly manner. Considering the importance of biopesticides the Development of Epicuticular fatty acids catabolizing fungi-enriched biopesticide formulation and validation of Beta oxidation enhanced pathogenicity in Citrus aphids has been designed for virulence enhancement of entomopathogenic fungi for the control of Citrus aphid a major pest of Citrus crops of north–eastern India. The chemical composition of cuticular and internal extracts obtained from all developmental stages of citrus aphid was analysed. GC and GC-MS analyses were used to identify the cuticular lipids in Citrus aphids. Fourteen free fatty acids, seven alcohols and cholesterol were identified in the cuticular lipids of citrus aphid. Cuticular fatty acids ranged from C6 to C22 and included unsaturated entities. Moreover, few antifungal entities like Undecanoic acid [CH3 (CH2)9COOH], Cyclopentane undecanoic acid methyl ester (C17H32O2), etc. were also found in the cuticular fatty acids of Citrus aphid which might play important role to resist the penetration process of fungal bioagent. Further research is going on for exploring entomopathogenic fungal strains with such enzyme-producing abilities to overcome such resistance which will lead to virulence enhancement. Among the fatty acid tested the oleic acid enriched media grown entomopathogenic fungal isolates showed higher virulence and recorded efficacy of *Paecilomyces fomosoroseus* (100% on 1st day) followed by *Cladosporium oxysporum* (100% on 2nd day onwards) against Citrus aphid.

Research on banana fibre extraction by mycogenic pectinase and surface modification through laccase enzyme is going on in order to facilitate degumming process which is required to dissolve the lingo–cellulose

during fibre-extraction process. Banana fibres are extracted using either alkali or acid treatment for degumming which are neither eco-friendly nor user friendly. Pectinase are a group of enzyme, able to break down pectic polysaccharides of plant tissue loosening the pseudostem tissue, thereby facilitates extraction of banana fibres efficiently. Therefore, exploration of pectinolytic enzymes from native fungal strains on banana pseudo stem and evaluation of their efficiency has been attempted for eco-friendly extraction of quality banana fibre. So far 17 fungal strains have been isolated of which nine isolates showed pectinase activity. Amongst the strains studied, *Phoma herbarum* and *Aspergillius niger* showed higher enzymatic production efficacy. Plackett-Burman Design was followed for optimization of mycogenic enzyme production by submerged fermentation using six variables such as Glucose, Peptone, K2HPO4, MgSO4, pH and CuSO4 at two levels and eight runs. The significant factors identified were Peptone @10 g/l; at pH 4 and MgSO4 @ 0.8 g/l for *Phoma herbarum*. The enzyme synthesised by *Phoma herbarum* (ENZ-5/2h-treatment) showed better results with higher tenacity of 201.407/den and toughness of 3.974g/den which was followed by *Aspergillus niger* (ENZ-4/2h treatment) with tenacity of 149.278/den and toughness of 2.252g/den. Scanning electron microscope (SEM) study of surface morphology of raw, enzyme, and chemically modified banana fibre indicated that abundant amount of pithy material observed in raw fibres. After chemical and bio-enzymatic treatment the fibre looked smooth with reduced size of fibre and pithy material removed from the fibre. The findings of the study showed that Young's modulus and tensile strength decreased with increasing banana fibre diameter. Blending of extracted banana fibre with other natural fibre was also carried out at 75:50 ratios.

The Centre carried out research study on enhanced carbonate precipitation of ureolytic and nitrifying microbe to treat rubber wastewater. In this study, rubber wastewater samples were collected from stabilization tank of rubber producer society campuses of Assam and Tripura. Exploration of ureolytic and nitrifying microalgae was done for isolation of unicellular microalgal strains and screening of urease-producing microalgae. Initial characterization like pH, TSS, TDS, COD, BOD, alkalinity, hardness, phosphate, fluoride, and chloride of rubber wastewater has been done. So far 17 microalgal strains of chlorella, chlorococcum, and microcystis have been screened for urea utilization. After screening, the urease activity for 8 cultures were determined in terms of ammonia production after 24 hours of incubation of 1% inoculated cultures in BG11+Urea media. Carbonate precipitation by ureolytic and nitrifying microalgae treated wastewater was also studied.

Waste is an unwanted substance produced from human activities. Zero waste is a goal that is ethical, economic, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. Considering the immense importance to manage waste a project entitled 'Raj Bhavan Assam: a zero-waste campus' has been undertaken with the purposes of holistic assessment of solid and liquid waste generation, state of management, gap analysis and formulation and implementation of standard waste management procedure for achieving a zero-waste campus in Raj Bhavan, Assam. Under the project, wetlands (reed beds) have been developed for black and grey water treatment, a material recovery facility (MRF) has been developed which separates and prepares single-stream recycling materials to be used by end users. Horticultural and kitchen waste shredder machines have also been installed at MRF in order to shred the horticultural and kitchen waste generated in Raj Bhavan campus for converting them to compost.

In the water quality improvement front the Centre undertook a project on water quality improvement of Dighalipukhuri, Guwahati, Assam to reduce and placate microalgal bloom and floating biomass accumulation on the waterbody. Two pronged strategies adopted to enhance oxygenation and nutrient remedial were: reduction of external nutrient load from septic tank effluent and surface runoff and reduction of internal nutrient build up due to microbial metabolism of nuisance microbes. Under the project Constructed Wetland (Reed Bed) for septic tank and restaurant effluent treatment were developed and for surface runoff water treatment for removal of nutrients, solids trappings and aesthetic enhancement with flowering plants

on pond bank were also developed. Artificial floating island for water column oxygenation, entrap suspended solids, dissolved nutrient removal and enhance microbial activity in root zone water column with flowering plants were placed in the pond water. Apart from all these chemical formulation for restoration of polluted waterbodies to eliminate toxic cyanobacterial blooms for improvement of water quality in terms of dissolved oxygen, reduction of BOD, COD, odour, and colour were also applied.

TERI–NE Centre has been working as Implementation Support Agency (ISA) under the project entitled 'Jal Jeevan Mission-2020' in four Public Health Engineering Departments (PHEDs) in three districts of Assam. The broad objectives of the project are to provide FHTC to every rural household, to prioritize provision of FHTCs in quality affected areas, to provide functional tap connection to schools, Anganwadi centres, GP buildings, health centres, wellness centres and community buildings, to monitor functionality of tap connections, to promote and ensure voluntary ownership among local community by way of contribution in cash, kind and/ or labour, to assist in ensuring sustainability of water supply system. Under the project TERI–NE as an ISA has facilitated the activities of Jal Jeevan Mission in Cachar, Karimganj and Hailakandi districts of Assam and prepared the Village Action Plan (VAP).

Agriculture and Rural Extension Area

Considering the adverse environmental impact of plastics, it is desirable to promote alternative packing materials. The Centre initiated a project in Meghalaya on cultivation of packing leaves plant with the objectives of promotion of packing leaves as substitute of plastics and also for livelihood enhancement of ST communities in the state. The packing leaf plant, *Phrynium pubinerve,* is a plant whose leaves are used as wrapping and packing material as alternative of plastic. The leaves are usually collected from wild sources and sold in the market in bundle form. To increase its availability and also to enhance the income of low-income ST group initiative for large-scale cultivation of *Phrynium pubinerve* has been undertaken under the project. So far 72 ha new plantation area has been developed in unutilized land

along with net houses nurseries for production of planting material at village level. Moreover, value-added products have also been developed from the leaf petiole. It is expected that the project initiative will minimize pressure on wild population of packing leaves; enhance income of the beneficiary by using leaves from the cultivation plot and by developing value-added products and minimize negative impact of plastic.

In another research project on inventorization, molecular identification and characterization of *Garcinia* species from northeast India for isolation of polyisoprenylated benzophenones as taxol mimics, information on seven (7) species and four (4) varieties of *Garcinia* were gathered from Assam and Meghalaya. Out of seven (7) *Garcinia* species and four (04) varieties, two (2) *Garcinia* species and one (1) *Garcinia* variety samples were sent to ICAR-Directorate of Medicinal and Aromatic plants Research, Anand for chemical analysis and also to MS University, Baroda for cell line work. DNA isolation and amplification of ten (10) species is going on at TERI North Eastern Regional Centre, Assam.

In the sericulture sector, a feasibility study was conducted on entrepreneurship model of muga seed production and certification of silkworm seeds with the objective to study the strengths, weaknesses, opportunities and threats of muga seed production and certification system, the resources required and prospects for success in muga seed production and certification by the entrepreneurs. The model proposed based on the field study suggested for the development of enterpreneurship in Muga seed sector based on the requirement of commercial disease-free layings (dfls) which has been calculated based on the available plantations for commercial rearing at private level.

Food-testing Laboratory

Establishment of food-testing laboratory accredited to NABL and subsequent FSSAI affiliation would safeguard the food safety concerns of consumers besides improving quality and business of food processing entrepreneurs of eight north-eastern states. A Food Testing Laboratory has been set up at TERI North Eastern Regional Centre, Assam to cater to the food safety concerns of consumers and also to regulate the quality of food products from the producers, sellers, and entrepreneurs from across the eight north-eastern states. The analytical facility which was partially funded by the Ministry of Food Processing Industries (MOFPI) is primarily developed for determining elemental composition, microbial quality as well as for detecting heavy metals and pesticide residues as per Bureau of Indian Standards (BIS) specifications. High-end equipments like ICP-OES, GCs with FID, ECD, NPD and FPD detectors, microwave digester, ultrasonicator bath, muffle furnace, and so on are being run in the laboratory for analysis and data generation. Apart from the scopes for ensuring food safety, in due course of time nutritional profiling and labelling of food items, GMO testing, and so on will also be considered for inclusion in the scope of services of the lab.

Integrated Policy Analysis

Resource Efficiency and Governance

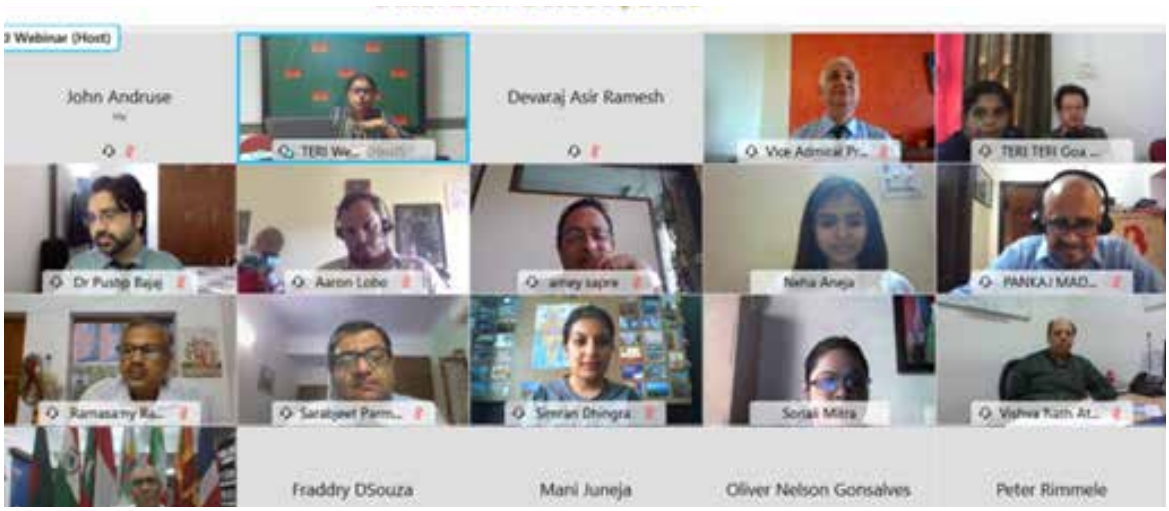
The Centre for Resource Efficiency and Governance (CREG) serves as a focal point for TERI's work on integrated sustainability assessment (ISA), resource efficiency and circular economy, sustainable agriculture policy, resource governance, and trade in natural resources. Resource efficiency, being the key agenda of the Integrated Policy Analysis Division, continues to remain in the focus.

The recent completed study on "Developing a Carbon Neutral Resource Efficient Strategy for Ladakh UT" focused on developing a climate resilient and resource efficient green development strategy for the region. The Division also initiated a study on "India-Australia Industry and Research Collaboration for Reducing Plastic Waste to Develop New Technologies and Business Models to Innovate Plastic Supply Chains". The Division's ongoing study to assess the life cycle impacts of various substrates used in packaging carbonated/ non-carbonated/alcoholic drinks in India and Vietnam is a unique exercise and it is possibly the first in recent times that a comprehensive LCA exercise is being undertaken for four major packaging materials, namely, aluminium, PET, MLP (multi-layered packaging), and glass.

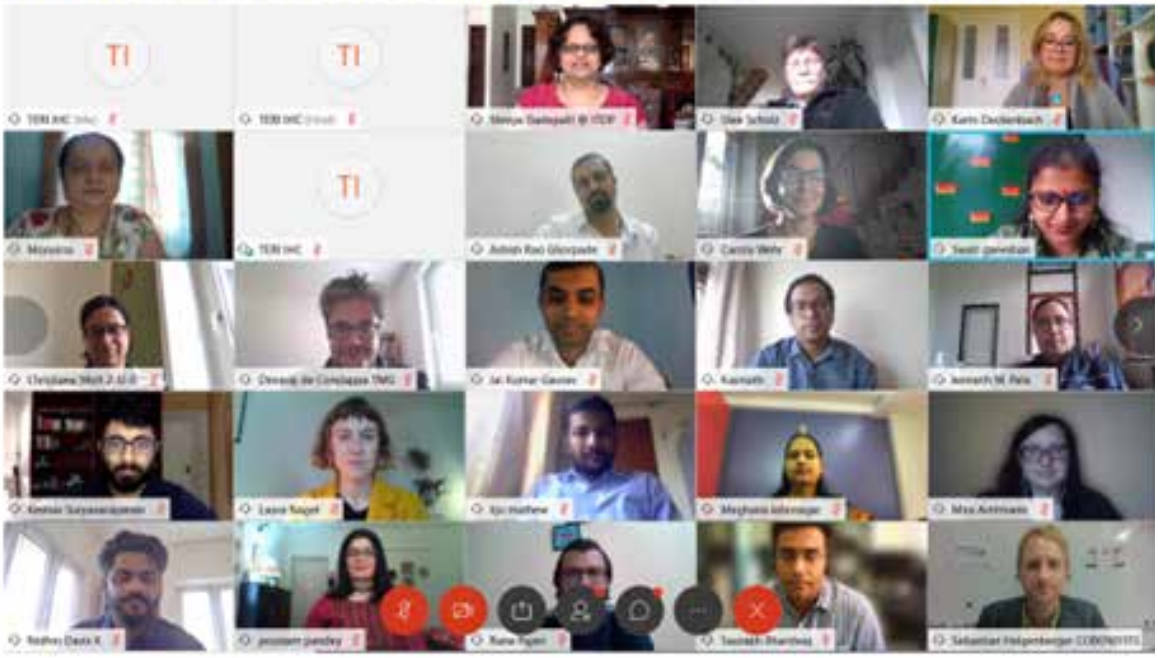
The Division also organized several diginars, including the one on Blue Economy, Resource Efficiency, and Energy Security, a subject that is gaining importance in India.

Webinar on Standards for fostering Resource Efficiency and Circular Economy in India, 13 July 2020

Webinar on Business models for fostering recycling and material recovery infrastructure, September 3, 2020



Ensuring sustainability of oceans for a healthy economy: securing livelihoods and enhancing security, 28 October, 2020



2nd IKI India Networking Workshop

KAS Energy webinar 20-21 January 2021

Staying Ahead of the Curve: Advancing S&T Innovation and Collaboration to accelerate Blue Economy in India
17 February, 2021 | 11:00 am - 16:00 pm (IST) DIGINAR - VI

Centre for Integrated Assessment and Modelling

The Centre for Integrated Assessment and Modelling (CIAM) develops and uses state-of-the-art tools and techniques to provide inputs through integrated assessments of energy, economy, and environment interactions. The modelling and analytical outputs provide useful insights to researchers, industries, and policymakers at the global, national, and sub-national levels. The CIAM has continued to further develop its tools and modelling framework to increasingly focus on the dynamic changes in India's energy sector in recent times. It continues to undertake energy demand–supply interaction, techno-economic analysis, and simulate alternative development scenarios to study the implication of alternative energy use patterns. Its activities are geared towards identifying, analysing, and prioritizing policy options with regard to energy and the environment through quantitative modelling of energy–environment linkages and undertaking economic and statistical analysis of energy and climate change related data.

Recently the Division has completed a study where the team was closely engaged in providing inputs to the Environment, Forest and Climate Change (MoEFCC), GoI through its study on long-term low-carbon development strategies for India. This study intended to analyse and develop a set of strategies that address the challenges of mitigation and link closely with its development objectives as well. The objectives of the study were to (i) analyse the ongoing and planned policies, their impact on the GHG emissions' intensity, and their contribution to emission intensity reduction of the Indian economy, (ii) project trajectories of GHG emissions of India in the post-2020 period till 2050 by modelling for energy sector emission and the best estimated projections for other sectors, (iii) project the emissions peaking year for India, (iv) assess the implications of various developmental paradigms/pathways/structural shifts/ technological changes on national greenhouse gas emission trajectories till 2050, (v) perform scenario analysis of alternative growth pathways and its impact

Virtual Launch of "India: Transforming to a Net-Zero Emissions Energy System" Report, 23 March, 2021

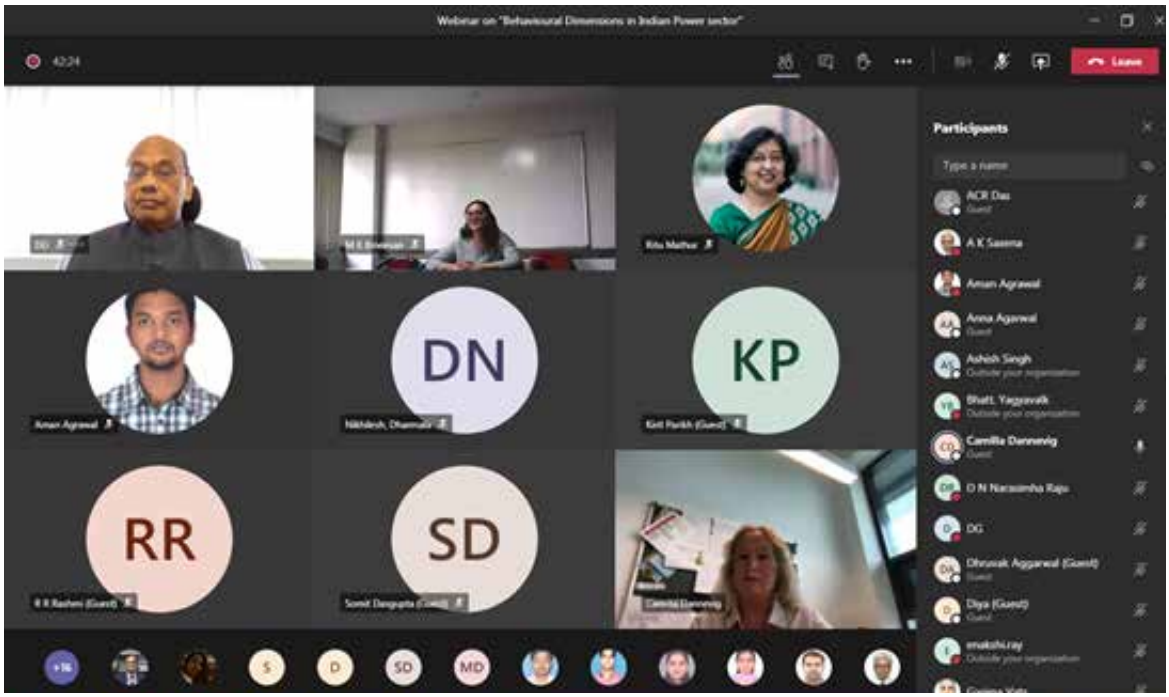
on emission projections for stabilization of GHG concentration, considering the requirements of growth, poverty alleviation, urbanization, and other foreseeable developments, (vi) study of feasibility and cost estimates for mitigation in different sectors of economy and technology, and (vii) identify the contribution of low-carbon measures in important sectors for the years 2020, 2030, 2040, and 2050.

During the year 2020/21, CIAM completed another project "India: Transforming to a Net-Zero Emissions Energy System" supported by Shell India Markets Pvt. Ltd. The project aimed at evaluating India's current options and limits across each of the energy sectors and sub-sectors towards examining the need for additional technology and policy options. The project involved calibration of the existing TERI-Shell MARKAL model to update the database and validate/align with the existing Shell model till 2016. As part of this study, three scenarios were developed: (i) Baseline – reflecting the current and planned policies of the Government of India, (ii) Net-Zero by 2050 – an ambitious scenario designed to assess whether adequate solutions exist to fully decarbonize the sector and/or examine the level to which each of the sectors could theoretically move to zero carbon by 2050, and (iii) Towards Net Zero by 2050 – extremely ambitious, but not purely theoretical, scenario in pushing all possible levers to the maximum. The key findings of the study indicate that the three key elements needed to move Towards Net-Zero are energy efficiency, electrification of end uses and processes, and switch towards decarbonized fuels. Electricity, hydrogen, and bioenergy are the key fuels required to contribute to India's energy sector decarbonization.

During 2020/21, CIAM has undertaken two new projects supported by GIZ and BEIS. The study supported by GIZ has the objective of improving the knowledge of how the climate modelling action in India relates to global and subnational low carbon development pathways, as well as to selected co-benefits of trade-offs of climate

policy. The other study, supported by BEIS (jointly with CIFF), has the objective to explore the economics of Energy Innovation and System Transition. In a risk-opportunity framework, agent behaviour dynamics will be explored in the context of relevant Indian policies.

The flagship publication of the CIAM "TERI Energy & Environment Data Diary and Yearbook (TEDDY)", an annual publication, seeks to support policy research and decision-making by providing policymakers and researchers with the facts and data that can further be used to develop actionable solutions warranted by rigorous analysis. It presents the state-of-the-art information on energy supply, energy demand, and environment. Each edition of TEDDY contains India's commercial energy balances that provide comprehensive information on energy flows within different sectors in the economy. It also provides analytical narrative, supporting the data that are also valuable and widely used for further research in related fields.



Webinar on "Behavioural Dimensions in Indian Power sector", 24 September 2020

Natural Resources and Climate

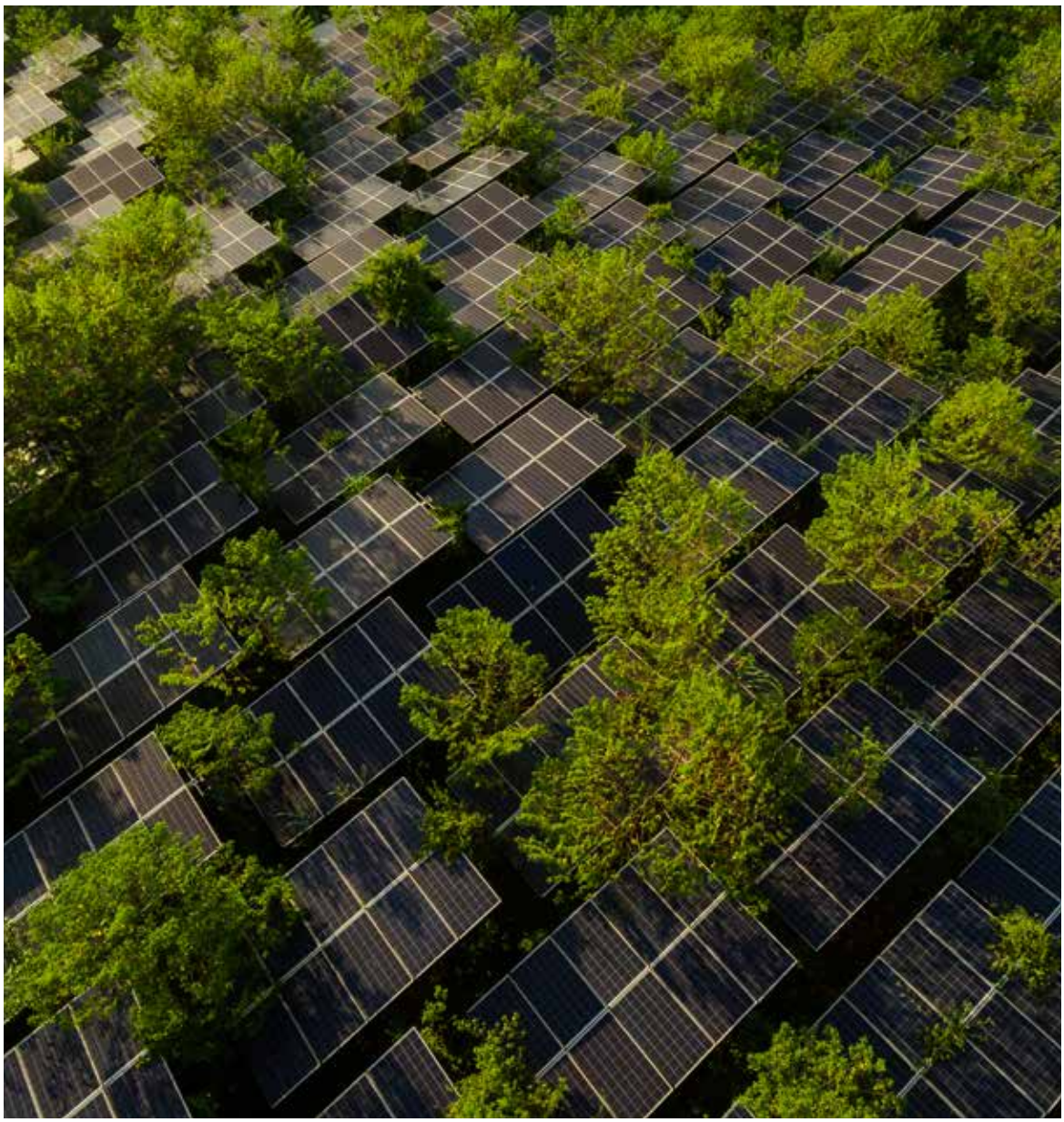
The Natural Resources and Climate (NRC) Programme spearheads research in providing innovative and resource-efficient solutions for management of water resources, waste resources, and bioresources (including application of bioresources); aims to become a global leader in providing scientific knowledge and solutions through evidence of air pollution, climate change, and their impacts, by involving ecological processes, technology, institutions, and policy initiatives; and seeks to spearhead on-field programmes to eradicate malnutrition from rural and urban areas of India.

The NRC Programme seeks to facilitate maximization of socially-acceptable resource recovery and recycling, and address health impacts, release of climate pollutants from waste disposal; provide safe water and improvement in water-use efficiency in industrial, domestic, and irrigation sectors and enhance water availability through water conservation interventions; link sustainable forest management and biodiversity conservation with poverty alleviation; facilitate actions at the centre and state levels to improve air quality in Indian cities by at least 50%; facilitate governments to go beyond commitment in Nationally Determined Contributions (NDCs) and create sustainable models, demonstrating efficient resource use in rural and tribal areas.

The NRC Programme consists of five divisions: (i) Earth Science and Climate Change, (ii) Forest and Biodiversity, (iii) Environment and Waste Management, (iv) Water Resources, and (v) Nutritional Security.

A multidisciplinary team of research professionals in the Programme conducts action research on issues, ranging from regional impacts of changing climate, international climate negotiations to grassroots innovation on climate action. Over the last two decades, the Programme has developed state-of-the-art capabilities for assessment of air pollution and its contributing sources, which are essential for development of air quality management plans. The NRC is also working for sustainable forest management and has been providing solutions to generate finance through carbon trading from forests,

fixing minimum support price of minor forest produce, developing quality planting material, establishing the methodology for carbon assessment and community-based ecotourism. The NRC focuses on areas covering policy and regulatory issues, waste management planning and financing, research and development (R&D) and technology deployment for waste processing, recovery and recycling, and material flows and linkages to circular economy. The NRC has comprehensive infrastructure and expertise for undertaking projects in the field of water-use efficiency and water conservation, watershed management, urban water demand management, glacier research, hydrological assessments, rural water supply and sanitation, water quality and pollution studies, and policy analysis. On the issue of nutrition, the NRC is committed to develop sustainable solutions to tackle malnutrition across all



sections of society through approaches such as research, policy interventions, and implementation of innovative approaches
and technologies.

The primary focus of the Programme is to promote landfill-free cities by facilitating resource recovery and recycling; establish sectoral benchmarks for water use to assist policy for enhancing water-use efficiency and creating a cadre of water auditors through training and capacity building; facilitate increase in water conservation through rainwater harvesting, groundwater recharge, and so on, at household and watershed levels; quantify sustainable harvest of minor forest produce and enhance income of forest-dwelling communities (FDCs) through value addition and market mechanism; develop Interactive Climate Tool (ICT) for decision-making and prediction of climate extremes at regional scales; and develop standardized tools for tracking achievement of implementation of NDCs.

Earth Science and Climate Change Division

Centre for Global Environment Research

The Centre for Global Environment Research (CGER) in TERI leads work on the various dimensions of climate change and cross-cutting themes. The CGER has comprehensively integrated issues pertaining to climate change mitigation and adaptation, mobilizing climate finance, international negotiations surrounding climate policy, and India's overarching climate governance. These core areas of work of CGER include coverage of research that spans the scientific aspects, technology and finance dimensions across areas and sectors, and policy on climate. Of late in the impacts and adaptation domain, the Centre has been aiming to build the gender narrative and is strengthening its portfolio on exploring linkages with migration. The Centre's capability to deliver successfully on projects and research resides on a multi-disciplinary set of team with diverse expertise in the domains of natural sciences, social sciences, and economics. The Centre's focus is on research that is applied and of interdisciplinary nature.

Globally, the Centre has tapped onto the work modulus under international commitments such as the Paris Agreement and Montreal Protocol, by collaborating with multilateral and bilateral organizations and international donor agencies. Under the Paris Agreement, the Centre is working on various articles along the themes of NDC implementation, transparency and MRV frameworks, climate finance and markets, adaptation and resilience, loss and damage, and global stock taking. The Centre contributes as the country lead in the International Climate Politics Hub, a global network of experts on climate politics, helping to support strategic alignment across the wider climate community in addition to providing research support on enhancing ambition and climate action in India by strengthening Track II Dialogues. The Centre has been contributing to the climate transparency initiative (TERI being one of the 14 global partners), an international partnership project that examines and reviews G20 climate actions, finance and vulnerability, and releases a comprehensive 'Climate Transparency' report. The Centre contributed to the Climate Transparency Report 2021, launched in October 2021. The Centre has also since long advocated on international partnerships on building capacities and on implementing complimentary work with other developing and industrializing nations. Under this ambit,

the Centre has contributed to Fiji's NDC implementation road map and the State of Environment report.

Specific to the Paris Agreement, the CGER has prepared a guiding framing document to aid the formulation of a long-term strategy for India (in line with Article 4.19). It identified five essential pillars that will enable the development and implementation of a strong long-term strategy, the interdependencies in their roles, and key decisions to be taken under each pillar. Further, in order to enhance preparedness towards the Enhanced Transparency Framework (Article 13, Paris Agreement) and NDC Implementation (Article 4), the Centre has carried out research on understanding Modalities, Procedures and Guidelines (MPGs) and its implications for developing countries such as India, tracking NDC implementation, and supporting the domestic institutional set up in the country. The CGER is working closely with the Ministry of Finance on various emerging discussions on climate finance under the UNFCCC and tracking climate finance flows from various sources. Further, as one of the key implementation partners of the SNAPFI project (supported by IKI), the Centre has been working on exploring the role of international climate finance towards implementation of NDCs in different geographies. On carbon markets, the Centre has contributed to India's Market Readiness Proposal as part of the World Bank's Partnership for Market Readiness initiative. Further, the Centre is providing technical assistance to project developers on voluntary carbon markets (VCS, ClimateSeed, etc.)

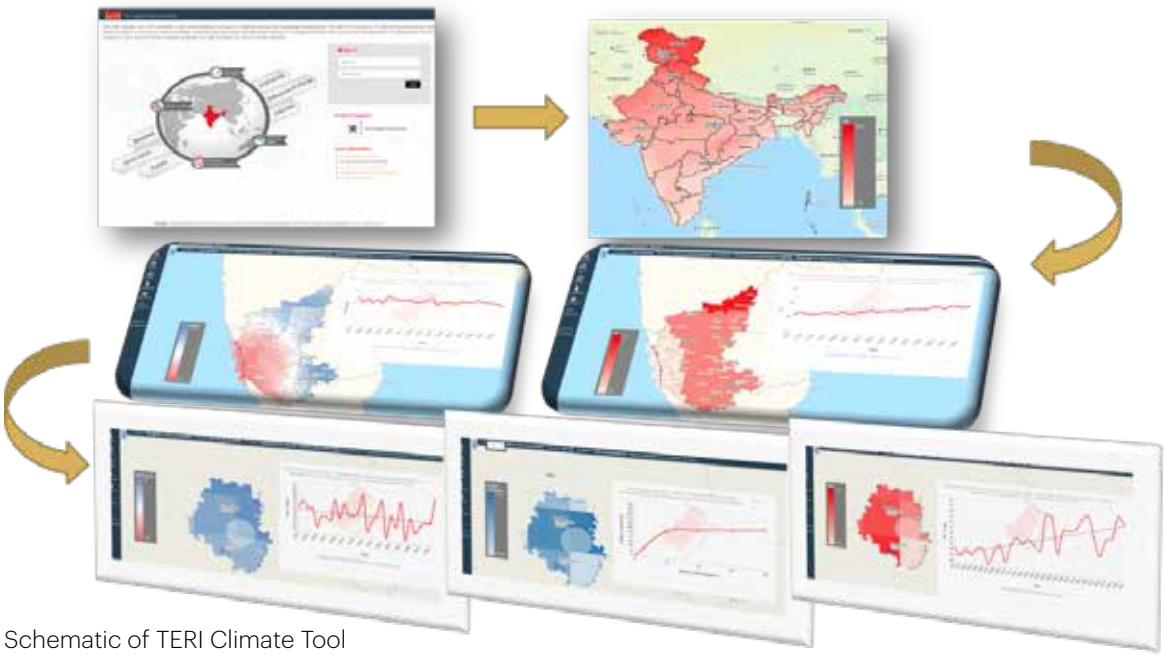
Under the Montreal Protocol and in the light of India's commitments within the Kigali Amendment, the Centre has been carrying out research on understanding the global trends to meet the obligations under the Kigali Amendment, providing platform to the industry to share innovations and measures on hydrofluorocarbons (HFCs) transitions, and inform policy makers about developments in MMoP, Open-ended Working Group (OEWG), and Ex-Com negotiations. The Centre has been leading a civil society initiative, namely SHEETAL: Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort for All in collaboration with AEEE and CEEW with the support from Children Investment Fund Foundation. It aims to provide opportunity for strategic actions to put forward the sustainable cooling agenda in India by facilitating the implementation of India Cooling Action Plan (ICAP).

In the domestic milieu, the Centre is working closely with the Union Territories of Chandigarh and Puducherry and the state of Uttarakhand to revise their State Action Plans for Climate Change according to the guidelines issued by the MoEFCC and, thereby, contributing to enhancing these states' capacities. Leveraging further on enhancing state capacity in climate adaptation and disaster risk reduction, the Centre has developed flood early warning system for the cities of Guwahati and Jorhat in Assam besides contributing to the work on mainstreaming climate action and disaster-risk reduction in the state of Uttarakhand. The Centre is involved in the evaluation of adaptation implementation in Maharashtra with a focus on building agricultural resilience. It has also through the Initiative for Climate Action Transparency, contributed to the development of MEL/MRV frameworks for the buildings, transport, renewable energy, water, and agriculture sectors. Further, the Centre, as part of the Indo-German flagship project Water Security and Climate Adaptation in Rural India (WASCA), is leading the efforts towards providing evidence base for contextualizing climate adaptation measures for enhancing water security in the designated project locations.

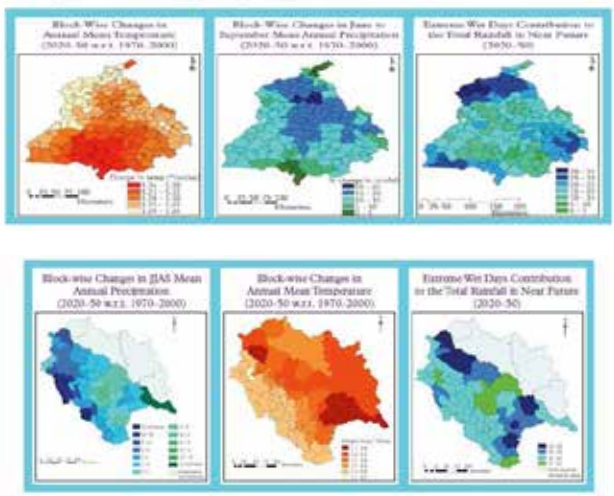
The Centre through its multifaceted approach to issues and themes under the climate and environment paradigm will continue to strive through pioneering research and collaborations with its noteworthy stakeholders and beneficiaries.

The Centre for Climate Modelling

The Centre for Climate Modelling (CCM) focusses on addressing the knowledge gaps in climate change science and develops a better understanding of climate variability at various spatial and temporal scales in an effort to effectively link climate science to policy research. With its unique integrated focus, CCM in this context utilizes its climate and impact modelling skills for better understanding of the climate variability at national, sub-national and local scales and their links to policy. The Centre has successfully provisioned multi-sectoral and multi-scaled climate services products designed for various types of stakeholders, for example, first-of-its-kind TERI Climate Tool (TCT) available at tct.teriin.org and assisted deployment of flood early warning system at urban scale, available at fews.teriin.org. Such novel scientific and policy-relevant products serve the purpose for impact and vulnerability, and adaptation assessments for the organization. As a first-of-its-kind study, the group also



Schematic of TERI Climate Tool



Granular climate services products

launched climate change and migration report for the state of Uttarakhand with its research partners at Potsdam. The group continues to engage with diverse stakeholders including municipalities and corporates in mainstreaming scientific knowledge in planning activities in terms of provisioning of climate products at granular scale.

The group's activity spectrum ranges from the use of state-of-the-art global and regional climate models such as CCSM 3.0[1], CESM[2] 1.0, GFS[3] and Met Office Unified Model (GCMs) and PRECIS[4], WRF[5], NorESM[6] and COAWST[7] (regional coupled) (GCMs), to linking these regional climate projections to various Impact Assessment Models such as ADCIRC[8] (for storm surge and coastal circulation), SWAT[9] (for water resources), DSSAT[10](for agriculture), and MIKE[11] (for urban flooding and storms).

Centre for Environmental Studies

The Centre for Environmental Studies group (CES) works with a broad aim to study the environmental dimensions of various economic activities and resource-use patterns and explore strategies to mitigate the adverse effects. The group conducts applied and policy research to address environmental problems and assesses the relationships between energy and environment in urban, industrial, and rural settings. The CES group has undertaken

Flood Early Warning System for Guwahati

various projects to examine environmental impacts associated with urbanization, industrialization, and other anthropogenic activities. The group was involved in the pioneering source apportionment study for Bengaluru city and has also been working for many years on the use of state-of-the-art three-dimensional multi-grid air quality models (ISCST3, AERMOD, WRF, C-MAQ, etc.), to predict urban/regional scale pollution of criteria as well as emerging pollutants such as ozone. Their research has focussed on several aspects of the issue of air pollution including regional scale assessment of air quality, impacts of air pollution on health and agriculture, indoor air quality assessment in rural and urban buildings, management of emissions from transport and industrial sectors, linking air quality to climate change, training and capacity building in air quality, etc. The CES has also been active in providing assistance to government bodies for the formulation of the State of Environment Reports and Environmental Policies. The group assisted the Ministry of Environment, Forest and Climate Change (MoEFCC) in the preparation of the draft National Environment Policy and has also been recognized by the MoEFCC as one of the National Host Institutes for facilitating development of State of Environment Reports at the state level. The CES group has also been focussed on providing state-level policy recommendations through several source apportionment studies, which guided state-level regulatory authorities to develop local

1 CCSM – Community Climate System Model by National Centre for Atmospheric Research (NCAR-US)
2 CESM – Community Earth System Model by NCAR
3 Global Forecast System
4 Providing Regional Climate for Impact Studies by UK Met Office
5 Weather Research and Forecasting by NCAR
6 Norwegian Earth System Model
7 Coupled-Ocean-Atmosphere-Wave-Sediment Transport Modelling System
8 ADCIRC – Advance CIRCulation Model
9 SWAT – Soil and Water Assessment Tool
10 DSSAT - Decision Support System for Agrotechnology Transfer
11 MIKE – Danish hydrological model

action plans for control of air pollution and its impacts. The group has made several policy submissions to highest levels in the government in the field of air quality management. The group has also worked closely with the government and assisted in drafting and designing of the National Clean Air Programme (NCAP) document and has also submitted an emergency response plan to both state and central government for tackling high air pollution episodes. The group continues to strengthen and build capacity and spread awareness on different environmental issues including air pollution. The group has also started research in the field of biochar application, an emerging technology for climate change mitigation. Training programmes are regularly conducted for different stakeholders to build their capacity in air quality modelling, exposure assessment, indoor air pollution, environmental pollution and health, and other environmental issues. In order to help policymakers to implement strategies to tackle air pollution problem and achieve the air quality standards in Indian cities, studies are ongoing in many cities. In this context, several new proposals are being formulated for source apportionment studies, real-time source apportionment studies, regional air quality studies, pilot demonstration of strategies for air pollution control, spatial mapping and forecasting of air pollutants, linking air pollution with climate change, post-harvest residue management studies through application of biochar, etc.

Land Resources Division

Centre for Biodiversity and Ecosystem Services

Biodiversity, upon which millions of people depend for myriad services, is under unprecedented pressure threatening to unravel and weaken the resilience of complex and fragile ecological systems, and endanger wildlife populations. TERI's Land Resources Division has been focussing on sustainable management of forest ecosystems, mitigation of land degradation, and conservation of biodiversity for over two decades. Realizing that loss of biodiversity has enormous implications for the society, poverty alleviation, and meeting the Sustainable Development Goals (SDGs), the Centre of Biodiversity and Ecosystem Services (CBES), embedded within the Division, takes a broad-based view of biodiversity. The focus is not only on species or habitat loss, but on policies, social, and economic issues that undergird arguably one of the most vexing problems facing the world today. Consequently, CBES emphasizes the mainstreaming of biodiversity through enhanced community engagement, involvement of a wide portmanteau of stakeholders, and a focus on valuing biodiversity and ecosystems.

Economic valuation of ecosystem services

TERI conducted several studies with respect to economic valuation of ecosystem services in 2020/21. Some of the notable ones include economic valuation of ecosystem services of National Zoological Park in Delhi, valuation of ecosystem services provided by Sardar Patel statue and 35 other attractions within the complex, and the World Bank-supported economic valuation of mountain forests and mangroves in the Kingdom of Saudi Arabia. The annual value of key ecosystem services comprising use and non-use values such as carbon storage and sequestration, employment generation, recreation,

Recent reports on ecosystem service valuation
Credit: Siddharth Edake

education and research, biodiversity conservation, the surrogate value of land has been evaluated under these studies using a robust and refined methodology.

The studies conducted aim to contribute to the technical capacity of the decision maker's for land-use planning through the assessment of important ecosystem services in actual and future development planning processes. This will result in the integration of ecological considerations into decision-making and planning policies.

Conservation of tiger reserves in India through carbon finance

Around 50 million people stay around the protected areas (PAs), such as tiger reserves (TRs), and depend on forest resources for their day-to-day needs and livelihood. This results in tremendous pressure on TRs and leads to human-wildlife conflict (HWC).

Carbon finance projects could yield additional finance, which is required to address the issues of community alternative livelihood and mitigation strategies for HWC in and around PAs. The PAs in India have been identified to have potential of generating around 10,000,000 carbon emission reduction (CERs), the tradeable form of carbon, which could be traded in the carbon market.

Keeping this in mind, TERI in collaboration with National Tiger Conservation Authority (NTCA) and VNV Advisory Services Ltd initiated four voluntary carbon market projects in Periyar TR, Kerala; Pench TR, Maharashtra; Dudhwa TR, Uttar Pradesh; and Sundarban TR, West Bengal. The aim is to to generate additional finance and use it for community development and biodiversity conservation activities. This will result in adaptation and enhancing carbon sequestration as well as reducing pressure on forests from unsustainable collection of fuelwood through sustainable fuelwood management and exploring energy-efficient technologies and alternative fuel.

Understanding the role of traditional agriculture in the form of shifting cultivation for sustainable development in Northeast India

Traditional agriculture pertaining to shifting cultivation (locally known as *jhum* cultivation) is being practised in Northeast India since the time immemorial. However, with modernization and changing society, this tradition is currently in transition and, hence, it becomes imperative to understand the role of shifting cultivation for sustainable development in the present context.

Hence, TERI is implementing a three-year project supported by Japan Fund for Global Environment of the Environmental Restoration & Conservation Agency (JFGE) that intends to compile the traditional practices and wisdom associated with this form of traditional

Carbon Finance projects in four Tiger Reserves of India
Credit: Siddharth Edake



Documenting various aspects related to traditional agriculture in Northeast India

agriculture and make a strong case for *jhum* cultivation, if practised traditionally (with longer *jhum* cycles), is a fine example of how a production system can be adapted to an ecological niche. The three main components of the project are: (1) the production of an edited academic volume on traditional farming for sustainable development in Northeast India; (2) compilation of knowledge in Nagaland and elsewhere in India; and (3) knowledge exchange with other regions.

Developing agroforestry-based carbon finance projects

In India, agroforestry has emerged as one of the viable alternatives for diversification from existing crop rotation. At present, more than 80% demand of wood and wood products in the country is met from agroforestry sector, 6% from natural forest, and 12% from imports. Agroforestry systems also store carbon and may qualify as an afforestation practice as is defined in the Kyoto Protocol, and could be included in the carbon market under the REDD+ scheme. Thus, agroforestry can contribute to more than 2 billion tonnes of CO_2e by 2030.

Understanding this potential, TERI along with state forest departments of Punjab, Gujarat, and Haryana has initiated three individual pilot projects to promote agroforestry, enhance the income of farmers, and also help these states to move forward towards carbon neutrality.

TERI's role is confined to assessing the carbon potential of these plantations, developing Project Design Documents (PDDs), assisting in preparation of monitoring report (MR), verification process, and overseeing the process of issuance of carbon credits.

Centre for Forest Management and Governance

The Centre for Forest Management and Governance deals with a diverse range of issues related to socio-economic, institutional, policy, and technical aspects of India's


Developing carbon finance projects in states practising intensive agroforestry

forest resources and rural development. The group is actively working in promoting community participation in forest conservation through various institutional, training, research, and policy mechanisms. The Centre continues to respond to new and emerging challenges while retaining several core areas of expertise. Over the last few years, it consolidated its work in the thematic areas of productivity enhancement, natural resource management, livelihoods, and climate change.

In addition, the Centre is involved in experimental research for afforestation in difficult sites including nursery development and silviculture work.

Among the major focal areas are the impact of current policies and guidelines dealing with socio-economic and institutional aspects along with necessary inter-sectoral linkages for sustainable utilization and conservation of resources and the role of community-based efforts. The CFMG also addresses issues of global warming and climate change, to find out ways of attaining development goals with minimum economic, social, and environmental costs.

The CFMG, thus, endeavours to facilitate the creation and development of models, systems, and concepts for conservation and sustainable utilization of our natural resources. The Centre has also put considerable efforts into documenting its research findings on the key issues involved in this sector. The major projects of the Centre are as follows:

Pilot implementation of India's forestry NAMA in Assam

GIZ and the Ministry of Environment, Forest and Climate Change (MoEFCC) are implementing an Indo-German bilateral project 'Development and Management of NAMAs in India' with the focus on two sectors: waste and forestry. The group has implemented the Pilot Forestry NAMA in Assam with major focus on sustainable fuelwood management. The project aims to enhance carbon sequestration and reduce pressure on forests from unsustainable collection of fuelwood through sustainable fuelwood management, deployment of energy-efficient technologies, and alternative fuel in selected districts of Assam. This would be achieved through increasing supply of fuelwood and enhancing carbon sequestration from plantation and assisted natural regeneration; promotion of efficient and clean fuelwood technologies such as improved cookstoves, LPG, and biogas; and capacity building of stakeholders for effective and sustained adoption of the fuelwood-saving technologies and adopting alternative livelihood options.

Under the NAMA project, the following deliverables have been completed:

- **Capacity building of Assam Forest Department for assessment of forest carbon** – Over 160 frontline staff of Assam Forest Department has been trained for assessment of five pools of carbon. A detailed manual in English and Executive Summary in Assamese for the field staff has been prepared for use in the field.
- **Deployment of improved cooking technology** – Over 21,535 households have been provided with various types of improved cooking technologies such as Sukhad Chullha through NAMA project, convergence with Pradhan Mantri Ujjwala Yojana and schemes of Assam Energy Development Agency (AEDA).
- **Livelihood enhancement activities** – Pilot NAMA project built the capacities of many youths and women to construct the Sukhad model of improved cook stove. The entire process of deploying the Sukhad model needs about 15 days ¾ from casting of stove to operationalization ¾ and involves a number of steps. The trained youths and women have demonstrated that for construction of every Sukhad model, the artisan would get paid in the range of INR 150-200. Moreover, if the demand is generated for a group of 100 households, then a team of 2 persons can get an additional livelihood option for over a month at a stretch.
- **Facilitation of plantations for carbon baseline measurement** – Assam Forest Department has conducted plantations during the period: 2018 to 2020. These plantations have been geo-referenced and baseline of forest carbon is estimated for these plantation sites in order to account the contribution towards carbon sequestration till 2030.

- **Assam Fuelwood Decision Support System** – An Excel-based tool has been developed in order to address the fuelwood production and reduction in use through deployment of improved cooking technologies. The tool allows the decision-maker to decide on the plantations models resulting in fuelwood production and also makes a choice of suitable improved cooking technology based on the available funding.
- **Upscaling proposal for sustainable fuelwood management NAMA for Assam –** In order to upscale the results and learnings from implementation of Pilot Sustainable Fuelwood Management NAMA project for Assam, a structure of projected impacts, required funding, and institutional mechanism for Assam and also at national level for selected states have been prepared.
- **Assessment of impact in change in forest carbon and reduction in usage of fuelwood in the project area –** Improved cooking technologies, namely Sukhad model of improved chullha, portable improved cook stove and LPG have been given to over 21,500 beneficiaries in the project divisions. The impact assessment suggests about 50% acceptance of various technologies and also proportionate reduction in fuelwood consumption in the project division and reduction of over 90,000 tCO_2e. It has also reflected in increment in forest carbon in the natural forests.

Implementation of NAMA project

Development of forest governance model in the context of community forest resource rights and exploring linkages with Panchayati Raj Institutions

TERI has been recognized as the Centre for Excellence and has been assigned the responsibility of developing governance models for the implementation of Community Forest Resource Rights under Forest Rights Act, 2006. As the country is so diverse, one single model cannot work. In order to develop the governance models, the area conducted 26 focussed group discussions (FGDs) in different areas of governance in the country (Schedule V, Schedule VI and others), namely in Madhya Pradesh, Maharashtra, Chhattisgarh, Meghalaya, Arunachal Pradesh, Karnataka, Andhra Pradesh, Rajasthan, Himachal Pradesh, Telangana, Tripura, Assam, Tamil Nadu, Uttar Pradesh, Uttarakhand, and West Bengal. The report has been submitted to Ministry of Tribal Affairs (MoTA) and it would help in issuing the broad guidelines and principles for the implementation of Community Forest Resource Right mentioning specific role of the state forest department, state tribal/social welfare department, revenue department, and gram sabha. Respective states wold issue similar guidelines in consonance with guidelines of MoTA and further develop a plan of action such as capacity building of local governments and communities.

As a continuation of this work, CFMG has been conducting assessment of linkages of various community-based institutions of forest management such as Joint Forest Management Committees (JFMCs), Eco-Development Committees (EDCs), etc. with the setup of Panchayati Raj institutions. The outcome of this work will help to evolve gram sabha-based forest governance and effectively involve local communities including tribals and non-tribals in sustainable forest management.

Capacity building and training of forest officers for assessment of five pool of carbon stock of forest ecosystem

With the possibilities of accessing carbon-based financing from forestry activities, CFMG has been

Focus group discussion(s) for developing governance modules for implementation of Community Forest Resource Rights in different states of India

organizing capacity-building and training programmes for forest departments of different states in the country to assess the carbon stocks of forests. It has also developed a manual on the carbon stock assessment of forests. As of now the training has been conducted in Chhattisgarh, Uttarakhand, Punjab, Assam, and Goa. A similar training programme is scheduled for Maharashtra and also in other states.

TERI has been conducting training programmes for Indian Forest Service (IFS) officers on topical themes for the last several years. In 2020/21, TERI conducted two national training programmes for senior IFS officers on the topic 'Forest and Climate Change: Opportunities and Challenges of Adaptation and Mitigation' and 'Climate Change Mitigation: Role of Forests within the Clean Development Mechanism'.

The intent of the online training programme is to help states evaluate the quality of forests and, accordingly, determine the future course of action for improvement of forest cover, and thereby contribute to achieving the country's nationally determined contributions (NDCs). The course will also be helpful in upgrading our forest working plans in order to align these with the new sectoral goals.

Nursery activities at Gual Pahari

The CFMG maintains an advance nursery-cum research centre for forest tree species, medicinal and ornamental plants. Nested in the lap of the Aravallis, the Forest Research Centre is spread across an area of 2.5 acres and supports facilities such as mist chambers, shade houses, hedge gardens, and clonal orchards with a capacity to produce 3000 clonal plants annually. It also has an open area of approximately 1.2 acres for shifting and grading of sapling. TERI's conserved gene bank has over

Herbal nursery at Gual Pahari

42 clones of Eucalyptus hybrid, 22 clones of Poplar, and various clones of Shisham (*Dalbergia sissoo*). The research centre has an established medicinal and herbal garden that supplies more than 5000 herbal plants annually to schools, the National Medicinal Plant Board, resident welfare associations (RWA), New Delhi Municipal Corporation nurseries, and various state forest departments.

TERI's support to the US-India partnership for climate resilience

Under this partnership, WSDS 2020 Thematic Track on Forest – A Tool for Adaptation and Mitigation of Climate Change was co-convened with TERI, NOAA National Centers for Environmental Information and the NOAA Cooperative Institute for Satellites and Earth System Studies, a research institute of NC State University. Forests in India are treated primarily as social and environmental resources and only secondarily as a commercial resource. The thematic track focused on the major challenges being faced in the forestry sector including deforestation, degradation, overgrazing, and conversion to other land uses, forest fires, excessive fuelwood collection, unsustainable harvests of non-timber forest products, weak institutions and poor governance, policy and market failures, land fragmentation and uncertain tenure, demographic and socio-economic factors as well as the impacts of globalization. The thematic track also stirred up discussions on the strengths, gaps, and opportunities of the climate change adaptation and mitigation by the forestry sector and the effects of climate change and

climate variability on forest ecosystems around the world. Further, the discussion also focused on the fact that the need of the hour for India is to adopt the carbon neutrality policy which shall help bridge the gap of the timely financial requirements to mitigate human–wildlife conflict and ensure community participation in biodiversity conservation by involving the local communities.

Assessment of carbon stocks of forest areas of selected Van Panchayats (VPs) under UFRMP, and facilitate these VPs in generating carbon finance

The objective of the project is to assess carbon stocks of forest areas, generate carbon finance under voluntary carbon markets, prepare Project Design Document (PDD), preparation of MRs and their validation and verification of projects for voluntary carbon markets, and building capacity of the community in carbon assessment and in generating carbon finance for the stakeholders (VPs).

The key objectives of the assignment are as follows:

1. Assessment of total carbon stocks of panchayati forests of 25 identified VPs under UFRMP
2. Prepare project design document (PDD) and MRs, validation and verification of projects for voluntary carbon markets
3. Generate carbon finance under voluntary carbon markets and building capacity of the community (van panchayats/stakeholders) in carbon assessment, preparation of PDDs, and in generating carbon finance
4. Propose and implement baseline and monitoring methodologies

Centre for Sustainable Land Management

Land provides many environmental and social benefits, including environment for agricultural production, source/sink functions for greenhouse gasses, recycling of nutrients, amelioration and filtering of pollutants, and transmission and purification of water. Due to increased anthropogenic pressure, degradation of land is one of the major issues. One out of every three people on earth is affected by land degradation. Hence, sustainable land management practice plays an important role. The key objective of sustainable land management is to balance environmental, economic, and social benefits while maintaining the quality of land resources.

Centre for Sustainable Land Management offers solutions for minimizing land degradation, rehabilitating degraded areas, and ensuring the optimal use of land resources for the benefit of future generations. CSLM focuses on the challenges in land acquisition, rehabilitation and resettlement of PAF, mine rehabilitation, training and capacity building on climate change and forestry issues, and policy support.

Assessment of implementation of The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (RFCTLARR) Act, 2013 in Jharkhand, Odisha, Chhattisgarh, Assam and Madhya Pradesh

The land acquisition regime created by The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (RFCTLARR) Act, 2013 seeks to make the affected persons partners in development, leading to an improvement in their social and economic conditions. Six years since its enactment, it is worthwhile to critique the Act and the implementation practices concerning livelihood-dependent families and women.

Hence, a project awarded by the Ministry of Tribal Affairs (MoTA) in 2020 addressed the critical gap in the existing literature on the outcomes of land acquisition

on scheduled tribes (STs) and other traditional forest dwellers (OTFDs), post-2013. This study is on land acquisition, rehabilitation and resettlement with the guidelines issued under RFCTLARR Act and various state land acquisition laws. It included analysis of comprehensive processes prescribed under various legislations for land acquisition for private purposes and efficiency of social impact assessment (SIA) in consultation with Panchayati Raj Institutions. The study's anthropological and sociological perspective provides reference points to policymakers, administrators, practitioners, academicians, researchers, and civil society to gauge the inclusiveness and sustainability of safeguards for the STs and OTFDs incorporated in the Central Law.

Mine rehabilitation

India is a storehouse and rich source of minerals, distributed throughout the country from fragile foothills of the Himalayas to the deserts, arid and semi-arid regions, along vast coastlines, plains, and rich forests. Due to this mineral richness, the country ranks among the top 10 mineral-producing nations globally, and its economy largely depends upon the revenues accrued from the mineral output. Despite the contribution of mining to the country's gross domestic product, management of mine waste should be considered. Considering harmful impacts of mining activities, the National Mineral Policy, 2003 of the Ministry of Mines, stated that 'mining activity and waste generated from it, often leads to environmental problems and affect the ecology of the nearby local area. Thus, vegetation and forestry practices shall be an integral part of mine closure and waste management.'

TERI undertook two projects of Hindalco industries for reclamation/rehabilitation of red mud waste in Jharkhand and Uttar Pradesh. The primary objective of the

research was to convert the inhospitable substrate of red mud into a favourable one by enhancing its physico-chemical analysis, followed by standardizing vegetation protocol through developing green cover at the project location.

The ecological rehabilitation of red mud residue deposits is complicated by many factors, including its hazardous nature, extremely high pH and salinity, poor water-holding capacity, and extremely low microbial activity. Given this, very few research studies have been conducted in this field, and among those, successful studies were minimal. Thus, the research findings of such studies would be beneficial in stabilizing the toxic red mud and developing vegetation protocol. Another important outcome of these interventions would be significant changes in the quality of red mud in the form of a decline in the pH value, improvement in the proportion of sand, and an increase in micronutrients. All these changes provided much needed nutritional support to the growing plants. The successful results would be replicated at other sites of red mud within the country.

Project activities for mine reclamation

Experience of TERI on mine rehabilitation

- Closure plan development of **red mud pond**, Chota Muri, Ranchi
- Reclamation of back filled **bauxite mine** dump at Lohardaga, Jharkhand
- Rehabilitation of **iron ore** mining dumps at Dhabadaba mining operations, Bicholim, North Goa
- Rehabilitation of **red mud** ponds at Indian Aluminium, Co. Ltd, Belgaum
- Reclamation of **red mud** dumps at HINDALCO, Muri, Jharkhand
- Reclamation of mine-degraded lands of **Vastan Lignite Mine**, Surat, Gujarat
- Rehabilitation of **limestone mines**, Mussoorie Hills, Uttarakhand

Capacity building and training of forest officers for assessment of five pool of carbon stock of forest ecosystem

With possibilities of accessing carbon-based financing from forestry activities, the Centre has been organizing capacity-building and training programmes for the forest departments of different states in the country to assess the carbon stocks of forests. TERI has been conducting training programmes for IFS officers on topical themes for the last several years. In 2020/21, CSLM organized two national training programmes in September 2021 for senior IFS officers. The first 5-day training programme was on 'Developing Green Climate Finance Project for Forest Department: national and global case studies'. The training course was attended by 21 IFS officers from 15 Indian states. The second 2-day training workshop on 'The Road to COP of UNFCCC: Global Initiatives by India, G-7 and G-20', was attended by 26 IFS officers from 22 Indian states.

Another online training programme 'Forest and Climate Change: Opportunities and Challenges of Adaptation & Mitigation' and 'Climate Change Mitigation: Role of Forests within the Clean Development Mechanism' helped states evaluate the quality of forests and, accordingly, determine the future course of action for improvement of forest cover, thereby contributing to achieving our nationally determined contributions (NDCs). The course aimed to help upgrade the forest working plans to align these with the new sectoral goals.

CSLM organized extensive training programmes to build the capacity of forest officials, frontline staff and communities on carbon finance, carbon stock assessments of forest ecosystems, climate action, forest governance, and biodiversity, more than 500 IFS officers under the Mid-Career Training (MCT) Programme for IFS Officers, and of local communities.

Carbon finance project in protected areas

Protected areas including national parks, wilderness areas, community conserved areas, nature reserves, etc., act as an anchor for biodiversity conservation, with

Capacity building and training of forest officials

significantly contributing in sustaining the livelihoods of local communities residing in close vicinity of the protected areas. A large fraction of the population lives in close proximity to the protected areas and, hence, depends on forest resources. This human interference is resulting in human–wildlife conflicts. So, the finance generated from the carbon-related projects will help generate additional finance, which can help resolve these issues.

TERI has proposed to initiate a voluntary carbon market project for Sundarban Tiger Reserve in India, to generate the additional finance, which can be used for community welfare and biodiversity conservation. This strategy can be replicated in all tiger reserves and protected areas in India, which will help the country achieve its NDC target of 2.5–3 billion tonnes of CO_2e.

Carbon stock assessment

Coastal Ecology and Marine Resources Centre, Goa

Coastal Ecology and Marine Resources Centre is a multidisciplinary research centre focused on key areas such as marine and coastal resources, biodiversity mapping, and water resource management. Various environmental awareness programmes, educational, and outreach projects and activities are being implemented at the Centre.

In the field of marine and coastal areas, multiple projects have been successfully carried out. The currently ongoing project on Deep-sea Mining (DSM), supported by the Australian Government, will further our understanding of DSM in the Indo-Pacific region. The project is being conducted by TERI through a collaborative research partnership with an Australian university, a global natural resources sustainability specialist, and through engagement with countries who have learned lessons from DSM. This would provide the basis for future policy development in the region.

In Water Science and Technology area, River Bank Filtration (RBF) technology projects have been implemented successfully to provide clean water for domestic usage and irrigation purposes, particularly in off-the-grid areas. Further, activities such as water quality testing for chemical and biological parameters and groundwater exploration studies have been initiated.

People's biodiversity registers are being prepared for villages in Goa and at district and taluk levels in Karnataka in collaboration with the Biodiversity Management Committees and the completed registers are validated by expert panel of State Biodiversity Board. This would lead to designation of Biodiversity Heritage Sites and provide a platform for need-based conservation projects in the foreseeable future.

In addition, the Centre has been organizing workshops, training programmes, and seminars regularly. A joint interactive webinar held on 6 July 2020 for staff and employees of ONGC on 'Circular Economy in Waste Management' was informative on how to ensure cleanliness and manage waste.

Deep-sea mining

Achieving a transition from a fossil fuel-based economy to an economy powered by green energy will require a large quantity of specialized minerals, on which the decoupling of economic growth and climate is reliant. Currently, mineral supply is terrestrial and limited in large part to a few geographical locations and countries, leaving the green transition conditional to geopolitics. Substantial quantities of specialized minerals are located within the Indo-Pacific Ocean, with deep-sea deposits of several key metals exceeding that in the global terrestrial reserves. The Deep Sea, therefore, presents a significant opportunity to secure and diversify the supply of critical minerals required for the energy transition. The technology and operations of DSM are an increasing focus of both governments and companies to avail of the notable opportunity presented. However, hand-in-hand with this opportunity for significant national economic and development benefits, there are large, deep-seated risks in mineral extraction from the seabed. Risks to marine ecology, including loss of biodiversity and creation of pollution, need to be rigorously understood. Governance systems need to be developed to catalogue the potential conditions under which DSM will be permitted. DSM in the Indo-Pacific region is still nascent,

and we fall short in our understanding of the economic opportunity, the risks to marine ecology and human society, and undeveloped governance systems.

This project will further our understanding of DSM in the Indo-Pacific through a collaborative research partnership between TERI, an Australian university, a global natural resources sustainability specialist, and engagement with countries who have learned lessons from DSM.

People's biodiversity register of the states of Goa and Karnataka

The People's Biodiversity Register (PBR) of the villages of Goa (Phase II) and at district and taluk levels in Karnataka were supported by the Goa State Biodiversity Board (GSBB) and Karnataka Biodiversity Board (KBB), respectively. PBR involves the recording and inventorization, in consultation with the local people, of the occurrence of various species of flora and fauna and resources present in the area, which may be of local significance. It is also an attempt at recording rapidly eroding knowledge of the medicinal uses of local plants, and the occurrence and management practices of land races of cultivated crops. Thus, the PBR provides a platform through which members of a community may initiate steps towards better management of their biodiversity resources.

The development of the PBR is being facilitated in the coastal villages of St Andre (Goa Velha), Curca Bambolim, Batim, St Laurence (Agacaim), Taleigao, Nagoa, Quelossim, Cansaulim, Verna, Majorda, and Chicolna Bogmalo, Goa, under the support of Goa State Biodiversity Board and four districts namely Kalaburgi, Bidar, Raichur and Yadgir, at both district and taluk levels in Karnataka.

River bank filtration technology

The River bank filtration (RBF) technology works on the principle of creating pressure by pumping action that forces the polluted water in a river to travel to RBF well through riverbed sediments, which leads to removal of contaminants such as bacteria and heavy metals by overlapping biological, physical, and chemical processes. The RBF project funded by DST endeavours demonstration of the bank filtration (BF) wells with off the grid solar pumping system and sensor-controlled irrigation system at lake and river bank sites in south Goa. The project presents a model of sustainability for educating farming communities with small landholdings being unique to Goa. During the initial project period, socio-economic data of the farmers was gathered to record the current need and demand for agricultural use. A geophysical survey was conducted based on which BF wells' locations were envisaged. The BF wells were installed at both the sites along Sal River at Navelim

Village and along Nauta Lake at Cortalim Village to provide clean irrigation water to the nearby fields. Further, the radio frequency identification (RFID) tag soil moisture sensor element that relies on off-the-grid technology, commonly used in agriculture, is expected to measure soil moisture in combination with relay and irrigation system (BF well). Water quality samples were analysed using standard BIS methods to characterize major physico-chemical and biological water quality parameters at both the study sites (pre- and post-installation). Better water quality of BF wells would provide the health benefits for the rural communities; this could be a model for other villages mainly in off-the-grid areas. Crops grown with good quality water would further give better yield and market price.

Another on-going RBF project, 'Expansion of the Indo-German Competence Centre for Riverbank Filtration— CCRBF' is a networking project between India and Germany sponsored by the Federal Ministry of Education and Research, Germany, that focuses on natural treatment techniques of RBF, managed aquifer recharge, and constructed wetlands.

TERI Western Regional Centre, Mumbai

Since its inception in 2006, TERI's Western Regional Centre (WRC), located in Mumbai, has been dedicatedly working to provide pertinent, independent, and objectively oriented research in the broad fields of nutrition, energy, climate change, environment, bio-prospecting, sustainable communities, and livelihood.

The Nutrition Security division based at the WRC has implemented several initiatives that directly and indirectly impact the nutritional security of households in both urban and rural communities. The nutrition intake of communities in remote areas largely depends upon their access to resources – water and energy as well as livelihood opportunities. Hence, the Centre endorses on action-oriented approaches to engage communities, capacity building, women empowerment, and promotion of innovative nutrient fortification and food processing for income generation. The Centre also provides support and market linkages to promote fortified products (https://www.teriin.org/projects/nutrition-security/projects.php).

At the backdrop of the COVID-19 pandemic, TERI-WRC's employees worked from home for the majority of the duration. Interaction with stakeholders including clients was held virtually whenever possible. The major highlights of the work carried out during the pandemic are represented as follows.

Nutrition Security

- Project 1: Nutritional Security and Immunity for Women and Families in Palghar District

Sponsor: National Projects Construction Corporation Limited (NPCC)

Project Timeline: January 2021–December 2021

The Division initiated a project to improve the immunity and nutrition of tribal women and their families in Palghar district, Maharashtra. The project, funded by NPCC, focused on capacity building of self-help groups (SHGs) and the youth from the tribal areas. It encouraged them to undertake Nutri and Immunity Gardens at their home's backyard and promote consumption of nutritious food and immunity boosters/remedies based on their traditional knowledge. Under the project, easy-to-understand resource materials including e-booklets, e-brochures, e-messages, audio and video clips in the local vernacular language were created and disseminated.

The project aimed to reach out to 500 women SHGs (around 5000 women), and create awareness on the following thematic areas:

- Significance of mushroom consumption and cultivation
- Traditional remedies to strengthen immunity
- Increasing protein consumption in daily diet
- Food fortification using locally available ingredients

Participants at a pilot workshop at Nashera Village

Resource materials for participants

A panel of experts and experienced advisors was formulated to ensure the maximum impact and outreach of the project.

- Project 2: Addressing the SDG-6 by Providing Access to Safe Water for Drinking and Sanitation in Pathardi, Palghar District

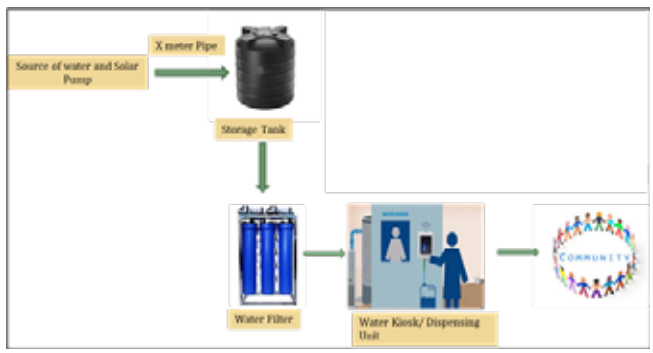
Sponsor: GKN Sinter Metals Pvt. Ltd

Considering the importance of providing safe and clean water for drinking and sanitation in water-scarce areas, TERI Nutritional Security Division initiated this project in Pathardi and Nashera villages of Palghar, Maharashtra. These villages face acute water scarcity, particularly in summer months. Most of the villagers do not use any water purification mechanism before using it for drinking, which results in the spread of waterborne diseases in the village during monsoons. Thus, this project aims to provide clean drinking water for the village school as well as the village residents, benefitting more than 500 residents including over 150 students.

Environment Resource Mapping

- Project 1: Promotion of Countermeasures against Marine Plastic Litter in Southeast Asia and India

Sponsor: United Nations Environment Programme (UNEP)



A schematic of the proposed plan for installing water purification system at the villages

Project Timeline: October 2019–March 2020

As part of a larger programme, the 'National Policy Workshop on Countermeasures for Riverine and Marine Plastic Litter in India' was organized virtually from May 12 to 22, 2020 by the National Productivity Council (NPC), New Delhi, which was sponsored by UNEP India. The workshop had two major sessions, namely:

- Community perceptions and behavioural aspects for plastic management and promotion of countermeasures
- Plastic pollution issues in India: Strategy and methodology to consider the outreach activity to change the behavior to address plastic pollution issues.

TERI participated and presented the highlights of the activities implemented in Mumbai as part of this project with emphasis on the impacts, stakeholders, and change in their perceptions regarding single-use plastic. Also, the UNEP has developed a film titled 'Save Our Oceans' to showcase the activities undertaken by TERI and its project partners in Mumbai.

Important links:

Session 1: National Policy Workshop – PPT: https://drive.google.com/file/d/1fOCqVcxSFQZAvNbV-X1ynk7ebyoZXlDh/view?usp=sharing

Session 2: National Policy Workshop – PPT https://drive.google.com/file/d/1MkX65rWI3IxVYxX2clgVXakOaK7iPqWy/view?usp=sharing

Save Our Oceans – Film: https://www.youtube.com/watch?v=Y2TWHnWsL3E&t=339s

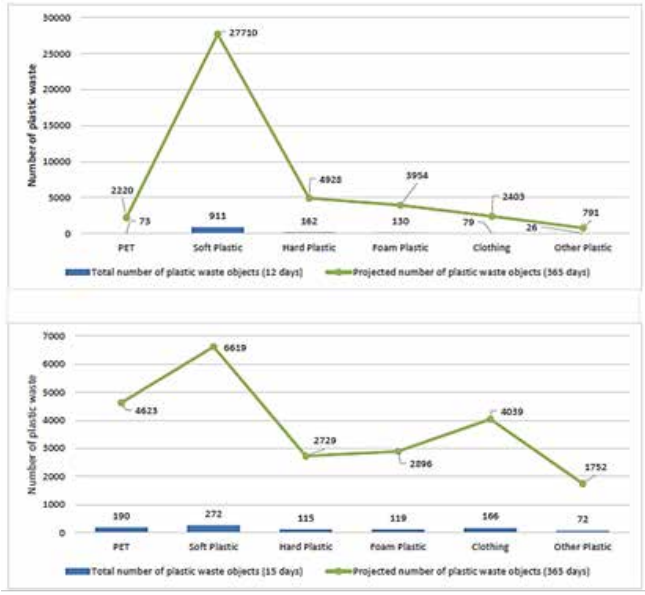
- Project 2: Long-term Plastic Flux Monitoring and River Assessment in Mumbai (Panvel and Vasai Creek)

Sponsor: The Ocean Cleanup

Project Timeline: October 2020–February 2022

While the use of plastic in different spheres of the modern lifestyle such as automobiles, electronics, and medical equipment cannot be done away with, efforts to tackle plastic waste entering the marine environment are essential. This calls for an assessment of the types and quantity of plastic waste entering water bodies, which would also provide insights about consumer behavior with respect to plastic waste management.

The Netherlands-based NGO, The Ocean Cleanup (TOC) has sponsored this initiative to assess plastic pollution in the Panvel and Vasai creeks. The creeks are surrounded by industries and human inhabitation, making them ideal locations to study plastic pollution. The project aims to assess the quantity and quality of plastic waste inflow in the marine environment and implement standardized methods for plastic data collection in Indian rivers. The monitoring of plastic waste was commenced in March 2021 at Panvel and Vasai creek bridges (3 days/week, 7 hrs/day) by implementing all necessary precautionary measures considering the prevalence of COVID-19 pandemic.



Plastic classification at Vasai creek (Up) and Panvel creek (Down)

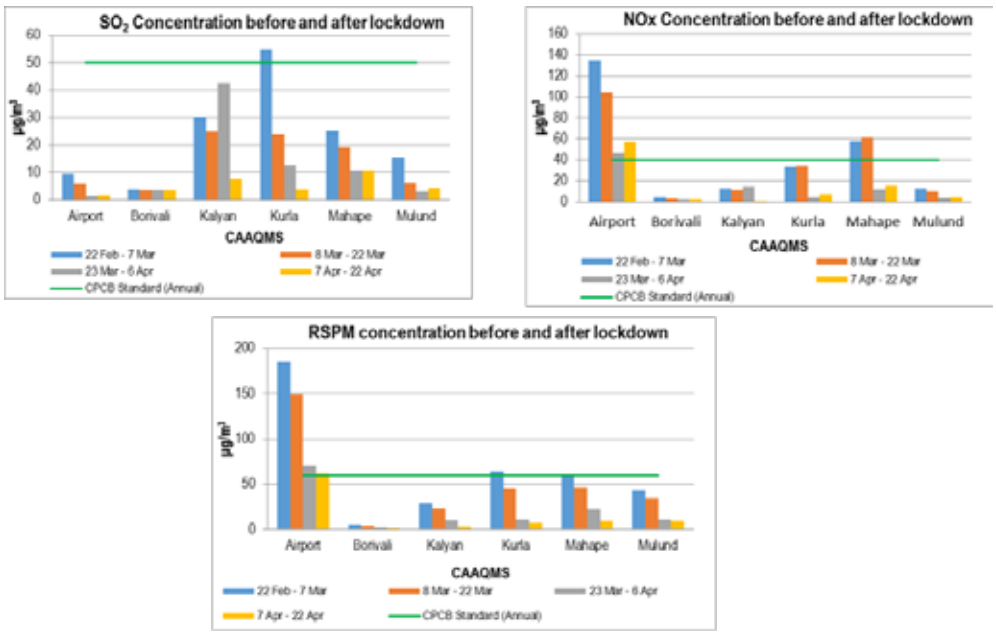
All necessary permissions were taken from the local municipal corporations to conduct this study. During the monitoring period, it was observed that the commuters dump waste daily, especially floral offerings in plastic carry bags, which further increased the load of plastic waste in the creeks. Soft plastic waste is found to be predominant in both the creeks followed by hard plastic in Vasai and polyethylene terephthalate in Panvel.

- Project 3: Air and Water Quality Status of Maharashtra 2019–2020

Sponsor: Maharashtra Pollution Control Board

Project Timeline: April 2020–September 2020

This has been the ninth consecutive annual report developed by TERI–WRC for Maharashtra Pollution Control Board (MPCB). The report documents the daily, seasonal, and annual trends in concentrations of air pollutants including sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulate matters (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), benzene (C_6H_6), and ozone (O_3) in Maharashtra, across 84 active Ambient and Continuous Ambient Air Quality Monitoring Stations (CAAQMS). In this year's edition, an additional section on a comparative analysis of pollutant levels before the pandemic-led lockdown (February 22–March 22, 2020) and after the lockdown (March 22– April 22, 2020) was also included. It was found that majority of the CAAQMS recorded considerable decrease in the concentration of



Concentration levels of criteria air pollutants before and after the lockdown

almost all three pollutants – SO_2, NO_x, and respirable suspended particulate matter. Thus, a slight improvement in air quality was recorded with respect to the Air Quality Index (2019-20).

The water quality report, prepared annually for MPCB, compiles statistically analysed annual data pertaining to assessment of various water quality parameters for the surface and groundwater resources of the state. The status of Maharashtra's surface water and groundwater quality was depicted in the form of illustrations and spatial representations, along with the details about the Water Quality Index for surface water resources including major basins as well as saline (sea/creek) and groundwater, to provide a comprehensive overview of water quality of these resources.

Important link

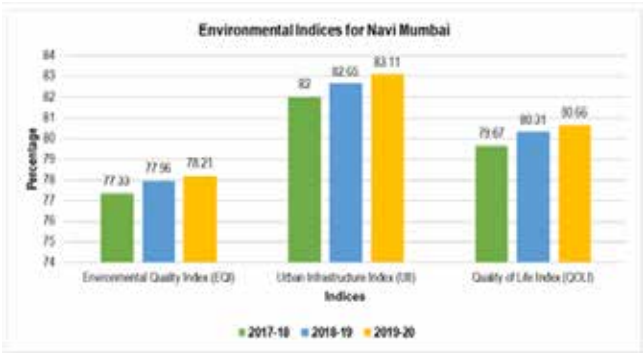
MPCB Air Quality Report (2019-20): https://www.mpcb.gov.in/sites/default/files/air-quality/AIRQualityReport20192022102020.pdf

- Project 4: Environment Status Report 2019-2020 of Navi Mumbai

Sponsor: Navi Mumbai Municipal Corporation

Project Timeline: June 2020–July 2020

As per Section 67A of the Maharashtra Municipal Corporations (MMC) Act, 1949, it is mandatory for all urban local bodies under Class I cities of Maharashtra to submit their annual Environment Status Report (ESR) to the General Body on or before July 31. The ESR is then submitted to the Ministry of Urban Development. TERI–WRC has been preparing the annual ESR for Navi Mumbai Municipal Corporation (NMMC) since 2013 according to the Driving Force – Pressure – State – Impact – Response (D-P-S-I-R) framework.



Environmental indices over the past 2 years for Navi Mumbai

In case of Environmental Indices, NMMC has managed to progress in terms of Environmental Quality Index (EQI), Urban Infrastructure Index (UII), and Quality of Life Index (QoLI) by 0.32%, 0.55% and 0.43%, respectively, as compared to the previous year. This was the result of pro-environmental initiatives taken by the NMMC.

Advanced Biofuels

- Project 1: Algal Biofuels and Bio Commodities at Airoli Plot

The research and development project on integrated production of algal biofuels and bio-commodities, as part of the DBT-TERI Centre of Excellence on Advanced Biofuels and Bio-commodities has progressed to active production and full-scale processing in 2020-21 after being set up in 2019-20. The project being set up at TERI's Airoli, Navi Mumbai premises includes a 220 m^2 (100,000 L) marine algal production system, related downstream processing units (settling tank, industrial centrifuge, lipid extraction unit, and distillation unit), an on-site laboratory, and an office. Algal harvest is conducted daily from the growth system. The harvested algae after further concentration are extracted off lipids employing a wet algal lipid extraction method. The de-oiled algae are utilized for the development of value addition commodities such as animal feed, aqua feed, and biodegradable food packaging plastics, platform chemicals, and pyrolytic bio-oil. These commodities are pursued by groups in other divisions of TERI and external institutes and industry partners.

Outreach Activities

- World Food Day Celebration – Nutri Quiz

To mark the National Nutrition Month and the UN World Food Day 2020 (October 16, 2020), the Nutrition Security Division conducted a 'Nutri Quiz'. It was an online quiz on food and nutrition, conducted to create awareness as well as to provoke the respondents to think about the food they eat and the food choices they make.

The quiz was conducted on the TERI website(https://www.teriin.org/event/teris-nutri-quiz-2020) and social media accounts.

It received responses from over 160 participants. Out of which first 10 individuals who scored the maximum points were rewarded with Supi products or TerraGreen's subscription. This not only served as an encouragement for the participants, but also as a means to reach out to people and introduce them to various TERI products and publications.

Algal biofuel set-up at Airoli, TERI–WRC

Nutri Quiz details on TERI's Facebook page

- Published Article: COVID-19 and Nutrition: How the Pandemic Induced a Much Awaited Behavioural Change

To mark the occasion of UN World Food Day, the division published an article titled 'COVID-19 and Nutrition: How the Pandemic Induced a Much Awaited Behavioural Change' on the TERI website, which was circulated through TERI's social media accounts. The article highlighted how the pandemic led people prefer more home-cooked food and shift towards healthier eating habits, ensuring better food safety and increased reliance on Ayurveda and other traditional medicine systems.

The article on TERI's Facebook page

- World Wetland Day Celebration 2021

The WRC, in collaboration with Navi Mumbai Environment Preservation Society (NMEPS) marked the World Wetland Day (WWD) 2021 celebrations by conducting an Online Wetlands Quiz, keeping in mind the restrictions laid down due to the pandemic. The quiz was active from January 18 to January 26, 2020, and a total of seven winners from two categories (age groups 13–18 and above 18) were announced on the occasion of

World Wetland Day Quiz on TERI's event page

WWD 2021. More than 1100 respondents participated in the quiz. The winners were awarded with Supi hampers and TerraGreen's e-subscription.

A brief article titled 'वेटलैंड्स: एक बहुमूल्य प्राकृतिक सम्पदा' was also contributed by the division for TERI Hindi website to mark the occasion.

Hindi article on wetlands

Environment and Waste Management Division

The mandate of the Environment and Waste Management Division includes research on policies, regulation, governance, health, technology, assessment for resource-efficient cleaner production (RECP), circular economy solution, prevention of marine litter, potential in industries, and other solutions for holistic waste management and resource optimization.

The Division successfully completed RECP implementation in 400 metal enterprises in Bangladesh, Nepal, and Sri Lanka (METABUILD, https://www.switch-asia.eu/project/metabuild/), resulting in significant resource and monetary savings. Currently, the activities are focussed on providing resource efficiency and sustainable consumption and production (SCP) consulting and implementation support in other regions. This includes 400 agri-food processing industries in Uzbekistan and Tajikistan as part of the REAP project (https://reap-centralasia.org/) and 300 enterprises in tourism clusters along the Lakshadweep shorelines of Maldives, Sri Lanka, and India to minimize marine litter as a part of the PROMISE project (https://www.switch-asia.eu/project/promise/). Furthermore, as part of climate-smart solutions, the Division is engaging with eco-inclusive enterprises to address social and environmental aspects. This is being done through the India Hub of SEED (https://seed.uno) hosted at TERI.

Work on wastewater treatment using membrane bioreactors in under way with preparations for on-site pilot testing. Different superabsorbent bio-nanocomposite has been developed by microwave-assisted method for removal of toxic dyes and heavy metals from waterbodies. We have also developed bio-inert and biocompatible nanocomposites for tissue-engineering applications. Work is also being done on the development of inorganic–organic hybrid and composites for dental restorative applications.

On the environmental health front, the Division, with support from both national and international sponsors and partners, has been working to build scientific evidence on the health benefits of clean air. It is also working to strengthen the resilience of populations to climate change through capacity building of decision-making systems and promote behavioural change. The focus areas of this work are divided under three broad themes: air pollution and health effects; climate change and health challenges; and environment in general. Working on the air pollution and health effects theme, the team has developed various knowledge products factsheet, policy brief, and infographics based on evidence generated on health survey and air quality monitoring in six districts with different ecological settings. A new heavy metal exposure index (HEI) has been formulated to mark $PM_{2.5}$ particle having higher toxicity due to toxic heavy metal. The team focuses on building various forms of information tools and knowledge-sharing mechanisms to address health challenges linked to climate change in partnership with the National Health Mission.

In terms of waste, the Division deals with waste streams including municipal solid waste, plastic waste and its linkages with marine pollution, E-waste, industrial waste, construction and demolition waste, and also wastewater treatments. The work includes development and pilot demonstration of technological and policy solutions for waste management and recycling and looking at regulatory, policy, governance issues, and scientific research with respect to climate linkages of waste management. It also includes feasibility studies, audit, and performance assessment for waste generation and management. The studies conducted by the Division in this domain focus on creating technologies and solutions to minimize waste generation and convert waste into useful products, with an objective to achieve sustainable development. The Division works with the informal sector workers and implement projects for diverting waste streams back to circular economy loop. The Division builds capacities of stakeholders

including students, informal waste workers, waste generators, industries, urban local bodies, and policymakers. During 2020/21, the Division grew to include international- and local-level projects addressing waste management issues in different spheres, for which the team worked on the ground level to demonstrate the impact. It now has sought funding from impact investment firms to transition into Centre of Excellence for Waste Management to carry out the activities that contribute to Swatch Bharat Abhiyan 2.0.

During 2020/21, under the NAMA project, sponsored by Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ) GmbH, baseline assessment reports and IEC awareness reports for Varanasi and Panaji were prepared. Also, webinars on solid waste management in the cities were organized along with a pilot demonstration of technological and policy solutions for waste management and recycling globally. Workshops were organized in various localities to impart knowledge and increase awareness about source segregation of municipal waste and training session were held on decentralized composting in the two cities. The focus is given on the implementation of relevant waste management practices and possibilities of implementing technologies such as composting, anaerobic digestion, etc., thereby reducing the amount of waste landfills under precarious conditions that would reduce the levels of GHG emission. The Division also conducted independent audits for waste management services across East Delhi, South Delhi, and North Delhi Municipal Corporations to identify gaps, which helped the corporations in waste minimization, resource optimization, and also made them aware on issues related to regulatory compliance.

During 2020/21, the Division successfully conducted various e-training programmes, stakeholder consultations, and webinars on waste management, plastic waste, marine litter, health vulnerability assessments, awareness of linkages between air pollution and health, and nutrition status and response strategies.

Centre for Waste Management

The Centre for Waste Management (CWM) involves development and pilot demonstration of technological and policy solutions for waste management and recycling globally. The focus areas of studies carried out by CWM include regulatory, policy, governance issues, and scientific research with respect to climate linkages of waste management. The area also conducts feasibility studies, audit, and performance assessment for waste generation and management. The studies carried out in CWM mainly focus on creating technologies and solutions to minimize waste generation and convert waste into useful products, with an objective of achieving sustainable development.

Waste streams addressed by the area include municipal solid waste, plastic waste and its linkages with marine pollution, E-waste, industrial waste, construction and demolition waste, and wastewater treatments. The CWM has undertaken many first-of-its-kind projects in the country including audits for waste management systems for cities, performance evaluation audits for waste-to-energy facilities, audits of mechanized road sweeping machines for cities, and extensive waste characterization studies for municipal waste. The CWM has grown with its capabilities to work with informal sector workers and implement projects for diverting waste streams back to the circular economy loop. CWM has also been building capacities of various stakeholders including students, informal waste workers, waste generators, industries, urban local bodies, and policymakers. CWM members also work with institutes of national repute to teach using a specialized curriculum on waste management and recycling, environmental impact assessment and environmental management system. During 2020/21, the CWM grew to include both international- and local-level projects addressing waste management issues in different spheres and worked on ground to demonstrate the impact. The area has sought funding from impact investment firms to transition into Centre of Excellence for Waste Management to carry out activities contributing to Swatch Bharat Abhiyan 2.0.

Resource-efficient Technologies

Thematic Overviews

Resource Efficiency in Agri-food Production and Processing

The REAP project (Resource Efficiency in Agri-food Production and Processing industries) (https://reap- centralasia.org/) was implemented under the European Union's SWITCH-Asia programme. The project aims to promote Sustainable Consumption and Production (SCP) practices in 400 agri-food production and processing industries along the entire supply chain in Uzbekistan and Tajikistan. Due to the COVID-19 pandemic-led travel restrictions, online training sessions were conducted for the local teams and assessment support to participating industries in Central Asia were provided. Subsequently, in-person support was also initiated.

Project team during the consulting support to industries in the REAP project

Prevention of Marine Litter in the Lakshadweep Sea

The PROMISE project (Prevention of Marine Litter in the Lakshadweep Sea) (https://projectpromise.eu/), which is part of the European Union's SWITCH-Asia programme, was officially launched in Maldives. Commenced with a beach clean-up activity at Hulhumalé, the launch ceremony was inaugurated by the First Lady Fazna Ahmed and officiated by the Minister of Environment of Maldives, Dr Hussain Rasheed Hassan. The event was attended by various senior government officials, including the Minister of Tourism, Minister of Fisheries, Marine Resources and Agriculture, Minister of Education, and Minister of Higher Education. The overall objective of the project is to contribute to the prevention and leakage of wastes from land-based sources into the Lakshadweep Sea with specific objective to promote regionally integrated source-to-sea solutions to reduce marine littering in tourism clusters along the Lakshadweep shorelines of the Maldives, Sri Lanka, and India.

Project team joined by the Maldives First Lady Fazna Ahmed during the beach clean-up activity in Hulhumalé

Project team with Maldives government officials at the launch ceremony

Local Treatment of Urban Sewage Streams for Healthy Reuse

LOTUS^{HR} (Local Treatment of Urban Sewage Streams for Healthy Reuse) aims to demonstrate a novel holistic (waste-) water management approach for the recovery of water, energy, and nutrients from urban wastewater. Demonstration systems for anaerobic treatment, algal treatment, and wetlands continued to be tested at the Barapullah drain in New Delhi. Based on these on-site test results, a ~10 m^3/day pilot plant has been designed

and preparations for its commissioning are underway. The anaerobic membrane bioreactor with ash-based ceramic membranes developed by TERI is being piloted as part of this project. In addition, TERI is also working on various socio-economic studies and programmes to educate school children on treated water reuse.

Testing of anaerobic membrane bioreactor at the Barapullah lab site

SEED India Hub Development

SEED (https://seed.uno), founded at the 2002 World Summit on Sustainable Development in Johannesburg by UN Environment, UNDP, and IUCN, is a global partnership for action on sustainable development and the green economy. SEED is based on the understanding that the promotion of social and environmental entrepreneurship is pivotal for environmental-friendly and socially inclusive development and poverty reduction. TERI continued its enterprise support and dissemination of hub activities at various forums and was also involved in implementing the SEED India Practitioners Lab Climate Finance 2020.

Development of Sericin/ Polysaccharide Encapsulated Fertilizer for Crop Management and Growth

This project deals with the development of sericin-based encapsulating matrix for sustained release of NPK fertilizer. Indian silk industry is the second largest producer of silk; 30% of sericin protein in silk is removed and is, thus, a waste that can be utilized.

Slow release fertilizers reduce the rate of removal of the fertilizer from soil by rain or irrigation water, thus, ensuring sustained supply of nutrition leading to improved efficiency of the fertilizer. The use of polysaccharide materials for controlled release of NPK fertilizer would be an eco-friendly option. Thus, in this study, starch alginate and sericin will be used to encapsulate NPK fertilizer. The kinetic grafting parameters will be optimized. The swelling and release characteristics including the efficacy of the encapsulated NPK fertilizer will be evaluated in the field study on mulberry plants.

Pure sericin

Thematic session on 'Mainstreaming climate finance solutions in SMEs including start-ups' at World Sustainable Development Summit (WSDS) 2021, held on February 12, 2021

Sericin grafted encapsulated NPK fertilizer beads for controlled and sustained release of NPK fertilizer

Light-cured sample along with brass mould used to prepare the sample and LED curing light to carry out the photo polymerization

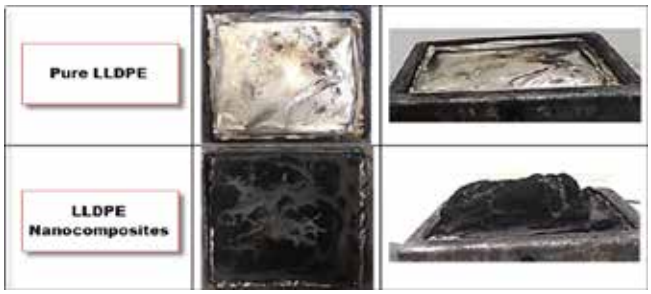
Dental Nanocomposite Resins Based on Hybrid Dimethacrylates: Mechanical, Wear, and Shrinkage Characteristics

The aim of this project is to develop dental composite resins made of dimethacrylates along with nanobioactive glass (NBG), methyl methacrylate (MMA)-modified oxozirconium cluster, polymethyl methacrylate-modified nanoclay, and silane-treated nanohydroxyapatite filler. In this part of the work, scanning electron microscopic (SEM) analyses of the synthesized fillers, namely, MMA-grafted oxozirconium cluster and PMMA-modified nanoclay have been performed. Synthesis of dental composite resins with different combination of fillers has been performed.

Water sorption and solubility study of all dental composites has been done. Wear and mechanical properties of all the synthesized dental composite resins have been studied. The synthesized dental composite resins showed enhanced bioactivity and good mechanical properties compared to human teeth. Incorporation of different combinations of fillers helps in lowering the shrinkage of the synthesized dental composite resins. SEM studies of the synthesized dental composites have been initiated.

Development of Intumescent Fire-retardant Nanocomposites for Medium Voltage Cable Sheathing Applications

In this study, mixed polyolefinic nanocomposites have been developed with intumescent fire retardant additives to study synergism and improve fire safety. These additives have been optimized for both mechanical properties and fire retardancy characteristics. Compatibilizing additives were also added to enhance interfacial adhesion. The developed nanocomposites can be used as fire retardant for low-to-medium voltage cable sheaths.



Char formation of neat LLDPE along with nanocomposites

Development of Polyolefin Composite Loaded with Co-Microencapsulated Intumescent Fire Retardant System Along with Nano-sized Wear Resistant Additives

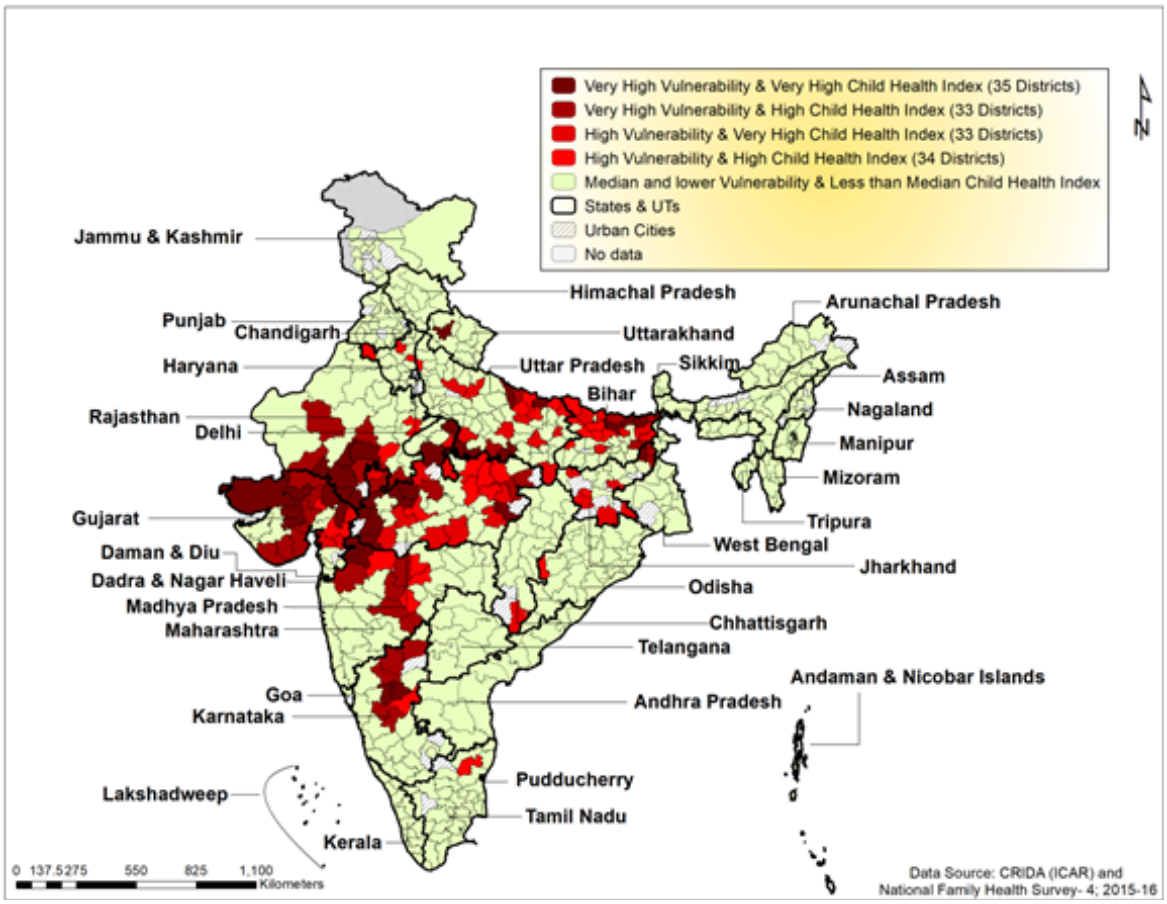
The use of low-density polyethylene (LDPE), high-density polyethylene (HDPE), and polypropylene (PP) is continuously on the rise and fire safety is an important aspect to be considered. Further, the use of non-halogenated fire retardants is fast gaining importance as

ammonium polyphosphate (APP) along with pentaerythritol, which has been found to be very effective. However, these are moisture sensitive and their thermal stability is low. In this study, a high temperature charring agent was synthesized. This was co-micro encapsulated with APP in melamine-formaldehyde resin. The microcapsule thus developed was blended along with nanosized silicon nitride in LDPE and HDPE. The microcapsules resulted in enhancing the fire retardant properties.

Environment and Health

The Environment and Health area aims to achieve the goals of building scientific evidence on the health benefits of clean air and strengthening the resilience of population to climate change through capacity building of decision-making systems and behavioural change in the community. The focus areas of the studies are divided under three broad themes: air pollution and health effects; climate change and health challenges; and environment. The area has support of both national and international sponsors and partners.

Under the air pollution and health effects theme, the team has developed various knowledge products factsheets, policy briefs, and infographics based on evidence generated on health survey and air quality monitoring in six districts with different ecological settings. A new heavy metal exposure index has been formulated to mark $PM_{2.5}$ particle having higher toxicity due to toxic heavy metal. The team constantly strives to catalyse behavioural change and accelerate clean air practices in communities by facilitating discussions and discourses with several stakeholders, such as petroleum companies, municipalities, healthcare providers, education providers, and related ministries. We are striving to strengthen the health systems through the development of a robust surveillance system for air pollution-linked illnesses across the country along with the Ministry of Health and Family Welfare.



The team focuses on building various forms of information tools and knowledge-sharing mechanisms to address health challenges linked to climate change in partnership with the National Health Mission. The team has created a new index – Child Health Index, using principal component analysis of district-level data taken from NFHS-4, which include key health parameters such as stunting, wasting, underweight, anaemia, and diarrhoea in the most vulnerable age group (below 5 years). Vulnerability Index of agriculture to climate change which is a relative measure of risk to agriculture due to climate change severity was also assessed. Child Health Index and Vulnerability Index of agriculture to climate change help to prioritize the regions and populations in India that require higher attention to enhance crop productivity, which would in turn improve population health. The effect of crop residue burning on health is one of our priority areas for both present and future.

TERI houses Centres of Excellence (CoE) for Health Adaptation Plans for Climate Change for the Ministry of Health and Family Welfare (MoHFW) under the Government of India. It contributes in developing national- and state-level plans for building resilience of the health system against climatic challenges. As CoE, TERI is a member of the national and state committees of health adaptation planning. Another thrust area is building health resilience of community through bolstering nutrition security by promoting climate-sensitive nutrition-powered agriculture.

The area works on a broad spectrum of exposure–response relationship studies including air pollution exposure studies in rural areas and urban hot spots; assessment of heavy metals in different environmental compartments; and examining occupational risks and health effects in microenvironments.

The team has developed a wide variety of digital tools, infographics, and videos for capacity building and knowledge dissemination. In 2020/21, the team initiated work on short-lived climate pollutants, air pollution, and health. Another dimension we are pursuing is promoting environmentally sustainable and climate-resilient healthcare facilities to ensure a better prepared health system action and response.

Water Resources Division

Water Resources Division (WRD) works on cross-cutting themes of sustainable water management with an aim to develop and implement integrated and strategic solutions. The WRD provides services in core areas including applied research, training, and implementation. To tackle emerging challenges in the sector, WRD adapts a holistic and dynamic approach.

The key competencies of the Division is in the following thematic areas: Quantitative and qualitative assessment of water resources; water audit and water footprinting; water-use efficiency including water conservation; wastewater treatment, recycle, and reuse; watershed and river basin management; urban water demand management; drinking water supply and sanitation sector; water quality and pollution studies; groundwater management and; high altitude glacio-hydrological studies and policy analysis.

The Division has been leading the Glacier Research Programme of TERI and as part of the programme, observatories are being maintained at three Himalayan glaciers and regular monitoring and analysis of the collected data is being conducted. The Division is assessing the impacts of the changes in glacier meltwater flow on the socio-economic status of the local communities, under the project funded by the Department of Science and Technology, Government of India. The outcomes of the project will help in quantifying the degree of dependence as well as vulnerability, leading to improved decision-making for climate change adaptation in the Himalayan states.

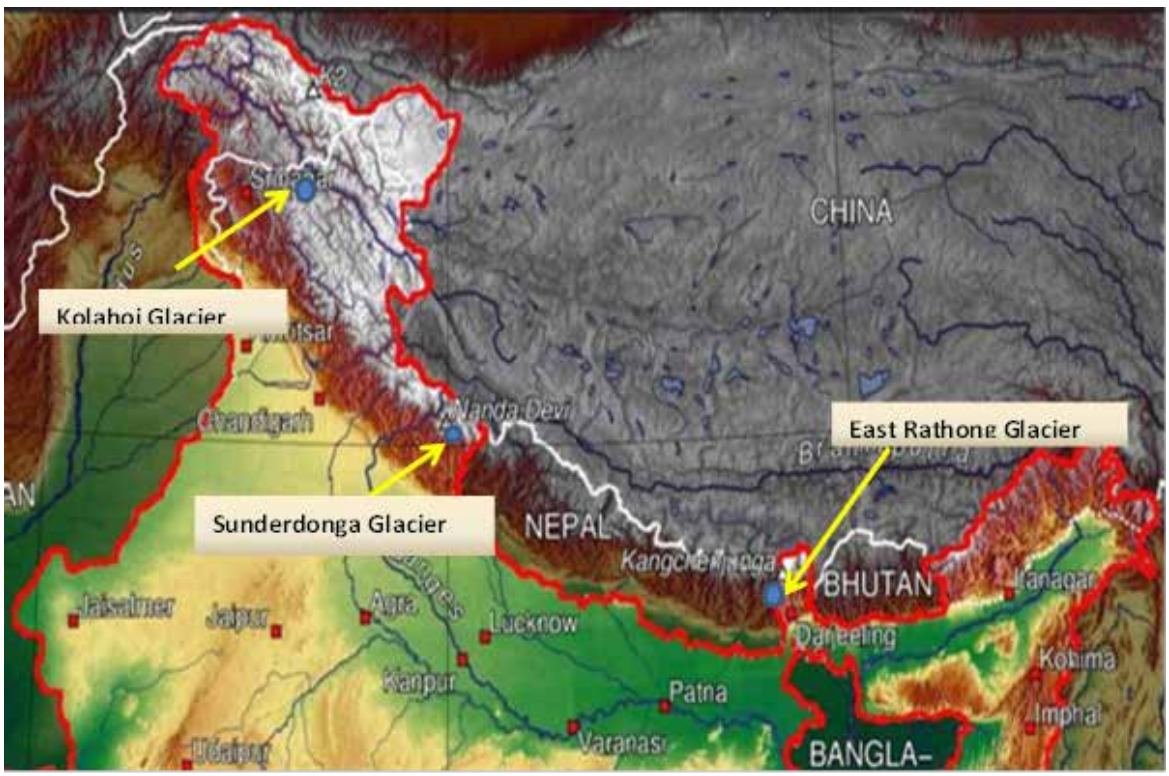
Centre for Himalayan Ecology

The primary focus of activities at the Centre for Himalayan Ecology (CHE), TERI is to improve the human understanding around the Himalayan glaciers and the impacts of climate change on the melting response of the Himalayan cryosphere, which ultimately regulates the perennial flows in major Indian river systems – Indus, Ganges, and Brahmaputra.

TERI's Glacier Research Programme

The Energy and Resources Institute, New Delhi started Glacier Research Programme in 2008 with the objective to "*To quantify the linkage and dynamic relationship between meteorological parameters, rate of glacier melting and meltwater discharge, in order to make an improved assessment of runoffs in the high altitude catchments of Himalayan rivers*".

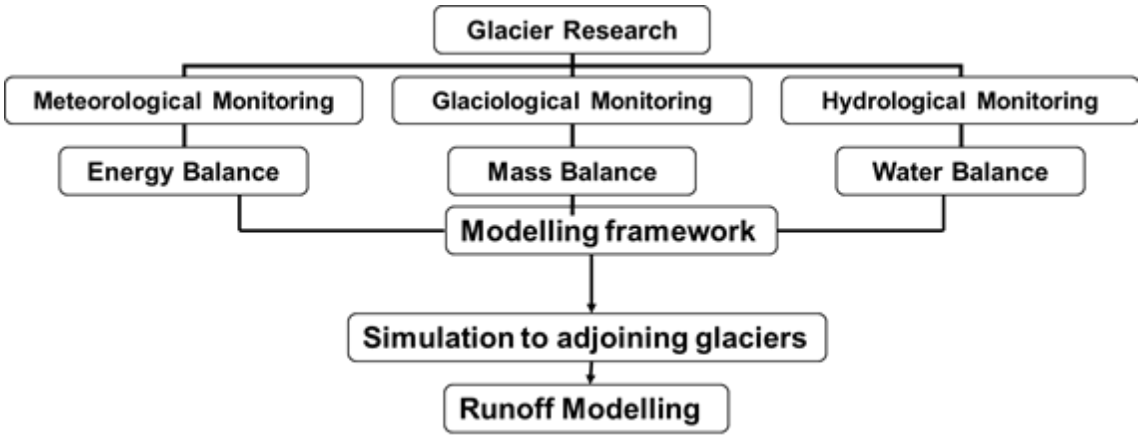
As part of the Glacier Research Programme, CHE is maintaining high altitude Hydro-meteorological research stations in three glaciers located in different climatic and geographical settings across the Himalayas – 1. Kolahoi glacier, Liddar valley in Kashmir, 2. East Rathong glacier, Rangeet river valley in Sikkim, and 3. Durgakot glacier, Sunderdonga valley, Uttarakhand. All the three glaciated valleys have been equipped with several hydro-meteorological equipments covering the altitudinal transect - Automatic Weather Stations (AWS) with sensors for air temperature, relative humidity, wind speed and direction, net radiation, precipitation, and snow depth; stream-level recorder and flow velocity metres; along with the ablation stakes and accumulation pits, for measurement of glacier mass balance.



Key Activities

A. Monitor and model the long-term changes in the glacier response to hydro-meteorological variables: With an integrated approach, simultaneous measurement of various parameters affecting the energy balance, glacier mass balance, as well as the hydrological balance of these glaciers is being undertaken. An integration of instrument and satellite data with results of field experiments is being conducted to improve certainty in runoff modelling for high-altitude catchments of Himalayan Rivers.

on these glaciers and the glaciated streams in the Himalayas. Results of TERI's glacier research have been published in various international peer-reviewed journals. CHE is also engaged in capacity building as part of its Glacier Research Programme – an elective course on 'Glacier Hydrology' is offered to post-graduate students at TERI School of Advanced Studies and many Ph.D. students are associated with the programme for their doctoral thesis. Four Ph.D. students have already been awarded their doctoral degrees. CHE has also established working relationships with many national and international glacier experts and has a strategic understanding with various research institutes and universities. Most of this work uses integrated social sciences and scientific approaches to focus on identifying the impact of decade-to-century-scale



Approach for scientific research on glaciers

B. Socio-economic Impact Assessment

An important aspect of research in Centre for Himalayan Ecology is to develop an understanding of the nature and degree of livelihood dependence of the downstream communities on melt water; and quantify the degree of vulnerability due to variations in the melt water and changes in precipitation, on the livelihoods of the downstream population. To achieve this objective, CHE is engaged in the development and validation of indicators, modelling platform as well as an improved adaptation framework for the mountain communities.

As part of the programme, CHE has executed several research projects

climate variability and subsequent change on water resources in the Himalayas, with a goal to develop a robust water resource management plan for Himalayan communities through a dynamic climate-responsive glacio-hydrological model.

Water Resources Policy and Management (WRPM)

The WRPM area has been instrumental in tackling the key issues of the water sector and helped in improving water management through various projects and contributed towards the goals of the National Water Mission. The area comprises of multi-disciplinary experts comprising of engineers, hydrologists, IWRM experts, social-scientists, glaciologists.

In the current pandemic scenario, TERI along with associated partners contributed in development of Standard Operating Procedures for Wastewater-based epidemiology for SARS-CoV-2 testing which can help in the early detection thereby improving the preparedness towards future outbreaks. The team undertook intensive wastewater surveillance study during 2020-2021 to detect the presence and load of SARS-CoV-2 virus, the first-of-its kind in Chennai city, India.

WRPM has been instrumental in steering a HORIZON 2020 project, sponsored by the Department of Biotechnology, Government of India with a consortium of leading institutes from India and Europe. Project Pavitra Ganga aims to fulfil SDG6 by unlocking the environmental and economic benefits of municipal wastewater treatment and reuse solutions for urban and peri-urban areas in India. The project links directly to the Namami Gange programme and builds on existing cooperation between EU/India, supported by national governments. As part of the project, the team has successfully carried out stakeholder consultations at various levels including rounds of interaction with high level policy makers. For disseminating project updates, e-newsletters are released at regular intervals for various stakeholders and also a policy brief on determinants for (un)successful waste water treatment and resource recovery was launched.

The area in partnership with European partners had introduced the EU Water Framework Directive (EU-WFD) River Basin Management (RBM) Cycle through a training programme to introduce the RBM Cycle as adapted to the Indian context to serve as a steering and management instrument for policymakers, senior officials, technical staff, and training institutes. The training was imparted to various stakeholders on different aspects related to river basin management.

To improve industrial water-use efficiency, the team is establishing potential benchmarks for industrial water use in the four water intensive sectors (thermal power plants, textile, steel, and pulp and paper industry). Comprehensive water audit exercise has been carried out in various industries to understand the water balance, establish benchmarks and understand and recommend potential areas of improving water use efficiency.

For water conservation, the area has carried out extensive pond rejuvenation work for groundwater recharge that was implemented at eight locations in the states of Punjab and Rajasthan. The total water potential created by these rejuvenated ponds is 1951475 kilolitres per year and they have been handed over to the local Panchayat Institutions and Village Development Committees after appropriate training for maintaining the rejuvenated ponds. Significant amount of water can be recharged through these ponds and it will help to contribute to the goal of the National Water Mission.

Supporting the Government of India's Swachh Bharat Mission, the group undertook construction of around 6000 individual household toilets in the state of West Bengal. As a part of the project, team also raised awareness and sensitized the users on the importance of sanitation and hygiene.

The area has successfully completed a study for development of Sustainable Groundwater Management

plan for Urban Area of Lucknow, with support from Uttar Pradesh Groundwater Department. Study involved an integrated assessment of water balance for the city considering availability of surface as well as groundwater resources, and its demand within different set of stakeholders. Study also developed a micro-zonation map for the city based on differential current as well as future water stress in different localities.

Testing of a micro-irrigation prototype in Indian agricultural fields

Testing of micro-irrigation prototype in drip irrigation system

Pond rejuvenation site at Unchagaon, Punjab

Pond rejuvenation site at Rakhra, Punjab

TADOX® Technology Centre for Water Reuse

The TADOX® Technology Centre for Water Reuse (TTCWR) is a dedicated new area in the Water Resources Division of TERI. The area works towards R&D, technology development, and transfer and implementation of TERI's Advanced Oxidation Technology called TADOX®, training and capacity building, research leading to Ph.D, publications, policy interventions, and contributing to the missions of national importance such as 'Namami Gange', 'Self Reliant India', and others.

About TADOX® Technology

TERI's Advanced Oxidation Technology (TADOX®) aims at treating industrial and municipal sewage wastewater streams having high colour, COD, BOD, TOC, non-biodegradable, recalcitrant and persistent organic pollutants (POPs), micorpollutants, and pathogens. TADOX® is under TERI's Patent and Registered Trademark and the winner of several technology innovation awards. The technology involves Advanced Oxidation Nanotechnology (AON) as secondary treatment; where in situ generation of hydroxyl radicals take place, leading to oxidative degradation and mineralization of pollutants.

TADOX® is developed under DST-Water Mission, Water Technology Initiative (WTI) Programme of the Ministry of Science and Technology, Government of India with joint funding from Department of Science and Technology, Government of India and ONGC Energy Centre (OEC) as an industry partner.

Completed Projects

- 2020/21: Industrial projects: 20–25 case studies developed, feasibility analysis at Stage 1 (50 L) and Stage 2 (10 KLD) in both industrial and municipal sewage treatment undertaken using TADOX® technology.
- 2017–2020: Completed DST-Water Mission, Water Technology Initiative (WTI), Ministry of Science and Technology, Government of India-funded project; co-funded by ONGC Energy Centre, Delhi as an industry collaborator.

Significant Achievements

- Having outstanding deliverables from DST Water Mission (WTI) Project, Ministry of Science and Technology, Government of India issued a press release on August 25, 2021, endorsing the successful development of TADOX® Technology. Also, DST published the findings of the project on its website:

Link: https://pib.gov.in/PressReleasePage.aspx?PRID=1748888

Link: https://dst.gov.in/new-advanced-oxidation-technology-can-enhance-waste-water-reuse-lower-cost.

- TADOX® is under three-filed patents and a registered trademark with the Trademark Registry Office, Government of India, under Class 42 (R&D) and Class 35 (Advertising). Under Class 9 (Product Display) is processing.

Facility Creation

- DG inaugurated 10 KLD TADOX-based Wastewater Treatment Facility

A new wastewater treatment facility with the capacity 10 KLD based on TADOX® was inaugurated on August 26, 2020 at TERI's Gwalpahari Centre by Dr Ajay Mathur, the then Director-General, in the presence of Mr Sanjay Seth, Senior Director, Dr Nupur Bahadur, Fellow, Sustainable Habitat Programme, and Mr Praveen Bhargava, MD, Perfact Group, as an industry partner to commercialize TADOX®. This facility creation is part of working of an SPV called Perfact Advanced Water Solutions Pvt. Ltd (PAWS), formed as a joint initiative of TERI and Perfact Group to commercialize TADOX®.

Training and Capacity building Programme

The area organized an online training and capacity building (OTCB) certificate programme on 'Developing Treated

Wastewater Reuse Facilities' from March 8 to 22, 2021, with 14 sessions in all for 90 minutes duration each. The programme covered various aspects of developing such a treated wastewater reuse facility, including Basics, Technology, Finance, Economics, Social, Legal, Planning and Policy, Engineering, etc. Also, discussion on successful case studies from India and abroad were held during the programme. In collaboration with IDECK, ICAP, and IWA-India, The OCTB Program was jointly organized by iDeCK, and ICAP-Trust. It was sponsored by the National Mission for Clean Ganga (NMCG), Ministry of Jal Shakti, Government of India. As industrial partners, there were three companies - VA Tech WABAG Pvt. Ltd, AAROHI Pvt. Ltd. & NJS Engineers Pvt. Ltd. IWA India and CEPT University were the knowledge partners. Smart Water & Waste World (SWWW) and Everything About Water (EAW), Water Magazines were the media partners. The first policy brief on TADOX® Technology was released on March 22, 2020, on the World Water Day and during the Valedictory Function of the OTCB programme.

Social Transformation

The Rural Energy and Livelihoods (REL) Division of TERI's Social Transformation Programme is active in a wide spectrum of fields including technology design and customization, skilling, action research, business model development for livelihood opportunities, pilot implementation of renewable energy-based solutions for quality and reliable power, livelihoods.

Its pioneering grassroots initiatives such as 'Lighting a Billion Lives (LaBL)' programme—started over a decade ago—and its value chain approach have served as template for many others in fields ranging from standardized technological solutions to energy enterprises creation. LaBL has impacted more than 5.7 million lives in 24 states of India and 13 countries worldwide through over 170,000 solar lanterns, 100,000 indigenously developed improved cookstoves, 58,000 TERI-designed integrated domestic energy systems, 36,000 solar microgrid connections, and 7600 home lighting systems, among others, besides creating more than 3000 green jobs. The key focus areas of the division include market creation for clean energy technologies in rural areas and the development of enterprise-based models for energy service delivery. In this context, the Division has been working to help generate opportunities for rural entrepreneurs including incubating local entrepreneurs on one hand and assisting government bodies to frame enabling policies on the other hand. Interweaving elements of gender and social inclusion at every stage of design and implementation of all its interventions have been the cornerstone of TERI's Social Transformation Programme. Its experience in approaching energy and other sectors through a gender lens aids in highlighting and strengthening the linkage between energy access and gender empowerment. With its focus on clean and rational use of energy, the Division continues to strive for a climate-resilient and Atmanirbhar rural India., an

Centre for Impact Evaluation and Energy Access

The Centre for Impact Evaluation and Energy Access (CIEEA), of TERI's Rural Energy and Livelihoods Division was created with the specific objective of assessing energy access at the grassroots level through in-depth expertise and a sound knowledge base that is reflected in research, documentation, policy formulation, innovation, and capacity building. One of the major thrust areas of the group is to lay a strong emphasis on social and gender inclusion in all the key focus areas of the group's activities so that just energy systems for a sustainable future can be created. To achieve this, the group's efforts have been directed towards creating tools and techniques to mainstream gender into policy, projects, and implementation frameworks for the governments, private sector, and international organizations. The group's strength is also reflected in the use of qualitative methodological approach comprising participatory appraisal tools, ethnographic case studies, socio-anthropological narratives, assessing the scope of peoples' participation, perception analysis, stakeholder analysis, gender analysis, and the overall design of mixed method methodologies.

The Centre is presently engaged in assessing opportunities and challenges for social and gender inclusion and community participation in various renewable energy activities including offshore wind energy, solar PV, water-energy-food nexus, and eco-tourism for developing robust protocols and guidelines to develop just energy systems. CIEAA has been actively disseminating study findings in the form of publications and presentations across national and international fora.

Local chilli produce

Women FGD in Darma village

Sunkia village, Mukteshwar

Men's FGD in Buri Bana village

Tumkur

Women cook stove builder (left), Sarala stoves (right)

Men involved in fishing (left), fish being dried in the absence of cold storage (right)

Women entrepreneurs (left), fishing boats carrying fish catch (right)

Fish sold in local market (left); women FGD in Veraval (right)

Centre for Impact, Evaluation and Energy Access, Bangalore (CIEEAB)

Centre for Impact, Evaluation and Energy Access, Bangalore (CIEEAB) has been working with rural communities, on aspects such as renewable energy, watershed development, women empowerment, social inclusion, livelihoods, and evaluation of corporate social responsibility interventions. CIEEAB completed an interesting and challenging evaluation of the Compensatory Afforestation Fund Management and Planning Authority Programme (CAMPA), 13th Finance Commission (TFC), National Afforestation Programme (NAP) and the National Bamboo Mission (NBM) schemes for Karnataka Forest Department. The study was sponsored by Karnataka Evaluation Authority. The purpose of this assignment is to evaluate if the schemes have met the objectives and, if so, to what extent, and to make recommendations to improve the effective delivery and enhance impact.

With the support of the Central Silk Board, CIEEAB has conducted third party evaluation of NERTPS schemes on

silk sector and apparel and garmenting units. The study aimed to assess the impact on the beneficiaries in terms of income, employment generation, economic improvement, socio-economic upliftment, evaluation of the present status of the project, effectiveness of the present monitoring mechanism, and provide suggestions for improvement. CIEEAB was engaged in the Evaluation of National Horticulture Mission in Karnataka from 2015-16 to 2018-19. The objective of this assignment was to evaluate the effectiveness, efficiency, and impact of the Mission, and to examine if the desired objectives of each component implemented were met.

- With the efforts of CIEEAB, TERI was Empanelled with Mazagaon Ship Builders Ltd. Mumbai for conducting impact assessment study of CSR Projects. A study on the interventions carried out in the sanitation and waste management sector was assigned to TERI. The study aimed to assess the direct and indirect impact on target group, community within periphery and outside periphery, study any shortfalls in the programme that hampered the progress in implementation and also to come out with required corrections in the future. It was also empannelled with with Karnataka Evaluation Authority.

Centre for Rural Action

Centre for Rural Action (CfRA) brings together the latest in techno-socio-institutional knowledge, to deliver locally appropriate solutions that addresses basic needs of underserved communities. Over the last few years, the area has worked extensively in the field of 'energy access' to accomplish TERI's commitment towards enabling affordable and sustainable energy services through interventions that address consumptive and productive energy requirements at the household and micro-enterprise levels, specifically in rural, remote, and peri-urban areas. In this realm, with 'energy access' as a pivotal theme for the Area's activities, effort has been to address two key aspects for effective and sustainable energy provisioning. The first is to ensure that affordable and reliable clean energy solutions (for lighting, cooking, and other productive needs) reach rural households. This has been driven through the development and implementation of innovative, responsive, and replicable technologies and delivery models; the creation of new partnerships and collaborations at the grassroots;

and the adoption of a bottom-up approach; and engaging members of the community to create inclusive energy provisioning supply chains. Lighting a Billion Lives (LaBL), TERI's flagship initiative for clean energy access, is a major programme being led by the area that implements localized village-level interventions to provide lighting and clean cooking solutions, fosters the creation of partners and networks at the village, block, and state levels; and enables the provision of a bouquet of customizable and reliable technology solutions for households and small enterprises.

As of March 2021, the intervention has impacted 5.65 million lives, across 24 states in India and 13 countries in Africa and South Asia. In the case of clean cooking solutions, CfRA has worked towards customizing forced-draft cooking technology to improve quality, to suit consumer preferences, and contextual cooking conditions. More than 11 variants of forced-draft cooking technologies, varying in complexity and cost, have been developed by CfRA over the past 8 years. Around 1 lakh cook stoves have been disseminated in different states so far.

The second key aspect that has underlined CfRA's work in the recent years is taking interventions in energy access beyond the conventional scope of addressing only basic lighting and cooking requirements directly and attempts to weave 'energy' as a contributor towards other associated aspects of development, such as health, education, livelihoods, empowerment, and mitigating climate change. In this context, the nature of some key projects undertaken by CfRA include installation of clean and reliable power infrastructures to improve the operational reliability of power looms in the Varanasi area. This has led to enhancement of livelihood opportunity for the weaver community. Similarly, solarization of boats is one of the major projects that is being undertaken to reduce air pollution in River Ganga. TERI is establishing centralized solar charging stations for charging the batteries that can run the boat. It has also helped to enhance the livelihood opportunity of boatman community. Similarly, the area has undertaken a project to provide energy infrastructure for reliable energy in different remote schools, which can enable better education for the children. With an objective to enhance livelihood and create green jobs, the area has been providing training on renewable energy in different states with the support from Ministry of Environment Forest and Climate Change (MoEF&CC). Going forward, the area will continue to expand its scope in developing and delivering innovative and integrated solutions, focussing on clean energy and resource-use efficiency with an emphasis on replicable interventions that support rural livelihoods, micro and small enterprise, and sustainable management of natural resources with better resilience to climate change. Building on its past experience in the areas of integrated rural development, Entrepreneurship Development and energy access, the area also aims to work towards expanding its activities in these areas.

Sustainable Agriculture

Agriculture is the world's largest industry. It employs more than one billion people and generates over 1.3 trillion dollars, worth of food annually. Pasture and cropland occupy around 50% of the Earth's habitable land and provide habitat and food for many species.

India is increasing, and so is the use of technology in the growing sectors of the country. A significant mass of the population is still dependent and practising agriculture as its primary source of income. India has been in a continuous tryst with its farming infra, practices, and associated communities since independence. With the sector still contributing around 15%–20% to the national GDP of the country over a few decades, and its diverse-cum changing needs across its regions, India has been driving necessary and timely interventions at industry, institution, and individual farmer levels for its constant manifestation.

With its allied sectors, agriculture is unquestionably the largest livelihood provider in India, more so in the vast rural areas. It also contributes a significant figure to GDP. Sustainable agriculture, in terms of food security, rural employment, and environmentally sustainable technologies such as soil conservation, sustainable natural resource management and biodiversity protection, are essential for holistic rural development. Indian agriculture and allied activities have witnessed a green revolution, a white revolution, a yellow revolution, and a blue revolution.

When agricultural operations are sustainably managed, they can preserve and restore critical habitats, help protect watersheds, and improve soil health and water quality. However, unsustainable practices have severe impacts on people and the environment. The need for sustainable resource management is increasingly urgent. Demand for agricultural commodities is rising rapidly as the world's population grows. Agriculture's deep connections to the world economy, human societies, and biodiversity make it one of the most important frontiers for conservation around the globe.

Sustainable agriculture can be defined in many ways. Still, ultimately it seeks to sustain farmers, resources, and communities by promoting farming practices and methods that are profitable, environmentally sound, and good for communities. It works on farms and ranches, large and small, harnessing new technologies and renewing the best practices of the past.

In short sustainable agriculture is:

- Economically viable: If it is not profitable, it is not sustainable.
- Socially supportive: The quality of life of farmers, farm families, and farm communities is essential.

- Ecologically sound: We must preserve the resource base that sustains us all.

Beyond the congressional definition, sustainable agriculture has been defined in several ways, for example, as a system that can indefinitely sustain itself without degrading the land, the environment or the people. It reflects our concern with the long-term viability of agriculture.

For decades, we've produced the bulk of our food through industrial agriculture—a system dominated by large farms growing the same crops year after year, using enormous amounts of chemical pesticides and fertilizers that damage soils, water, air, and climate.

Sustainable agriculture must be all three—ecologically sound, economically viable, and socially responsible. And the three must be in harmony. But a growing number of innovative farmers and scientists are taking a different path, moving towards a farming system that is more sustainable. This system has room for farms of all sizes, producing diverse foods, fibres, and fuels adapted to local conditions and regional markets. It uses state-of-the-art, science-based practices that maximize productivity and profit while minimizing environmental damage.

The key finding of sustainable agriculture in India is that we identified 30 sustainable agriculture practices prevalent in India. Some are focused only on one aspect of agriculture (we call them practices). In contrast, others are more holistic concerning the overall agriculture or most parts (we call them systems). We collectively refer to them as sustainable agriculture practices and systems. Many practices have overlaps among themselves, and some individual practices are also advocated under a few systems.

Sustaining agricultural productivity depends on the quality and availability of natural resources such as soil and water. Agricultural growth can be sustained by promoting conservation and sustainable use of these scarce natural resources through appropriate location-specific measures. Indian agriculture remains predominantly rainfed, covering about 60% of the country's net sown area and 40% of the total food production. Thus, conservation of natural resources in conjunction with the development of rainfed agriculture holds the key in meeting burgeoning demands for food grain. Towards this end, National Mission for Sustainable Agriculture (NMSA) has been formulated for enhancing agricultural productivity, especially in rainfed areas focusing on integrated farming, water- use efficiency, soil health management, and synergizing resource conservation.

The Sustainable Agriculture Programme of TERI has achieved its vision which is now uniquely poised to deliver path-breaking technologies and products using biologicals interwoven with nanotechnologies and biocompatible materials. Simultaneously, TDNBC projects are also shouldering the scientific and social responsibility of providing safe and sustainable solutions to mankind. Such activities are being pursued jointly through strategic collaborations with Deakin University, and over 26 academic and industrial partners worldwide across various research streams through signing the MoUs, webinars/ workshops/conferences. The testimonial to this successful collaborative venture is 12 completed, and 31 ongoing PhD projects on diverse topics of mutual interest to both TERI and Deakin University and in achieving the same many faculties are involved from both the sides. Also, we do understand that to strengthen the research perspective, the decision-making skills and critical thinking skills of students, not to mention their understanding and appreciation of various cultures and landscapes is significant to achieve the goals, and we are just doing the way ahead to have student exchange programme to fulfil the requirement of their research work based on the need. We are committed to undertake grander research and education, and for that, we have designed our labs and placed high-end equipment's. Our research has been recognized through national and international conference presentations, multiple awards to PhD students and faculty members. In the last decade, we have produced over 220 research publications in most reputed journals, 8 granted patents and 5 new patent applications and 26 externally funded projects to its credit and 5 IPRs.

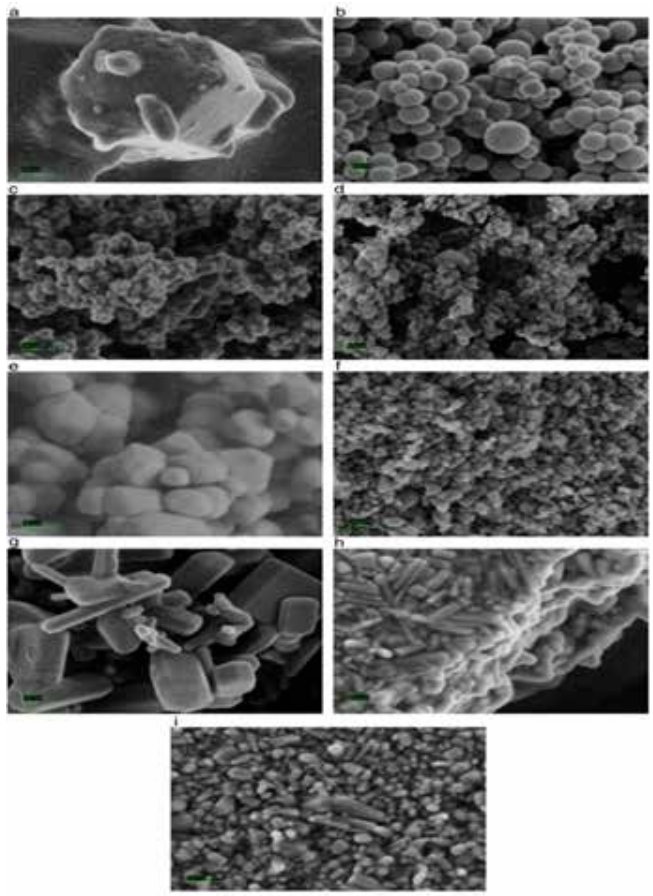
OUR FLAGSHIP PROJECTS

National Centre of Excellence for Advanced Research in Agricultural Nanotechnology (NCEARAN)

Global food demand is increasing rapidly, as are the environmental impacts of agricultural expansion. Food demand is expected to increase anywhere between 59% and 98% by 2050.

A more efficient agricultural productivity approach, one that uses less agrochemicals and is vital to meeting the global food demand along with protecting environment and human health. Nanotechnology is a multi-disciplinary scientific field with the potential to revolutionize the agriculture and food industry with new tools that promise to increase food production and control diseases in a sustainable manner. The Centre endeavours to innovate next-generation nanofertilizer, nanopesticide, and nanocarrier products and technologies. The developed products would provide twin-solution by enhancing efficacy and reducing risk to human health and environment in comparison to their bulk-counterpart. The collaboration between TDNBC, TERI, and its Partners—All India Institute of Medical Sciences (AIIMS), Tamil Nadu Agricultural University (TNAU)—will create region- specific nanotechnology solutions for the selected locations in India.

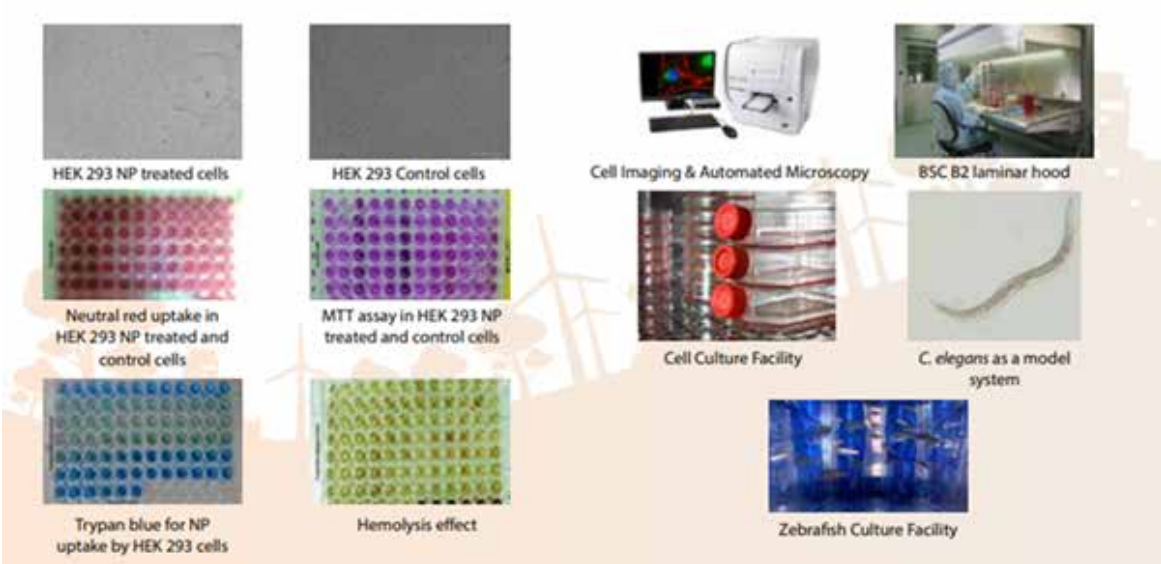
The NCEARAN is the first of its kind research platform in India, which endeavours to carry out end-to-end research to innovate green nanoproducts including nanofertilizer, nanopesticide, and nanocarrier products and technologies. Safe and efficacious nanoproducts will be developed by the Centre in order to meet the global food demand along with protecting environment and human health.



National Facility for Nanotoxicology Research of Nano-Agriproducts

The National Facility for Nanotoxicological Research of Nano-Agriproducts (NFNRNAP) is working in collaboration with AIIMS, New Delhi and endeavours to facilitate development of safe nano-agriproducts by following standard *in vitro* and *in vivo* test guidelines.

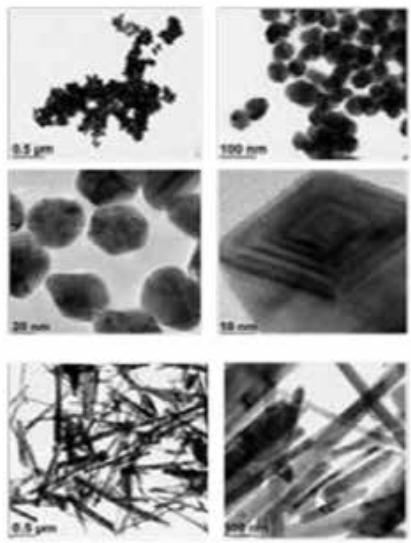
In vitro and *in vivo* nanotoxicological research is pivotal for fulfilling the regulatory requirements and commercialization of nano-agriproducts. The facility is focused to conduct investigation of the effects of the nano-agriproducts on human health and environment using *in vitro* and *in vivo* model systems for toxicity and risk assessment.



Nanomaterials for Agriculture, Environmental remediation and Energy

Nano-agriproducts development by encompassing a full-circle approach is poised to enable researchers and industries, in meeting regulatory compliance along with maximizing benefits and minimizing risk among farmers and consumers. Food demand with rapidly increasing population is outpacing sustainable supply and aggravating residue issues. A more efficient agricultural productivity approach, one that uses less agrochemicals but is highly efficacious, is vital for meeting the global food demand along with protecting environment and human health. Nanotechnology is a multi-disciplinary scientific field that has the potential to revolutionize the agriculture and food industry with new tools, which promise to increase food production and control diseases in a sustainable manner.

Energy is essential for the sustainable development of an economy. Supply of unrestricted energy to ever growing population without impacting the environment negatively is the current challenge. World energy supply largely depends on fossils which are neither sustainable nor environmentally safe. Thus there is a major push towards renewable technologies such as solar, wind, hydrogen, and biofuels. Nanomaterials play a crucial role for these next-generation renewable technologies owing to their unique electrical, optical, and mechanical properties. The unusual quantum properties at nanoscale benefit the charge transport and band engineering enabling high performance of the device. The relevance of these technologies could further be increased through materials obtained from bioresource that have exciting properties and are cheaply available in abundance.

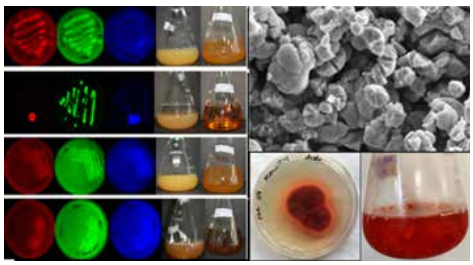


Nano-agri products developed at CEARAN

TERI–Deakin Nanobiotechnology Research Centre is thus primarily focusing on exploiting wide range of unexplored bioresources that offer materials having excellent linear and non-linear optical and electrical properties. Efforts are being made on designing hybrid nanomaterials and tailoring their optoelectronic and photonic properties for wide range of applications, particularly energy.

The key thrust areas include:

- Exploiting materials from untapped bioresources for energy, optoelectronic, and photonic devices
- Designing hybrid nanostructures with properties suitable for various device applications
- Integrating energy with agriculture



Ideation Centre: centre for processes and structures to support translational research and innovations in nanobiotechnology

The Nanobiotech@DBT is a platform initiated by the efforts from the Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India and being taken forward by the TERI–Deakin Nanbiotechnology Research Centre. This programme is aimed to bring the nanobiotechnology community together on a single platform to collectively engage and consolidate their efforts to deliver high-impact research with translational values. This platform would enable researchers and stakeholders to collectively define problems, connect, discuss, meet, ideate from conceptualization to implementation and share information, resource and infrastructure to deliver impactful and strategy-driven results. This platform consists of two components: a web-enabled network and a physical centre. The web-enabled network offers consolidated information and resources on nanobiotechnology community, knowledge-sharing platform, access to information and links of resources, facilities and infrastructure and an idea forum. The web-enabled network will allow researchers, domain experts, mentors, investors, incubators, and stakeholders to expand and connect the community together through interactions, collaborations, and partnerships to foster translational research. The physical centre, on the other hand, is aimed to facilitate physical interactions among researchers, stakeholders, and domain experts through periodic brainstorming sessions, workshops and review meetings; facilitate connecting with labs and facilities across the country for consolidation and validation of ideas; generate interfaces and processes to mentor researchers by making use of complementary skills available across the institutions/organizations across the country to leverage the depth of knowledge; mediate in providing inputs to stakeholders to directionalize research towards priorities of the country and draft policies relating to nanobiotechnology and serve as a central contact point to stakeholders/organizations interested to invest in advanced technologies that have the potential to achieve lab-/pilot- scale success.

Next-generation Mycorrhizae Products

Arbuscular mycorrhiza fungi (AMF), an obligate symbiont to the plant roots, act as a natural biofertilizer, providing the plants with water, nutrients and improving crop health and stress tolerance. Also, the plant–AMF symbioses form one of the oldest symbiotic systems from as old as 400 mya, driving researchers to accept it as 'Mother of all Symbiosis'. Owing to its substantial benefits as a biofertilizer, AMF are considered an alternative to the currently used chemical fertilizers. Since TERI is working on different aspects of sustainable agriculture, it explores the potential of AMF in terms of application and understanding its biology to further enhance the AMF capabilities as a biofertilizer, using different sustainable intensification approaches. Apart from being a biofertilizer and an obligate symbiont to most of the plant roots, AMF serve as a host to various

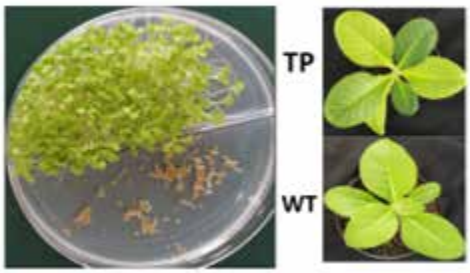
endobacteria. The Centre works to explore and understand the omics of the AMF following different genomics, transcriptomics and metagenomic approaches by sequencing the DNA/RNA on the latest next-gen sequencing platforms.

Further, various molecular techniques such as qPCR are applied to confirm the bioinformatics data. The Centre has done remarkable research to extract the beneficial genes and gene products from the AMF, such as AMF biomarkers. The present omics research focuses on getting the genomics and transcriptomics data of the previously unreported AMF species and understanding the endobacteria thriving inside it by analysing the gene transfers between them. These molecular and bioinformatics studies will further help in the AMF strain improvement and get beneficial gene products, which may help overcome the current drawbacks in the broad application of AMF as a biofertilizer.

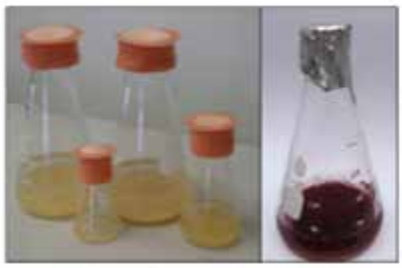
Our focus is on harnessing the untapped potential of mycorrhizae for sustainable agriculture. Mycorrhiza is a fungal system that forms a symbiotic relationship with plant roots and helps them tap nutrients from the soil that would otherwise have been inaccessible to the plant roots. We have successfully translated the nutrient-tapping potential of AMF and developed a technology that eventually produces mycorrhizae-based biofertilizer. The *in vitro* mass production technology of our is culmination of research and development carried out at the Centre for Mycorrhizal Culture Collection (CMCC), which is a Mycorrhizal Bioresources Centre for managing the next-generation germplasm bank. The CMCC aims at conservation of mycorrhizal biodiversity by means of collection, propagation, isolation, characterization, and maintenance of cultures under *in-situ* conditions. Today, the Centre houses more than 350 isolates of AMF and 257 isolates of ectomycorrhizal fungi (EMF) collected from various parts of Asia, Europe, and America.

Microbial, Plant Genomics

Plant Functional Genomics at TDNBC focuses on development of plant-based natural products, and other industrially relevant plant–biotechnologies, together with plant molecular studies on incorporating novel traits, are among the most characteristic activities of our team. We focus on next-generation metabolic engineering approaches to produce plant-specialized metabolites. These include recombinant plant cell suspension and algal culture technology, chloroplast synthetic biology and genome editing for incorporating improved

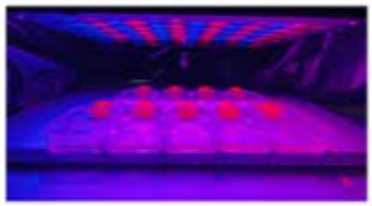


Novel Nutraceutical Producing Chloroplast Transgenics



Plant Cell Suspension Technology

Development of genome edited plants using CRISPR technology

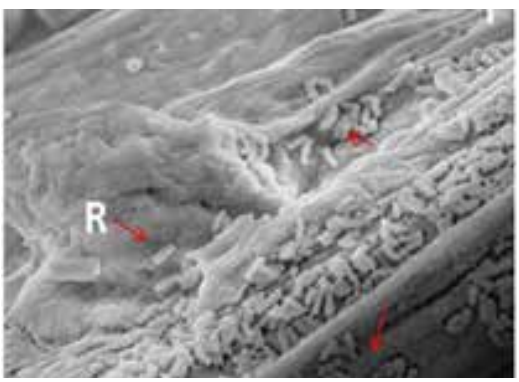


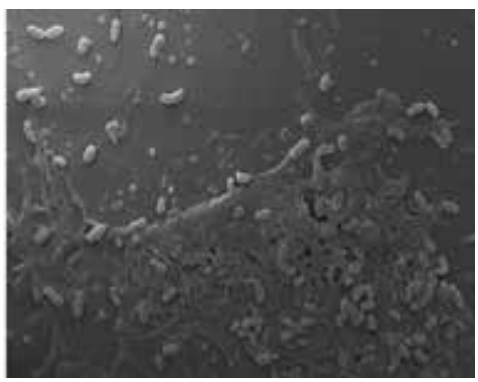
Microalgae growing under red and blue LED lights

agronomic traits. The discoveries in basic plant research play a crucial role in developing technologies to improve agriculture by introducing important traits to a crop of interest. Our team employs integrated approaches to identify genes and understand their function for imparting significant agronomic impact in crops useful for growers, industry, and consumers.

Functional Biofilms to Benefit Agriculture

Among different types of mycorrhizae, arbuscular mycorrhizae are ubiquitous plant root–fungus associations found in the soil near 80% of terrestrial plants, including agricultural and horticultural species. Mycorrhizal interactions promote plant growth and improve stress- tolerance and crop yield apart from improving soil properties through bioremediation. Interestingly, these fungi have recently been confirmed to be associated with several bacterial species that exist on the surface of mycorrhizal structures such as spores or reside inside them, sometimes both. These associated species of bacteria are increasingly seen to augment functionalities such as growth promotion or enhanced pathogen tolerance. The bacteria achieve this by aiding further utilisation of the resources hidden under layers of soil or by providing additional biotic and abiotic stress resistance and strengthening the symbiotic association. Therefore, in nature this is likely a three-way plant–fungi–bacteria





symbiotic association that has existed since ages in our ecosystem and has played an important role in maintaining crops by enhancing nutrition and yield.

These three-way associations have been recently studied for various functional traits that could shed light on the real reason for their mutually beneficial co-existence over generations in their ecosystems. We have successfully isolated a wide variety of bacteria associated with mycorrhizae and have promising leads from their functional genomics study to understand how these bacterial species co-exist with their plant hosts and use the soil ecosystems to enhance plant growth.

Presently, multiple approaches involving practical experimentation and bioinformatics analysis are being applied to understand the nature of this phenomenon. The intention is to develop advanced bioformulations with beneficial bacterial species for consistent performance of mycorrhiza under different climates and agricultural zones. This technology is being tested in controlled soil trials.

DBT–TDNBC–Deakin Research Network across Continents for Learning and Innovation (DTD-RNA)

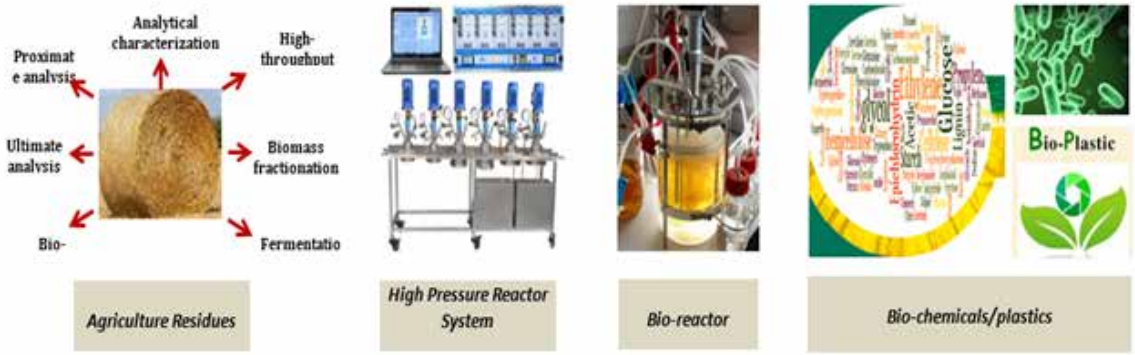
TERI, India and Deakin University, Australia are actively engaged in nanotechnology-based research on agriculture, material science, food storage, and safety. Considering the importance and relevance of joint research platform, TERI–Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India and Institute of Frontier Materials (IFM), Deakin University, Australia, in association with Department of Biotechnology, Government of India has created 'DBT–TDNBC–DEAKIN—Research Network Across continents for learning and innovation (DTD-RNA)'. The Network aims to serve as a training and capacity-building hub to foster and facilitate multi-disciplinary collaborative research in nanotechnology.

Algal Nutraceuticals Enhancement and Green Recovery

After a decade-long research and the mission to achieve cellulosic ethanol market, now the biorefineries have started to broaden their product portfolio, owing to the surplus availability of the agricultural feedstocks. Capturing the additional value from biomass, especially the waste streams generated in the process of converting biomass to biofuels would lead to the development of a sustainable biorefinery. Hoilistic Biomass Refining would provide a novel technology platform which has potential to replace the fossil-derived products available in the market. These products demonstrate low-carbon footprint, renewable, environment friendly and improve sustainability in a circular economy-based process. Hence, at TDNBC, TERI we are working towards the repositioning of the biorefining activities and develop integrated technologies to develop bio-based chemicals, biomaterials, biochemicals, biofertilizers, biopolymers biofuels, bio-based nanomaterials and nanoproducts. TDNBC, TERI stands as an excellent infrastructural and operational resource to carry out interdisciplinary research and technology development programme in this niche area with the high-pressure reactors and bioreactors facilities along with its strong analytical division set-up for biomass characterization using NMR, TGA, HPLC, GPC, FTIR, GC and LC-MS. The primary objectives of this programme are to innovate, excel, and develop the capacity building in the following areas:

- Biomass chemical composition analysis and characterization
- Novel biological and chemical catalysis pathways
- Biorefining and bioprocess development for advanced bio-based products/ chemicals/ nano-materials
- Life cycle analysis and Environment impact assessment

The outcomes from this area would serve as the driving force for the implementation of new 'green' industries



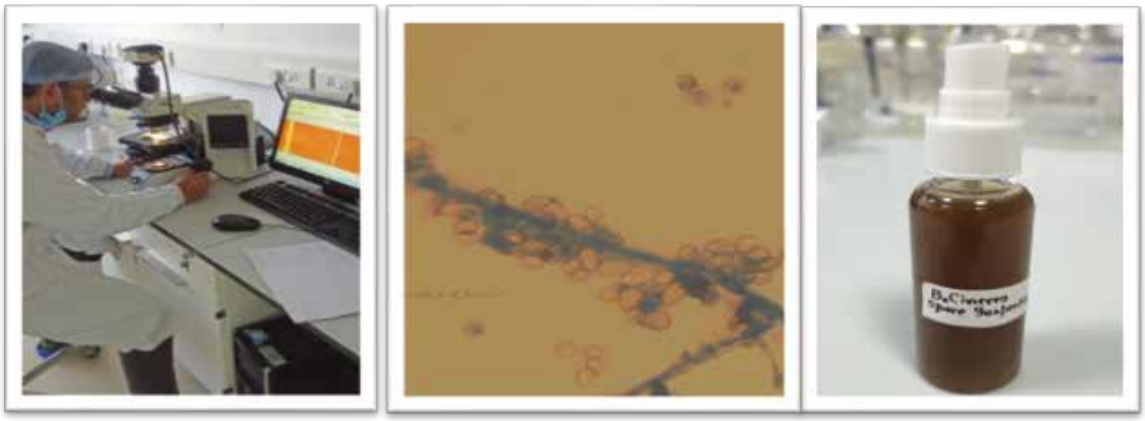
in India, based up on sustainable feedstocks, and will help the attaining the global leadership in the development of next generation technologies based on renewable resources.

Bio-efficacy Study of Different Fungicides and Pesticides against Major Diseases in Horticultural Crops

A bio-efficacy platform has been built at the Sustainable Agriculture Division for evaluating fungicides and bactericides against key diseases in horticultural crops under controlled settings. In a time-bound project approach, TERI has been offering services to many pesticide firms. We have put many formulations to the test for diseases including grey mould (*Botrytis cinerea*), anthracnose *(Colletotrichum capsici*), and early blight (*Alternaria solani*), among others. The following are some of the agricultural applications of this platform:

- Efficacy of a fungicide at various concentrations in relation to the severity of the disease
- Determine the best dose for commercial useStudies on the toxicity of nano-fungicides

Growth of sub-cultured Botrytis *cinerea* after 10 days



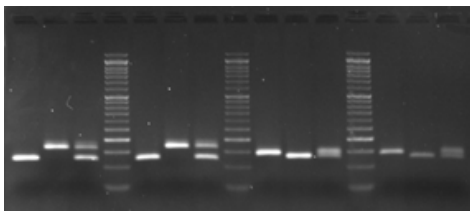
Spore counting and preparation of spore suspension (*Botrytis cinerea*)

Bell pepper plants formulation spray

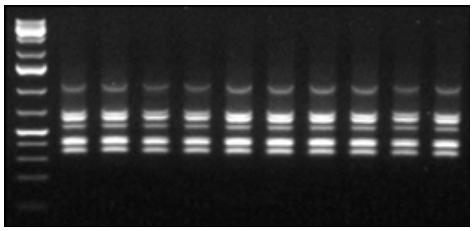
Plants after five days treated with formulations

Molecular Marker and Finger Printing Services

PCR-based molecular markers have been widely used in the field of biodiversity conservation, crop improvement and health. AFLP technique is the most suitable for use in underprivileged and new species because it can be readily used without much standardisation. It has high-multiplex ratio with highly reproducible profiles when conducted by a trained researcher. Whereas SSR (microsatellite) are locus-specific markers widely used for confirmation of hybrid/varieties of crop plants.



Hybrid/varietal confirmation using SSR marker



Clonal fidelity of *in vitro* propagated plants using ISSR

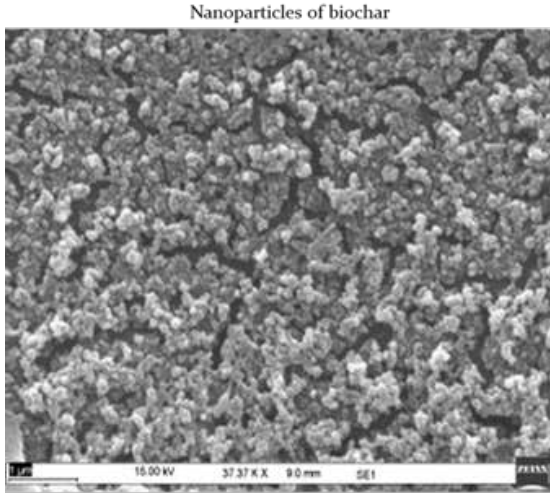
The Sustainable Agriculture Division of TERI has been using AFLP and SSR markers since 1997 and provides AFLP- and SSR-based services to seed and horticulture industries. TERI is DSIR-approved lab and has provided DNA fingerprinting services for more than 50 seed companies across country. We have used these markers in a wide number of plant and animal species, for instance, paddy, wheat, maize, pearl millets, tomato, bamboo, teak, neem, tea, seabuckthorn, jatropha, pongamia, date palm, eucalyptus, Withania, mosquito, houbara, and mycorrhizal fungi. These markers could be useful for following applications:

- Hybrid validation, variety identification
- Genetic diversity analysis, population structure
- Linkage and association mapping
- Confirmation of species
- Clonal fidelity of vegetative propagated plants
- DUS testing of new variety
- AFLP fingerprinting service
- SSR marker-based DNA fingerprinting services

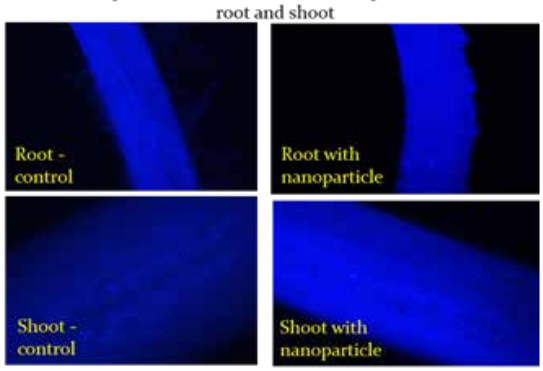
Nano-biochar As a Promising Carrier for Slow and Controlled Delivery of Micronutrients to Plants

The key challenges of low agri-inputs use efficiency and environmental hazards associated with conventional fertilizers application methods provide an impetus to develop novel carriers for slow, controlled, and rationale

Nanoparticles of biochar



Uptake and translocation of nanoparticle in root and shoot

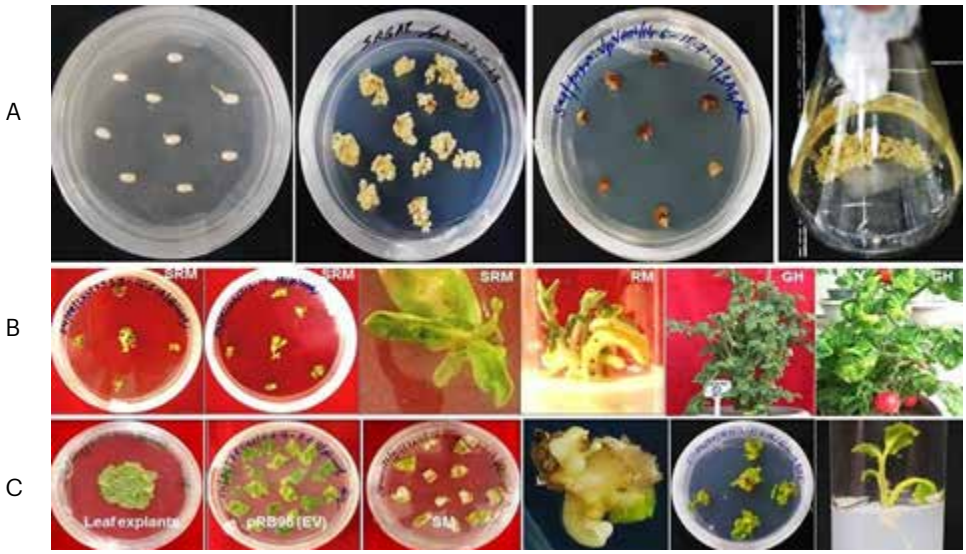


delivery of agri-inputs. Numerous methods on organic, inorganic, and polymeric delivery systems have been investigated, thus far for slow and controlled delivery of agrochemicals. However, their application and commercialization are limited in scope because of the lack of field trial data and expensive synthesis techniques. Thus, there lies a crucial need to choose materials and adopt methodologies that can be efficiently and easily employed at field-scale inexpensively. Biochar, being one of the established materials used in soil amendment since ages, could be a promising alternative. Nanotization of biochar could further enhance its functionality and tailorability for successful delivery of agrochemcials in plants. This work aims to establish nanotized biochar as a novel carrier for the delivery of agrochemicals that may result in its agronomic biofortification. We synthesized biochar nanoparticles of average size of 40 nm and as a demonstration immobilized zinc (micronutrient) on the surface of nano-bichar. Owing to its high porosity and favourable surface charge, ~67% of Zn was loaded on nano-biochar surface. Our preliminary results showed excellent uptake of these Zn loaded nanoparticles of biochar in seed and its translocation to root, shoot and leaves of rice plantlet. Detailed investigation on the influence of zinc on the morphological, physiochemical, and expression of zinc transporters showed enhancement in overall growth of the seedling and increase in the zinc transporter transcript levels. The findings suggested that the developed nano formulation could be used for slow delivery of micronutrients, pesticides, and other agrochemicals.

Genetic Engineering for High-value Natural Products

The proposed approach is based on the promise of modern genetic engineering technology for the production of biopharmaceuticals, proteins, high-value nutraceuticals, and flavours. For instance, this initiative aims to introduce and express Laz, a lipid-modified azurin protein encoding gene from Neisseria meningitides in tomato fruits via chloroplast and Agrobacterium-mediated nuclear transformation. Azurin is a redox protein that preferentially penetrates human cancer cells and exerts cytostatic and apoptotic effects by binding to p53—a tumor-suppression protein.

Similarly, industrial application of plant cell suspension culture systems (PCSCs) for sustainable production of pharmaceuticals, nutraceuticals, cosmeceuticals, and high-value chemicals is gaining considerable attention. A rice cell suspension culture system is a powerful platform to produce these high-value compounds.



This initiative achieved significant progress in this direction:

1. Transgenic tomato plants over-expressing Laz peptide have been developed
2. Chloroplast transformation technology established in tomato using pRB96 empty vector control. Establishment of transgenic rice cell suspension culture system has been achieved

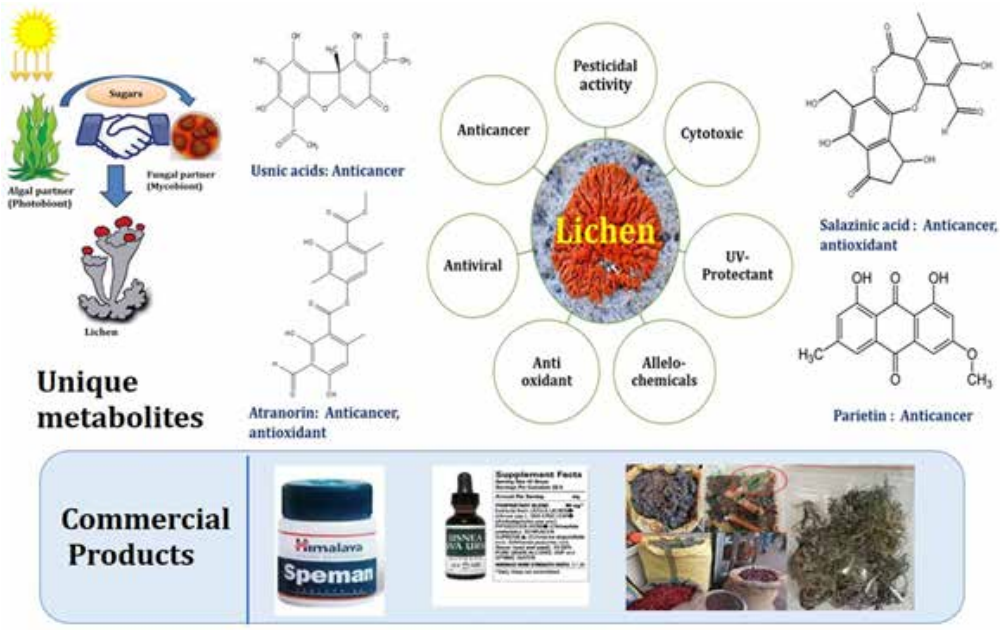
Transgenic rice cell suspension culture system at various stages of development

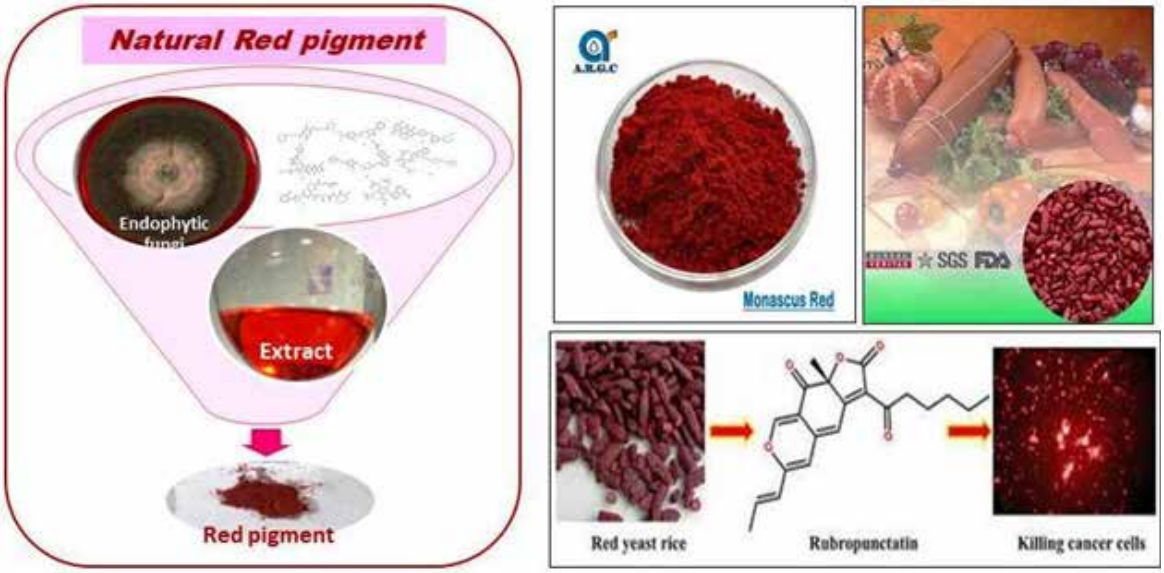
B. Development of transgenic tomato plants over-expressing Laz peptide (SRM: shoot regeneration medium, RM: rooting medium, GH: greenhouse)

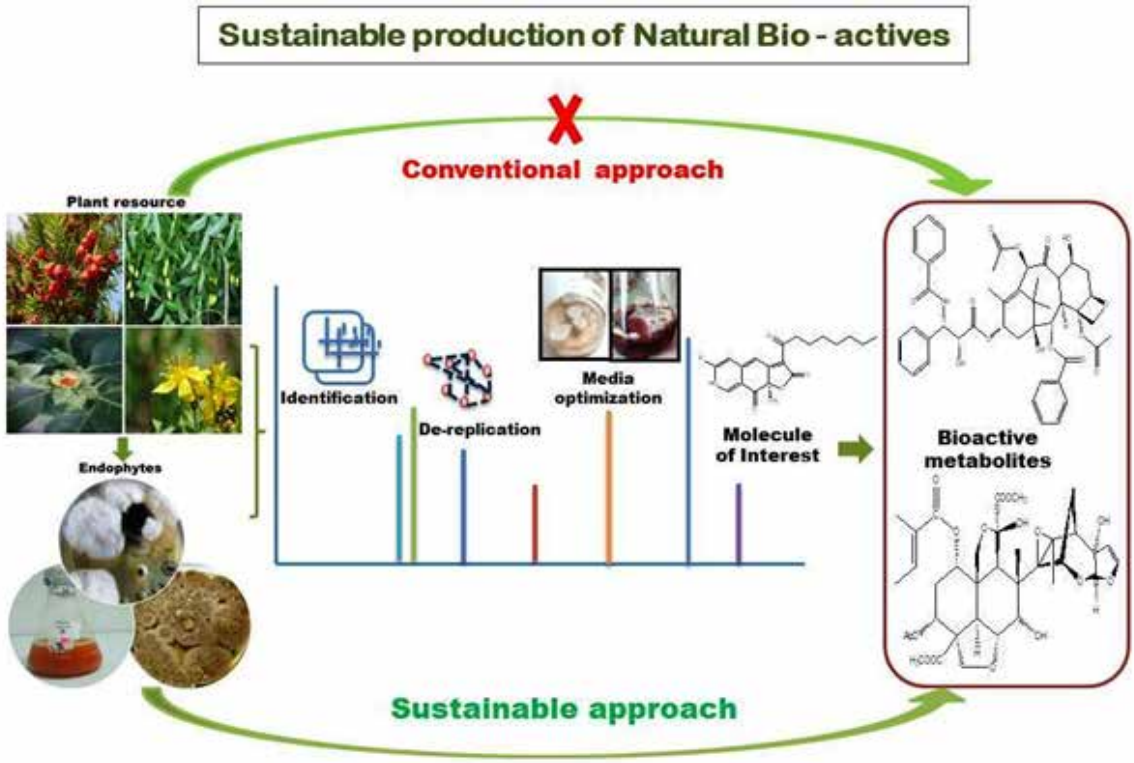
C. Chloroplast transgenic tomato plants with pRB96 empty vector control

Natural Bioactive Metabolites from Microbes as Untapped Bio-functional Compounds

Natural bioactive metabolites play a pivotal role as lead chemical entities for environment friendly neutraceutics, pharmaceutics and or as biofertilizer. Bioactive secondary metabolites from natural origins are extremely useful in food, pharmaceutical, and cosmeceutical industries due to their various biological activities such as antioxidant, anticancer, and antifungal. Amidst the plethora of resources of natural origin available, the natural product chemistry group is majorly exploring endophytic fungi, microalgae, and lichens as an untapped reservoir of potential bioactive molecules. Owing to the versatility, chemical diversity, amiability to scale-ups and well-discussed long history of products, these bio-cell factories are considered as potential treasure of bioactive compounds. The research group keenly works on all the aspects of discovery, isolation, and identification of metabolites with potential as nutritional/ functional food agents and phytomedicines. The major aim of this research programme is to obtain active scaffolds from these resources displaying potent antimicrobial, antifungal, antioxidant, anticancer, and pigment-producing capabilities. Another aspect of the ongoing research is to increase the bioavailability as well as functionality of the pharmacophore by employing state-of-the-art nanotechnology. The isolated metabolites are subjected to encapsulations and nanoformulations for futuristic applicability.




Natural Red pigment
Endophytic
Extract
Red pigment
Monascus Red
SGS FDA
Red yeast rice
Rubropunctatin
Killing cancer cells


Sustainable production of Natural Bio - actives
Conventional approach
Plant resource
Endophytes
Identification
De-replication
Media optimization
Molecule of Interest
Bioactive metabolites
Sustainable approach

Sustainable Habitat

The Sustainable Habitat Programme (SHP) has been envisioned to catalyse the 'Right to Sustainable Habitat' by mainstreaming principles of sustainability in the fields of buildings, transport, and cities. The Programme is based on beehive model where institutional strengths of various centres of excellence (CoEs) are pooled-in to provide technical support to development agencies, including governments, at international, national, and sub-national levels, thereby creating transformative impact.

Transport and Urban Governance Division

Centre for Urban Planning and Governance

To foster improved and informed decision-making for sustainable urban development, the Centre for Urban Planning and Governance focuses on strategic planning, policy research, and capacity building TERI has been supporting cities in actively working towards mainstreaming the concept of liveability in urban planning and policy frameworks and developing strategies to drive their climate agendas forward. TERI has contributed to the global urban discourse and curated sessions on implementation of the New Urban Agenda and SDG 11 in South Asian cities at UN's HABITAT III in Quito, WUF 9 in Kuala Lumpur, and WUF 10 in Abu Dhabi. In India, TERI has conducted a series of national and regional policy dialogues to facilitate discussions on critical urban issues. It has organized sessions at the Urban Thinker's Campus by UN-Habitat with National Institute of Urban Affairs, and conducted Australia–India

CUPG team conducted a field recce visit to Panaji, Goa, in March 2021 for the Urban Living Lab project supported by the Royal Danish Embassy. The project focuses on addressing sustainable mobility, urban flood management, and data-driven governance.
Photo by Adishree Panda, Research Associate, TERI

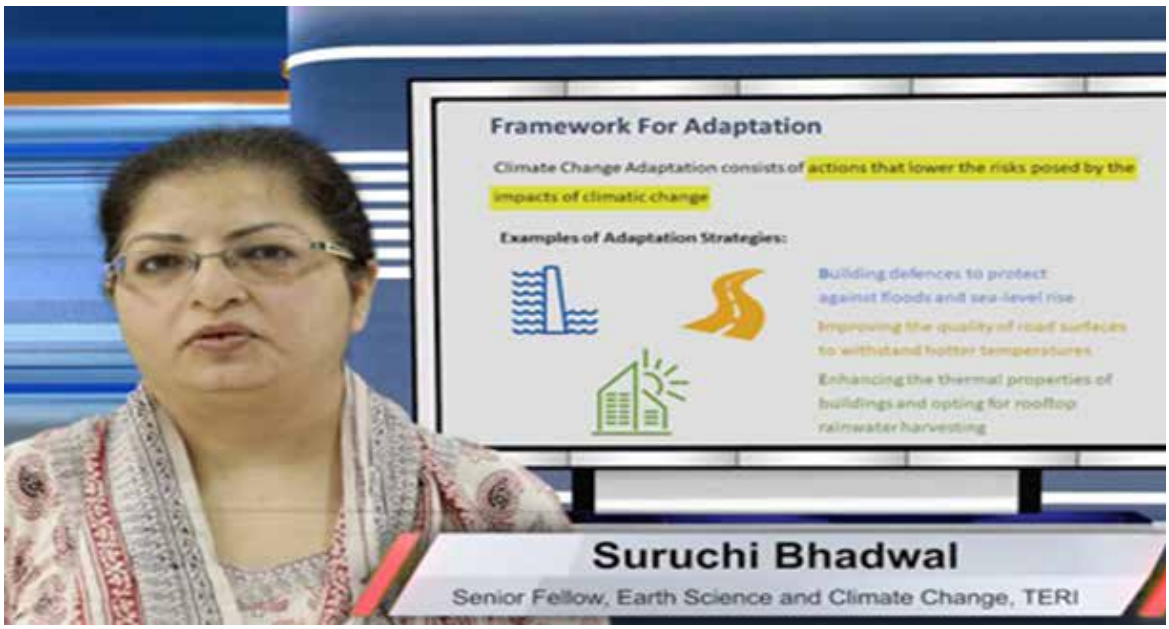
Knowledge Exchange Workshops on smart energy management initiatives, and Indo-Afghan TechCamps on Sustainable Urbanization.

TERI is supporting the Royal Danish Embassy in establishing an Urban Living Lab for Smart and Sustainable Cities in Panaji, Goa, and providing knowledge inputs across themes, including sustainable mobility and data-driven governance. Moreover, TERI has supported Andhra Pradesh Capital Region Development Authority (APRCDA) in preparing a holistic climate change action plan for the new capital city of Amaravati. It conducted climate risk assessments for the urban local bodies of Telangana. As part of the Internal Urban Cooperation programme of the European Union, a webinar series on mainstreaming urban climate action was also conducted for urban practitioners and policymakers.

TERI is an alliance partner with the National Institute of Urban Affairs (NIUA) for the implementation of the ClimateSmart Cities Assessment Framework by the Ministry of Housing and Urban Affairs (MoHUA) and is an

In the field recce visit to Panaji, Goa, in March 2021 for the Urban Living Lab project, TERI along with project partners OPML and Tandem Research conducted a survey to understand the infrastructure needs of pedestrians in the city.

active member of the Global Compact of Mayors (GCoM) by the European Union.



Webinar Series on Mainstreaming Urban Climate Action - Webinar Module II: Frameworks for Climate Change Adaptation and Mitigation, on 17 September 2020

Webinar Series on Mainstreaming Urban Climate Action - Webinar Module III: Global and Indian Best Practices of Climate Action in Cities, held on 24 September 2020

WSDS 2021 Thematic Track: Private Sector's Role in Achieving Climate Resilience: Leading Examples from Coastal Cities, held on 10 February 2021

WSDS 2021 Thematic Track: Planning Cities for a Sustainable Future, held on 12 February 2021

Centre for Sustainable Mobility

Transportation continues to be a key sector in India's economic revival, especially in the times of pandemic and lockdowns. It has emerged as one of the focus areas from the energy consumption and climate-change perspectives. India's rapid urbanization and faster economic growth have led to a marked impact on the country's mobility sector, or vice-versa. During 2005 15, the energy consumption in India's transport-related activities increased at a CAGR of 8.3%; a much higher rate than the fuel consumption in the transport sector globally (CAGR of 2%) during the same period.

Challenges such as reduced energy security, high congestion and pollution levels, skewed transport demand for personal vehicles and lower penetration of efficient public transport, and adverse health impacts and welfare losses have come along with increased demand for conventional fuel driven road transport vehicles.

The Centre for Sustainable Mobility (CSM) has been working in various segments in the field of transportation. It includes long distance mobility, aspects of urban mobility, and modelling and projections for transport demand – both in the passenger and in the freight businesses. The CSM, TERI has been working on

research areas related to the adverse impact of transport sector on air quality and greenhouse gas (GHG) emissions. The key objective of CSM is to promote energy-efficient, environment-friendly, sustainable and inclusive development of the country's transport sector – during an emergency situation such as COVID-19 as well as during the normal period. CSM adopts a multidisciplinary approach in providing low-carbon transport solutions to various stakeholders, made possible by its diverse team of research professionals trained in the fields of transport and urban planning, economics, and engineering.

The CSM has a vast experience of conducting studies on electric mobility, charging infrastructure, impact on energy, scoping analysis, and presents it in an easy-to-comprehend and handle web-based tool. CSM has a very wide range of capabilities in the fields of modelling and

Report Launch and Discussion on the Roadmap for Electrification of Urban Freight in India, held on 18 December 2020

TERI organized workshop to promote sustainable urban freight in Surat which was held on 25 November 2020

WSDS 2021 Thematic Track: Is a Decarbonised Transport Sector Possible in India by 2050?, held on 11 February 2021

scenario building, low-carbon passenger as well as freight transport solutions, including research works in the field of electric vehicles and alternate/green technologies, non-motorized transport, development of tools (web-based or offline), and training and dissemination activities.

GRIHA Council

We at GRIHA Council stand for credibility, integrity, and inclusiveness, while upholding Indian ethos for future-ready and sustainable habitat. The United Nations Framework Convention on Climate Change in their third biennial update report on India recognized GRIHA work in the field of energy efficiency, site planning, conservation, and efficient utilization of resources as the national green building rating system of India. At present, there are more than 2100 projects registered under the GRIHA rating with a green footprint (built- up area) of 650,000,000 sq.ft.

Furthering its partnerships, GRIHA Coucil in the year 2020 21 signed MoUs with:

- Energy Management Centre (EMC), Kerala
- Confederation of Indian Micro, Small and Medium Enterprises (CIMSME), Kerala
- Kerala Infrastructure Investment Fund Board (KIIFB)
- IIFL Housing Finance Ltd. (IIFL HFL).

In addition, the MoU with Council of Architecture was renewed.

The 12th GRIHA Summit was once again co- created in association with University of New South Wales (UNSW), Sydney, which was held virtually from December 15 to 16, 2020 with the theme 'Rejuvenating Resilient Habitats'. The event was inaugurated by Honourable Vice President of India Shri M. Venkaiah Naidu. The event was supported by many premier international and national organizations such as the Royal Danish Embassy in New Delhi, the Airports Authority of India (AAI), the Bureau of Energy Efficiency (BEE), and the National Real Estate Development Corporation (NAREDCO) as well as other multilateral, bilateral, and private organizations. The Summit platform was leveraged to discuss the design of our buildings and cities in a way that they are more resilient to climate change, health- related risks, natural calamities, etc. Resilient habitat is therefore an approach in disaster-risk reduction and climate change adaptation that target the most vulnerable communities.

Several GRIHA publications were launched during the Annual Summit: The GRIHA Version 2019 Abridged Manual, 30 Stories Beyond Buildings and GRIHA's annual magazine Shashwat. A limited edition web

application 'REACT' (Resource efficient & Affordable Choice of Technologies) was also launched during the summit. The application features an interactive activity where participants can compete against each other to optimize the resource demand for a virtual apartment.

GRIHA Council conducted a webinar on 'Building Fitness Indicator (BFI) - A social initiative of GRIHA Council' on April 28 (World Day for Safety and Health at Work), 2020. It was aimed at creating awareness about post-COVID precautionary measures to take at workplaces. It offered hands on experience of the BFI tool that allows any organization to measure the preparedness of their

GRIHA Version 2019 Abridged Manual (Volume 1) was launched by Hon'ble Vice President of India, Shri. Venkaiah Naidu

GS12, Day 2 – Rating Award Ceremony during valedictory of the 12th GRIHA Summit. No. of Rating awards – 33. No. of exemplary performance awards – 07

The 7th issue of GRIHA's annual magazine, Shashwat was launched by Hon'ble Vice President of India, Shri. Venkaiah Naidu

GS12, Day 1 – Inauguration of the 12th GRIHA Summit in the presence of Hon'ble Vice President of India, Shri. Venkaiah Naidu & Minister of State, I/C, Housing and Urban Affairs, Shri Hardeep Singh Puri, Ambassador of Denmark to India, H.E. Freddy Svane

workspaces to prevent the spread of COVID-19.

The GRIHA virtual fest was organized from 21 to 25 July 2020 providing an opportunity to various stakeholders such as builders, architects, NGOs, manufacturers, academicians and government agencies to showcase their products and services. The initiative laid emphasis on the direct interaction of the stakeholders with the clients aimed at improving connectivity within the market.

GRIHA Council also organized student competition in association with NASA (National Association of Students of Architecture) for the eighth consecutive year on 22 March 2020. The students were required to design an all-weather EWS (Economically Weaker Section) dwelling in accordance with the GRIHA for Affordable Housing rating variant. More than 25 colleges from all over India submitted their entries for the competition. Design entry

from the Indian Education Society's college of Architecture, Mumbai was declared the winner, followed by two special mentions for TKM College of Engineering, Kollam, Kerala and M.N.I.T. (Deemed University), Jaipur.

GS12, Day 2 – Signing of MoU between GRIHA Council & Energy Management Centre, Kerala

GRIHA organised the student competition in association with NASA. The students were required to design an all-weather EWS dwelling in accordance with the GRIHA for Affordable Housing rating variant.

GS12, Day 2: GRIHA Council released a limited edition web application-GRIHA REACT (Resource efficient & Affordable Choice of Technologies). The application features an interactive activity where participants can compete against each other to optimize the resource demand for a virtual apartment.

The GRIHA virtual fest was organised to provide an opportunity to the various stakeholders such as builders, architects, NGO's, manufacturers, academicians, and Government agencies to showcase their products and services.

Sustainable Buildings–Delhi

The Sustainable Buildings Delhi, a part of the Sustainable Habitat Programme, strives to promote low-carbon and low-cost solutions to developmental concerns in the built environment. In light of the COVID-19 pandemic, the current projected gross domestic product (GDP) growth for India stands at a meagre 1.9% for FY21. It is critical at this juncture to envisage a 'new normal' for a post-lockdown scenario that can integrate the principles of sustainable development with economic stability, social equity and the lessons learnt during the past few weeks. For the next year, a slew of new partnerships, collaboration, research activities, and implementation plans have been prepared to meet these objectives.

Sustainable Buildings Division at TERI provides innovative, integrated and cost-effective solutions to mainstream the principles of sustainability in the buildings sector. Working with a diverse range of organizations, including nodal ministries/departments, PSUs, corporates, academia and international development agencies, Sustainable Buildings Division promote resource and energy efficiency through optimization in design, construction, operation, maintenance, and demolition of facilities. Activities range from the design and development of energy- and resource-efficient projects to framing national-level policies and suggesting global strategies to adopt and implement energy efficiency in buildings.

The Division's state-of-the-art lab facilities at TERI Gram, Gwal Pahari, Gurugram conduct material testing, thermal-visual comfort studies, building envelope optimization and water-related assessments. The Division has over the years supported governments at the national, state, and local levels in formulation, review, and amendment of policies. It has set up Project Management Units within the state departments to help in the implementation of building standards, codes, and rating systems. It specializes in providing design consultancy of green buildings and implementation of energy-efficient systems with a focus on occupant comfort and well-being.

In 2019, Sustainable Buildings Delhi engaged with the Bureau of Energy Efficiency, Ministry of Power and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) to develop a National Directory of Energy-Efficient Building Materials. The Mahindra-TERI Centre of Excellence (MTCoE) fortifies the available testing infrastructure in the country by augmenting the limited number of NABL-accredited facilities providing thermal testing services for building materials. The first solar monitoring station for Delhi-NCR is installed at the MTCoE. Sustainable Buildings - Delhi successfully implemented Ground Source Heat Pump (GSHP) technology assisted with Solar PV at Kimin, Arunachal Pradesh. The division established Energy Conservation Building Code cells in Madhya Pradesh and Karnataka to provide hand-holding and technical support to State Designated Agencies (SDAs).

Mahindra TERI Centre of Excellence (CoE) has received accreditation from the National Accreditation Board for Testing and Calibration Laboratories (NABL), a constituent board of quality council of India. NABL is an autonomous body under the aegis of the Department of Science and Technology, Ministry of Science and Technology, Government of India. The laboratory, a joint research initiative of Mahindra Lifespace Developers Limited (MLDL) and TERI, was assessed and accredited in accordance with the international standard ISO/IEC 17025:2017, 'General Requirements for the Competence of Testing and Calibration Laboratories'.

Demonstration of Ground Source Heat Pump (GSHP) integrated with Solar PV system in Kimin Arunachal Pradesh at Community Health

TERI successfully implemented a Ground Source Heat Pump (GSHP) integrated with Solar PV system in Kimin Arunachal Pradesh at Community Health Center under the aegis of Arunachal Pradesh State Council of Science & Technology (APSCS&T) funded by Department of Science & Technology (DST). The pilot technology addresses both heating and cooling loads

Ground Source Heat Pump (GSHP) integrated with Solar PV system (Kimin, Arunachal Pradesh)

and demonstrates energy saving of about 30% without creating any negative impact in the atmosphere. The facility was inaugurated by Shri Nabam Rebia, Rajya Sabha MP on 22 February 2021.

Establishment of Energy Conservation Building Code (ECBC) Cell in Karnataka

TERI has successfully notified ECBC code and rules Karnataka with support of State Designated Agency (SDA). The KECBC 2014 had been updated as KECBC 2018 and notified in the Karnataka State Gazette on 28 May 2020. The Code is mandatory and the enforcement of the Code came into effect in the State from the date of notification for efficient use of energy in commercial buildings.

Study on Sustainable Space Heating Solutions in Indian Himalayan Region

The Indian Himalayas are one of the most ecologically fragile regions in the world.

Given its cold climatic conditions and unavailability of regular source of power and limited financial capacity of local communities, people in the Indian Himalayan Region (IHR) often resort to fuelwood to provide thermal comfort in their built environment. The traditional space heating mechanisms not only contribute to the increasing emissions in the region but also lead to degradation of natural resources and adversely impact the health of people residing in these areas.

With this objective, WWF India (World Wide Fund for Nature) and TERI collaborated in a study and released the report, Sustainable Space Heating Solutions in the Himalayan Region, which studies the impact of the adoption of newer and cleaner energy technologies on emissions in the IHR and suggests that sustainable space

heating systems can bring down CO2 emissions.

Teri Signed MoU with Glazing Society of India (GSI). The MoU envisions promoting applied research around glazing systems and their implementation in building envelopes. The MoU was signed on 23 February 2021 between Mr. A. R. Unnikrishnan, Chairman, GSI and Mr. Sanjay Seth, Senior Director – Sustainable Habitat Programme, TERI in the presence of Dr. Ajay Mathur, Director General, TERI; Dr. Vibha Dhawan, Designate Interim Director General, TERI; Ms. Shabnam Bassi, Associate Director – Sustainable Buildings Division, TERI; Mr Gopal Ganatra, Treasurer, GSI and Mr G N Gohul Deepak, Executive Director, GSI

Sustainable Buildings - Bangalore

Sustainable Buildings—Bangalore at TERI Southern Regional Centre has been working with real estate developers, private sectors organizations, public sector organizations, corporate entities, and institutions to provide green building design consultancy services for energy-efficient buildings. The Centre has been additionally working on research projects and policy frameworks with Central and State Governments, public/private institutions on energy efficiency and thermal and visual comfort for various applications. The Centre also organizes workshops, training and knowledge dissemination programmes for building industry professionals, research scholars, students and academicians.

In the year 2020-21, the centre took forward the on-going research on dynamic shading and radiant cooling technology funded by the Government of India, through the Department of Science & Technology. Under the same, the Centre completed the construction of two test beds and four prototype of dynamic shading. Under funding from DBT (Department of Biotechnology), the area continued the research on design and engineering of cold storage containers using bio-waste as an energy source.

Two consultancy projects were completed with ITC Limited, Chennai which earned it IGBC Gold Rating. Some of the completed projects have been discussed in detail here.

ITC Residential Project at Velachery Road Chennai

The residential project was developed by ITC Limited at Velachery Road Chennai. The project has been designed as per IGBC Green Homes rating system and achieved IGBC Gold rating. The project encompasses the best of green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting,

water re-use from STP, and rain water and solid waste management.

ITC Residential Project at Cart Track Road Chennai

The residential project developed by ITC Limited at Cart Track Road Chennai. The project has been designed as per IGBC Green Homes rating system and achieved IGBC Gold rating. The project encompasses the best of green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting, water re-use from STP, and rain water and solid waste management.

Some of the on-going projects are elaborated here.

Green Building Design Consultancy for IGBC compliance for the Proposed Buildings by Government of India

Indian Navy is developing a campus in India as per IGBC guidelines where TERI is acting as green building design consultant for IGBC certification. TERI has provided recommendations for efficient architectural design, management of waste, water and integration of renewable energy system. This project is confidential in nature.

DST: Habitat Model for Efficiency and Comfort

The proposed project aims at investigating novel and cost-effective movable window shading solutions, developing benchmarks and framework for performance assessment of new age shading devices, through field studies, lab testing, test bed monitoring. The second part of the project investigates the potential of natural heat sinks in minimizing chiller requirement in slab cooled buildings in high dense urban environment. After establishing performance of the above two indigenous products and developing the commercialization plans, it is proposed that TERI will construct a demonstration model energy-efficient habitat integrating the above solutions. Two patents were filed for residential and commercial shade smart devices.

Test bed at TERI Bangalore

Green Building Consultancy for Karnataka Trade Promotion Organisation's Exhibition Centre in Whitefield – Bengaluru

A new facility has been proposed by KTPO authorities with an objective to design it as green building to be certified as GRIHA-rated building. TERI, as a green consultant, is supporting the project in achieving the rating. TERI has completed the preliminary reports for the design evaluation including GRIHA due diligence visits.

Kanvinde R Choudhury - GRIHA Large Development Rating-IIT-Bhillai Phase-1

The Government of India is setting up a permanent campus for Indian Institute of Technology at Bhillai, Chhattisgarh. The total site area is 340 acres. The campus development has been divided into three phases: I, II, and III. Phase 1, with site area of 58 ha (58000 sq. m) has been detailed out with the following buildings being planned: Academic Core, Hostels, Sports Facility. and Housing. The projects consist of hostel, housing, sports facilities, swimming pool, spectator gallery and open-air theatre with total built-up area of 333623 sq. m. The client intends to achieve the highest standards in sustainable campus development and then apply for green rating under GRIHA Large Development rating system. In this respect, TERI, as a green consultant, is assisting in green building design consultancy and minimum 3-star certification as per GRIHA Large Development rating system. TERI has submitted the documentation for Master Plan rating.

Karekar Associates

Consultancy for comprehensive GRIHA services to achieve GRIHA star rating for proposed reconstruction work of NABARD officer's quarters, Plot-2 (MF-29 and MF-30) at Nandini layout Bengaluru. In this respect, TERI, as a green consultant, is assisting in green building design consultancy and minimum 3-star certification as per GRIHA rating system.

Godrej Green Woods Private Limited - Green Building Consultancy Services

Communication Outreach and Advocacy Unit

The Communication Outreach and Advocacy Unit (COAU) serves as the organization's pillar of support and the crucial link for all its outreach activities. The Unit's primary focus is to ensure that the organization as a whole evolves to cater to multiple stakeholders that enable the establishment of resilient partnerships, effective collaborations, and long-term associations with the outside communities as well as across the multidisciplinary programmes within the organization.

TERI's governing vision of a sustainable and viable future becomes a stronghold for the organization, especially for the COAU, to reach out to multiple stakeholders through various activities to share TERI's best practices with them. The Unit has, over the years, formed robust links with diverse media agencies that have enabled TERI's multiple and varied activities to be covered extensively in various publications of all forms. COAU's healthy relationships with external media houses as well as platforms have allowed for an easy exchange of information and the establishment of a mechanized information dissemination system. The COAU strives to share TERI's research and knowledge with varied audiences, including governments, youth, and the civil society. It effectively uses its strong links with the media to ensure that through this, TERI's current work and research reach discerning audiences, who can benefit from the expert knowledge and actionable policy work that are developed in-house. The Unit undertakes a plethora of engaging activities over the course of the year to encourage dissemination of knowledge and stronger communication with the research community and the media.

World Sustainable Development Summit Secretariat

TERI's annual flagship Track II initiative, the World Sustainable Development Summit (WSDS), organized within the COAU, has established itself as a responsible and an effective platform for mobilizing opinion-makers to identify and advance pioneering actions to address some of the most relevant issues concerning sustainable development.

With the 2021 edition, the Summit series marked 20 years in its journey of making 'sustainable development' a globally shared goal. Over the years, the Summit

platform has brought together thought leaders, heads of state and government, scholars, corporates, youth groups, and civil society representatives from across the world.

With 2021 finding us against the backdrop of a global pandemic and its close inter linkage with climate impact the umbrella theme for WSDS 2021 was 'Redefining Our Common Future: Safe and Secure Environment for All'. Discussions at the platform focused on the current crisis and the road map that nations need to adopt enroute a greener recovery.

The 2021 edition was inaugurated by the Hon'ble Prime Minister of India, Shri Narendra Modi, and saw participation from 118 countries. The Summit, which was instituted in 2001, has, over the years, brought together 52 Heads of State and Government, 13 Nobel Laureates, 78 Ministers, 1800+ Business Leaders, 2400+ Speakers, and over 26,000 Delegates from around the world.

The 20th edition of the WSDS has underscored the need for swift, far reaching, and multi- sectoral initiatives to

Events @ TERI

In the last 2 decades, TERI organised a large number of conferences, training programmes and seminars on diverse issues and topics, to complement its research agenda. The range of activities undertaken in the institute also includes training and capacity building, exchange of experiences concerning best practices and information dissemination. TERI has organised high-quality capacity building programs like conferences, workshops and seminars with international and national experts to brainstorm on several issues. The Events team at TERI functions under the Communication Outreach and Advocacy Unit to provide logistic support for conduct of all events within and outside TERI, to enable the maintenance of quality and cost effectiveness.

The breaking out of the Covid 19 pandemic has shaken the entire world. The lockdown taught us new ways to communicate and make announcements about our work in various fields, we organised almost 200 VIRTUAL EVENTS in the year 2020–2021.

address climate change. Resonant with themes that will define conversation at the 26th UN Climate Change Conference of the Parties (COP 26) in Glasgow scheduled to be held in November, WSDS 2021 has served as an important reminder for businesses, governments, academia, and other stakeholders to step up their climate action.

Environment Education and Awareness Area

Environment Education and Awareness (EEA) promotes Education for Sustainable Development (ESD) amongst children, youth, educators, as well as adjoining communities. In light of the pandemic, EEA has transformed its learning spaces to digitized mediums to reach out to a larger section of its target group. The medium includes webinars, discussion forums, workshops, opinion polls competitions, and digitized IEC materials.

The flagship programme 'Green Olympiad' was completely digitalized in 2020-21 where online exams were held in two batches reaching out to 87,588 students. The first cycle of GO4Youth–targeting undergraduate and postgraduate students was also done digitally.

The Green Boot Camp (GBC) was a virtual camp that promoted ESD amongst students. It covered a range of environmental issues and addressed their emotional and physical wellness. 'LIVE with water' a school education programme was initiated with the support of Government of Netherlands for schools in the vicinity of the Barapulla drain in Delhi. This project aims to empower schools with knowledge, build capacity of students and teachers, and facilitate action to increase wastewater use to meet an increasing water demand for health and sanitation in the city. In the Phase III of the Green school project, innovative digital programs were designed that enabled engagement of student in various project activities. A special training programme was conducted to enable the faculty of Mahatma Gandhi Institute of Rural Energy and Development (MGIRED), Bengaluru to design and execute outcome-based training programmes.

A special webinar to observe World Environment Day, 2020 was presented that inspired biodiversity conservation initiatives in India so as to motivate and inspire the youth. EEA partnered with the Second International Conference and Festival for Youth-Led Climate Action, POP FESTIVAL 2020 to present diverse 'Education for Sustainable Development (ESD) Approaches for Youth Empowerment'. Within TERI, EEA also actively collaborated with other divisions to devise and implement sustained outreach programmes as along with supporting field-based research.

Creative Content

The Creative Content group conceptualizes and implements outreach activities to make TERI's diverse work and knowledge accessible to key stakeholders, especially the general public. The group develops written and visual material for TERI's website, handles media relations, and strengthens online engagement through social media platforms.

TERI's work on water sustainability, climate change and migration, and scenarios and enablers for reaching net zero emissions, among others, received wide coverage in traditional and new media.

TERI's website maintained a regular content flow, including research reports with a growing emphasis on project-specific content including videos and infographics. On social media, TERI's engagement continued to grow across existing platforms and a new presence on the photo=sharing platform Instagram.

TERI's community radio station Kumaon Vani, located in Mukteshwar in Nainital, Uttarakhand, produced and broadcast a number of programmes and continued to raise public awareness on COVID 19 and combat misinformation, among raising local issues related to environment and conservation.

The Creative Content Division also completed its Media Fellowship programme on climate change reporting in the Himalayan region. Supported by the Earth Journalism Network, the programme trained a number of local journalists from various Himalayan states in India and countries such as Nepal, Bhutan, etc. in climate science, policy, and multimedia production. Their stories and reports featured in various news media.

TERI Press

TERI Press, the publishing arm of TERI, is one of the India's prominent publishers in the areas of environment, energy, and sustainable development. TERI Press publishes books, journals, and magazines on these topics at all levels. These range from children's books to higher education titles to professional reference books and magazines to journals. Keeping in view TERI's commitment to the dissemination of research and academic knowledge, in published form, TERI Press is dedicated to publishing quality books and has received both national and international recognition for its versatility and efficiency. With increasing social debate and educational emphasis on sustainability, there is a growing need for quality, environmental education content. TERI Press, in its endeavour to bring greater ecological awareness, has a wide range of print publications; widely accessible e-books; and sophisticated, interactive e-learning products that cater to every type of reader and knowledge requirement on diverse areas of the environment. TERI's children books, produced under the imprint of 'Terrapin', not only engage and sensitize young minds with environment-centric knowledge books but also encourage the habit of reading among children across India.

We work with academics across the globe to produce quality content and materials to improve learning outcomes for students and contribute to the development of the subject areas in which we publish. With over 400 published titles on energy, climate change, sustainable architecture, environmental studies for adults and knowledge books for children, TERI Press has been a valuable source for filling the learning gap on environment and sustainability. Our magazines, such as 'TerraGreen' and 'Energy Future', educate readers on key local and global environment issues. TERI Press also conceptualizes customized knowledge resources based on the needs and assessments of the target group. This includes undertaking environment-related projects to encourage an active social connect with the environment. In fact, TERI Press is the most preferred knowledge partner for leading corporates and ministries, such as GAIL India, the Ministry of New and Renewable Energy, Government of India, BSES Rajdhani Power Limited, Shakti Foundation, Oil and Natural Gas Corporation, United Nations Industrial Development Organization, Energy Efficiency Services Limited, and many more. With every carefully chosen and published title, quality has been the single major idea that drives TERI publications. TERI Press books and learning resources create a lasting impression and aim to make a positive difference.

During 2020–21, with the ongoing pandemic situation TERI Press continued disseminating relevant content to its readers with enhanced usage of digital platforms.

DOMESTIC OPERATIONS

Domestic Operations

Advanced Biofuels Programme

The Advanced Biofuels Programme exploring actively to produce next-generation biofuels and high-value renewable raw materials in a sustainable manner, to achieve make these processes cost economically viable.

Current global economy is mainly relying on fossil fuels (dead carbon). Considering rising crude oil prices along with climate security issues owing to the greenhouse gas emissions, the need for alternative renewable energy sources is well recognized by the economists, scientists, and environmentalists. Advanced biofuels do not rely on fossil resources and can be produced from next generation non-edible feed such as lignocellulosic biomass, agricultural residues, aquatic weeds, algae and organic waste. Though several technologies/ processes developed for production of advanced biofuels using non-edible feed as renewable raw material, the technologies are yet to be demonstrated in commercial scale. Major challenge of this process is the cost. In order to make these processes economically viable, it is essential to integrate these processes with production of high-value bio-commodities in a bio-refinery approach. To address aforementioned challenges and to address climate change issues, Advanced Biofuels Division is exploring to develop clean technologies for production of biofuel and renewable materials by using 2nd and 3rd generation feed (lignocellulose biomass, algae biomass,

spent organic matter, livestock manure) as raw material. To achieve the goal this division's research thrust focused on following thematic areas: microbial biofuels and biochemicals and pyrolytic biofuels, biochar, and green chemicals.

Microbial Biofuels and Biochemicals Area

The research activities of Microbial Biofuels and Biochemicals Area concentrate on development of bio-based renewable technologies for production of biofuels: biohydrogen, bioethanol, biomethane, biobutanol, algal biodiesel, and renewable biochemicals: 2,3 Butane Diol, 1,3 Propane Diol, lactic acid, neutraceuticals, high-value bio-pigments (carotenoids), in an integrated manner through microbial and algal interventions.

Algal cultivation for feed development for advanced biofuels and biocommodities production at a large scale (100,000 L) in Mumbai coast spanning across 220 sq. m

Active research explorations have been carried out by the group under DBT-TERI Centre of excellence project on 'integrated production of advanced biofuels and biocommodities. This has paved the way for demonstration of large-scale outdoor marine algae cultivation in an outdoor 100,000 L photo bioreactor system (custom-designed sunlight distributed), spanning across 220 sq. meter area, in Mumbai coast. This is the first of its kind in India, TERI has successfully demonstrated for outdoor 100,000 L) algae cultivation in 100,000L photobioreactor, in a coastal site. This system is operating continuously since 2020 to raise algae biomass by using sea water and atmospheric CO_2 as feed and sunlight as energy. This algae biomass is used

Focus/Thrust areas

as next-generation feed for extraction of lipids for biodiesel production. The lipid extracted residual biomass is being explored to use as feed for production of value-addition commodities: aqua feed, animal feed, biodegradable food-packaging plastics (in collaboration with IIT Guwahati), platform chemicals (2,3 butane diol, 1,3 propane diol), pyrolytic bio-oil and bio-hydrogen. Value-addition commodities are critical for the overall economic viability of the process. Aqua feed, in particular, is the most immediate proposition as value-addition commodity. Aqua feed formulated using algae biomass has shown significant results for fish growth enhancement.

Outdoor marine algae cultivation in 100,000 L sunlight distributed photobioreactor commissioned in Mumbai coast

Wet algal lipid extraction unit installed in Mumbai coast for algal lipid extraction

Green hydrogen production from next-generation biomass through biological route

Aquatic plants (water hyacinth and *Azolla*) and algal biomass are being tested as next- generation feed for biohydrogen production though use of select C_5 and C_6 sugar utilizing microbes.

Water hyacinth is an aquatic invasive species that multiplies vary fast in wetlands. It is estimated that water hyacinth is covering more than four million hectares of freshwater surface in India, leading to generation of 450 tonnes of water hyacinth biomass (wet weight) per hectare per year. Rapid colonization of this weed prevents sunlight from reaching surface of water thus imparted growth of the flora, fauna, and microbes. To ensure ecosystem sustenance it is thus essential to remove this weed from waterbodies regularly, putting increase financial pressure on the municipal bodies.

Azolla species is one of the fastest-growing aquatic fern that can grow in contaminated water and has potential for generation of substantial biomass. *Azolla* sp. has high biomass productivity potential (12 tonnes/ha/year). Major fraction of this biomass include lipid and carbohydrates (50–55%, cellulose, hemicellulose, starch), protein (25–30%), essential amino acids and thus it has the potential to be used as feed for production of clean fuels and bio-commodities (aqua feed, animal feed, bio fertilizer, etc.). Considering this, large-scale *Azolla* cultivation has been carried out in TERI Gram, Gurugram.

To recover energy from this biomass, a hydrolysis process has been developed to recover fermentable sugars to use as feed for biohydrogen production. The technology for green hydrogen production from these biomass sugars, is developed and up-scaled successfully in pilot scale (100 litre) by using *Enterobacter cloacae* and *Clostridium butyricum as* cell factory.

Carrying forward these activities lipid extracted algae biomass is being explored to produce green hydrogen. Scale up of this process is in progress.

Bioethanol production from first and second generations' feedstock

Bioethanol has got wide attention as an alternative transport fuel owing to its positive impact on environment and its potential to reduce dependence on conventional fossil fuel. With an aim to develop technologies for bioethanol production from the first and second generation feedstock, bioethanol production

from a range of feed stock is being explored. Intensive research explorations paved the way for development of bioethanol production in 10-litre scale from low-cost commercial grade sugar by a newly isolated novel strain, Candida tropicalis TERI DC. Further a co-fermentation process has been developed for bioethanol production from water hyacinth and corn cob biomass through use of *Pichia stipitis* and *Candia tropicalis* TERI DC as microbial cell factory.

Scale up of bioethanol production process 13. 5 L bioreactor

Process development for upstream production and downstream extraction of 2,3 butane diol, an industry platform specialty chemical

2,3-butane diol (2,3-BD) is a special chemical with reported applications in several industries. It is used as a precursor molecule for synthesis of range of chemicals (1,3-butadiene, butanes, methyl ethyl ketone (MEK), gamma butyrolactone, diacetyl, esters). These downstream products have applications in chemical industries; fuel-additive, textiles, polymers, synthetic rubbers and plastics, and so on. This chemical has got wide attention as precursor of bio-jet fuel.

With a goal towards zero-waste discharge, this area is also researched with possibility to develop microbial process for production of 2,3 butane diol from glycerol, the co-product from algal biodiesel transesterification process. The bioprocess for 2,3 butane diol production from glycerol and low-cost commercial grade sugar has been developed with *Enterobacter roggenkampii* strain TERI CT as host.

2,3 butane diol production process was up scaled in 13. 5 L bioreactor

Scale up of downstream extraction of 2,3 butane diol from the fermentation broth, though employment of integrated membrane filtration and vacuum distillation approach and membrane filtration, followed with fractional distillation approach

Enhanced methane recovery from livestock waste

Livestock waste is one of the major GHG sources and cattle manure is one of the major livestock organic solid waste that has high-COD content. Hence, it is imperative to treat this organic waste and to tap the high-energy content from this waste prior to discharge into the environment. With an aim to enhance energy recovery in the form of methane and to enhance rate of biomethane production, research explorations of this area are focused on development of efficient biomethane production by modulating the dynamics of complex microbial consortia. This process was successfully up scaled in 20 litre scale. This process resulted in lowering the hydraulic retention time (HRT) of the process with increase in volumetric biogas production and increase in methane production efficiency of biogas process.

Membrane filtration unit

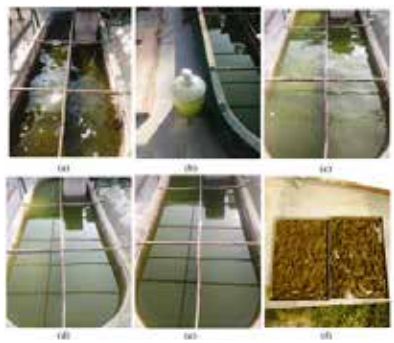
Pilot scale rotary evaporator

Fractional Distillation unit

2,3 Butane Diol extracted from the fermentation broth

Upstream production and downstream extraction of high value bio-pigments from algae and photosynthetic bacteria

Realizing the application potential of high value bio-pigments (carotenoids) in pharmaceutical, nutraceutical industries, a microwave-assisted downstream extraction process is developed for recovery of lutein, beta carotene, and red pigments from algae (*Chlorella*), cyanobacteria (*Spirulina platensis*) and photosynthetic bacterial (*Rubrivivax* and *Rhodobacter*) biomass.



Large-scale cultivation of *Spirulina platensis* in 1000 L outdoor raceway pond for carotenoid production (beta carotene and Lutein)

Rubrivivax cultivation for production of Speroidene ad lycogen pigment

TRISHA, Mukteshwar

TERI initiative TRISHA (TERI's Research Initiative at Supi for Himalayan Advancement) was started at the village Supi in Nainital district of Uttarakhand in 2003, where 7.5 hectares of land was provided on lease for 30 years by the Government of Uttarakhand. Since agriculture is the main occupation, research and extension has been largely undertaken to improve the livelihoods of local farmers. Since 2003, TERI has expanded its work in various areas of Uttarakhand with the support of the Department of Biotechnology, Government of India, NABARD, and the Louis Dreyfus Foundation as well as many more CSR activities of organizations such as HDFC, CONCOR, and IRCTC. The aim was to ensure sustainable development of local farmers through agriculture, horticulture, medicinal and aromatic plant cultivation, protected cultivation, and value chain development interventions.

TRISHA Supi is situated at a height of 7500 feet above the sea level and it is a distinct venture towards sustainable Himalayan development. It involves the following:

- Diagnosing deficiencies and applying biotechnological tools for improvement of nutritional, physical, and biological heath of agricultural lands
- Developing low-cost technologies and solutions for farming communities, for example, rainwater harvesting, solar energy, polyhouse and greenhouse technologies
- Focusing on innovative solutions to increase yield by providing planting materials of an array of high value temperate crop varieties, including horticulture plants, medicinal herbs, culinary herbs, stone fruits, and high altitude crops with a complete package of practices
- A cluster-based approach for sustainable farming in hilly areas of Uttarakhand and formation of Farmer Producer Organizations (FPOs), especially for women
- Creating ideal models of advance farming and value addition
- Enhancing the resource use efficiency
- Increasing capacities of marginal and small farmers through various on farm and off farm training and capacity building programmes
- Development of market linkages and buyback programmes and guaranteeing economic returns to farmers

TERI Supi also runs a community radio "Kumaon Vani" basically for highlighting the local issues and it is a major tool of extension. Kumaon Vani covers more than 300 villages of Kumaon and Garhwal regions.

There are various facilities at Supi, including polyhouses, greenhouses, glasshouses, herbal garden, processing units, soil testing laboratory, resource centre, advance horticulture models, rainwater harvesting models, and nursery areas of various herbs.

TERI has created a platform for local farmers to enhance livelihood opportunities and securities by providing sustainable solutions and eliminating intermediaries and created a win-win situation for local communities and concerned stakeholders.

TERI Southern Regional Centre, Bengaluru and Goa

The Southern Regional Centre (SRC) laid the foundation to promote the rational use of energy across sectors. The global commitment towards net zero to achieve energy efficiency is going to play a pivotal role. It is a firm belief in energy use optimization as a first step before integrating renewables. With three decades of experience, the Centre strengthens the capacities of policymakers and technical experts from end-use energy sectors to gain access to technological advancements

and innovative new concepts, strategies, and mechanisms for the formulation of projects in energy efficiency and renewable energy. The Centre adopted an applied research model providing a solution to waste minimization and resource conservation to varied sectors. The programmes implemented by southern state governments under sustainable development were continuously evaluated by researchers and guided to reinforce plans. The Centre strives to instil a sense of responsibility among youth for the environment and encourages them to formulate out-of-the-box solutions for environmental problems. SRC's focus is mainly to support corporates and governments and accelerate energy use efficiency and more effective uptake of renewables to slash emission cuts.

The Southern Regional Centre consists of the following six multidisciplinary teams that work in their specialized fields:

(i) The Industrial Energy Group (IEG) provides consultation to corporates regarding many best practices for energy efficiency and conservation that can be easily incorporated into daily operations and solutions that can reach beyond greenhouse gas (GHG) reduction and lead to operating cost reductions. It draws an action plan on trust converting to an all-renewable energy future, which is impossible unless we achieve energy efficiency at scale. During the year under review, the group completed projects such as (a) implementation of the PAT schemes – supporting designated consumers through mandatory energy audits and verification audits, mainly cement, iron and steel, power, and petrochemical sectors; (b) prudence check of capital expenditure incurred by the utilities – KPTCL and MESCOM; (c) Assessment of Energy Efficiency, Load Management and Renewable Energy Options for Cutzamala Water Supply and Treatment System – Mexico; (d) providing technical assistance to the Government of the Republic of Guyana, and; (e) Energy Efficiency and Conservation Provincial Action Plans – Pakistan.

(ii) The CIEEAB works with communities, particularly in rural areas, on renewable energy, watershed development, forestry, women empowerment, livelihoods, and efficient utilization of natural resources. Other activities are the dissemination of relevant technologies, monitoring, evaluation, and providing consultancy. During the year under review, the Group executed projects such as (a) evaluation of the CAMPA, TFC, NAP, and NBM schemes for Karnataka Forest Department; (b) evaluation of NERTPS schemes on the silk sector and apparel and garmenting units – the Central Silk Board, and (c) evaluation of National Horticulture Mission in Karnataka from 2015–16 to 2018–19.

(iii) The CRSBS team in Bangalore facilitates the design, development, and mainstreaming of sustainable buildings to improve energy and environmental performance levels of both new and existing buildings and raise awareness on sustainable buildings. During the year under review, the Group conducted research and consultancy work such as (a) research on dynamic shading and radiant cooling technology through the Department of Science & Technology, Government of India and (b) consultancy to new buildings of ITC Limited, Chennai.

(iv) The Resource-efficient Technology (RET), Bengaluru is working on research and development (R&D) activities in the development of biodegradable and environmentally friendly plastics for short- and long-term applications. During the year under review, the main research project of the Group was 'Development of Sericin/Polysaccharide Encapsulated Fertilizer for Crop Management and Growth' funded by the Central Silk Board.

(v) The Environmental Education and Awareness (EEA) promotes Education for Sustainable Development (ESD) amongst children, youth, educators, and adjoining communities. EEA has transformed

its learning spaces to digitized mediums to reach out to a larger section of its target group in light of the pandemic. In partnership with UNEP DTU, it organized a webinar on "Home Electricity Footprint" to ultimately reduce household power consumption. Owing to lockdown, industries, offices, and commercial spaces were closed. This reduced the nationwide energy demand but increased the domestic power consumption. The webinar gained immense importance, with different partner institutions conducting the same programme across three southern states of India.

(vi) The Coastal Ecology and Marine Research Centre (CEMRC), Goa, which is attached to Southern Regional Centre, Bengaluru, is a multidisciplinary research centre and has been conducting both research and implementation in the areas of marine and coastal resources; biodiversity mapping; water technology and management; and various activities in areas of environmental awareness, education, and outreach projects.

TERI North-Eastern Regional Centre

The research and development activities of the Centre include treatment of wastewater using potential algal strains and phototrophic biofilm-facilitated adaptation conditioning of algal and bacterial association leading to easier harvest of biomass; wastewater treatment; water quality improvement; waste management; production of quality planting materials and demonstration; sericulture; medicinal plants; improvement of livelihood through the adoption of location-specific sustainable land-based and off-farm activities; rural development and extension-oriented activities; and implementation of projects related to the development of agriculture, horticulture, natural resource management, medicinal plants, and watershed development activities.

In its efforts to promote horticulture in the region and improve the productivity, the Centre continues to produce quality planting materials of horticultural crops such as black pepper, Assam lemon, and Khasi mandarin, which have a significant economic value for the region in boosting the economy. Also, an essential oil extraction unit has been set up at Byrnihat for extraction of plant-based essential oil.

In the capacity building initiative of the Centre, TERI-NE organized various training programmes for the key stakeholders of the projects to equip them with skills in executing the project activities for ensuring their livelihood in a sustainable way.

In the area of biotechnological research, the development of epicuticular fatty acids catabolizing fungi enriched biopesticide formulation and validation of beta oxidation enhanced pathogenicity in citrus aphids have been done for virulence enhancement of entomopathogenic fungi for the control of citrus aphid, a major pest of citrus crops of the northeastern India. Fourteen free fatty acids, seven alcohols and cholesterol were identified in the cuticular lipids of citrus aphid. A few antifungal entities such as undecanoic acid [CH3(CH2)9COOH] and cyclopentane undecanoic acid methyl ester (C17H32O2) were also found in the cuticular fatty acids of citrus aphid, which might play an important role in resisting the penetration of the fungal bioagent. Further research is underway for exploring entomopathogenic fungal strains with such enzyme producing abilities to overcome such resistance that will lead to virulence enhancement.

Research on banana fibre extraction by mycogenic pectinase and surface modification through laccase enzyme is going on to facilitate degumming process, which is required to dissolve lignocellulose during the fibre extraction process. Exploration of pectinolytic

enzymes from native fungal strains on banana pseudo-stem and evaluation of their efficiency have been attempted for eco-friendly extraction of quality banana fibre. So far, 17 fungal strains have been isolated, of which nine isolates showed the pectinase activity. Among the strains studied Phoma herbarum and Aspergillus niger showed a higher enzymatic production efficacy. Scanning electron microscope (SEM) study of the surface morphology of raw, enzyme and chemically modified banana fibre indicated an abundant amount of pithy material in raw fibres. The findings of the study showed that Young's modulus and tensile strength decreased with the increasing banana fibre diameter. Blending of extracted banana fibre with other natural fibres was also carried out at 75:50 ratios. The Centre carried out a research study on enhanced carbonate precipitation of ureolytic and nitrifying microbes to treat rubber wastewater.

Considering the adverse environmental impact of plastics, it is desirable to promote alternative packing materials. The Centre initiated a project in Meghalaya on cultivation of packing leaves plant with the objectives of promotion of packing leaves as a substitute of plastics and also for livelihood enhancement of ST communities in the state. To increase its availability and also raise income of the low-income ST group, an initiative for large-scale cultivation of Phrynium pubinerve has been undertaken under the project. So far a new plantation area of 72 ha has been developed in unutilized land along with net house nurseries for the production of planting materials at the village level. Moreover, value-added products have also been developed from the leaf petiole. It is expected that the project initiative will minimize pressure on wild population of packing leaves; increase income of beneficiaries by use of leaves from the cultivation plot and production of value-added products; and minimize the negative impact of plastic.

In another research project on inventorization, molecular identification, and characterization of Garcinia species from the northeast India for isolation of polyisoprenylated benzophenones as taxol mimics, information on seven (7) species and four (4) varieties of Garcinia was gathered from Assam and Meghalaya. Out of seven (7) Garcinia species and four (4) varieties, samples of two (2) Garcinia species and one (1) Garcinia variety were sent to ICAR-Directorate of Medicinal and Aromatic plants Research, Anand for chemical analysis and also to MS University, Baroda for cell line work. DNA isolation and amplification of ten (10) species is going on at TERI North-Eastern Regional Centre, Assam.

In the sericulture sector, a feasibility study was conducted on entrepreneurship model of muga seed production and certification of silkworm seeds with the objective to study the strengths, weaknesses, opportunities, and threats of muga seed production and certification system, the resources required, and prospects for success in muga seed production and certification by the entrepreneurs. The model proposed based on the field study suggested the development of entrepreneurship in the muga seed sector based on the requirement of commercial disease free layings (DFLs), which has been calculated based on the available plantations for commercial rearing at the private level.

Waste is an unwanted substance produced from human activities. Zero waste is a goal that is ethical, economic, efficient, and visionary to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. Considering the immense importance to manage waste, a project entitled "Raj Bhavan Assam – a Zero Waste Campus" has been undertaken with the purposes of holistic assessment of solid and liquid waste generation, state of management, gap analysis, and formulation and implementation of standard waste management procedure for achieving a zero waste campus in Raj Bhavan, Assam.

In the water quality improvement front, the Centre undertook a project on "Water Quality Improvement of Dighalipukhuri, Guwahati, Assam" to reduce microalgal bloom and floating biomass accumulation on the water body. Two-pronged strategies adopted to enhance oxygenation and nutrient remedial were the reduction

of external nutrient load from septic tank effluent and surface run-off and the reduction of internal nutrient build up due to microbial metabolism of nuisance microbes. Under the project, artificial floating islands for water column oxygenation, entrap suspended solids, dissolved nutrient removal, and enhance the microbial activity in root zone water column with flowering plants were placed in the pond water. Apart from all these, chemical formulation for restoration of polluted water bodies to eliminate toxic cyanobacterial blooms for improvement of water quality in terms of dissolved oxygen and reduction of BOD, COD, odour, and colour was also applied.

TERI-NE Centre has been working as the Implementation Support Agency (ISA) under the project entitled "Jal Jeevan Mission-2020" in four Public Health Engineering Departments (PHEDs) in Cachar, Karimganj, and Hailakandi districts of Assam. The broad objectives of the project are to provide FHTC to every rural household, to prioritize provision of FHTCs in quality affected areas, to provide functional tap connection to schools, Anganwadi centres, GP buildings, health centres, wellness centres and community buildings, to monitor functionality of tap connections, to promote and ensure voluntary ownership among the local community by way of contribution in cash, kind and labour, and to assist in ensuring sustainability of the water supply system. Under the project, TERI-NE as an ISA has facilitated the activities of Jal Jeevan Mission in Cachar, Karimganj, and Hailakandi districts of Assam and prepared a Village Action Plan (VAP).

Establishment of a food testing laboratory accredited to NABL and the subsequent FSSAI affiliation would safeguard the food safety concerns of consumers besides improving the quality and business of food processing entrepreneurs of eight northeastern states. A food testing laboratory has been set up at TERI North-Eastern Regional Centre, Assam to cater to the food safety concerns of consumers and also to regulate the quality of food products from producers, sellers, and entrepreneurs from across the eight northeastern states. The analytical facility, which was partially funded by the Ministry of Food Processing Industries (MoFPI), is primarily developed for determining elemental composition and microbial quality as well as for detecting heavy metals and pesticide residues as per the Bureau of Indian Standards (BIS) specifications. High-end equipment such as ICP-OES, GCs with FID, ECD, NPD and FPD detectors, microwave digester, ultrasonicator bath, and muffle furnace is being used in the laboratory for analysis and data generation. Apart from the scope for ensuring food safety, in due course of time nutritional profiling and labelling of food items, GMO testing, and so on will also be considered for inclusion in the scope of services of the lab.

Goa Centre

Goa Centre is a multidisciplinary research centre focused on key areas such as marine and coastal resources, biodiversity mapping, environmental education and water resource management. Various environmental awareness programmes, educational, and outreach projects and activities are being implemented at the Centre.

The Centre works at influencing policy and strengthening the institutional support required for better management of natural resources. Conserving coastal ecosystems through sustainable development and community-based resource management programmes has been the expertise of this Centre. The Centre is also engaged in research that focuses on a variety of sectors such as biodiversity, marine and coastal resource management, aquaculture and training, water treatment technologies, impact and vulnerability assessment of water resources to climate change, coastal education, and studies at the interface of environment and development. In addition to participation in research projects that are local, national, and international in scale, the Centre actively contributes to local thinking and provides intellectual inputs on sustainable development issues through outreach by organisation and participation in seminars, training programmes and workshops.


ADVICE
TIPS
ASSISTANCE

SUPPORT UNITS

Support Units

Information Technology and Services Division

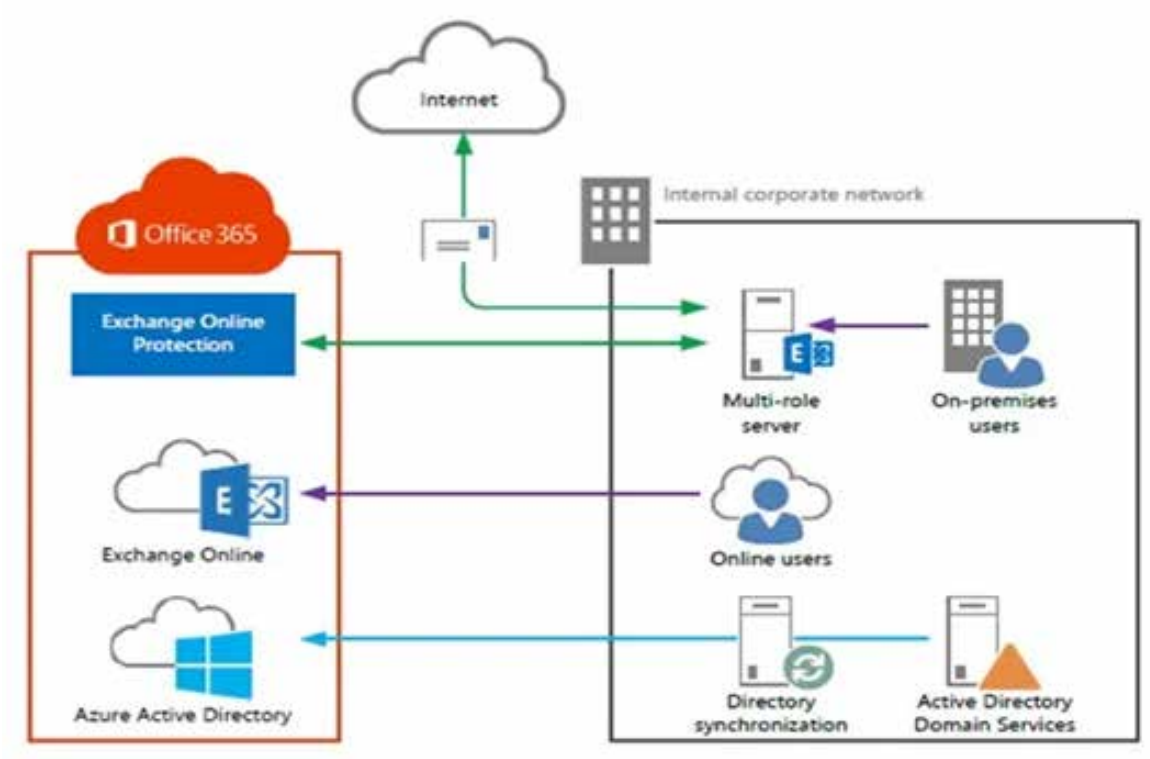
The Information Technology and Services Division of TERI is responsible for providing state-of-the-art IT infrastructure, latest communication platforms, and smart applications to other Divisions for their smooth operations. The Division is also responsible for developing customized applications for researchers as well as web and online platforms as part of providing support for knowledge sharing and capacity building.

IT Division has strengthened communication networks and deployed unified communication tools and smart mobility solutions. This has enabled collaboration across TERI's offices and centres through instant messaging, web conferencing, and videoconferencing and has also allowed researchers on the move to remain connected and work remotely. The driving objective is to provide secure access to IT applications and services from anywhere, anytime, and on any device to everyone. It is also aimed to make IT services flexible enough to change as per the need of the business and end users.

IT Infrastructure

Keeping up with the latest IT standards, IT infra team also is moving towards hybrid and cloud-based architecture. Most of our websites are hosted on Amazon Web Services (AWS) and Azure; this is done to ensure the maximum uptime of our websites and other services; there are 25+ servers that are hosted on cloud.

Our on-premises data centre hosts 45+ servers that are used by many locally-hosted applications or web services and storage solution is also hosted in the data centre, which can be used for accessing the information/ data anywhere within the TERI network. This data centre also has Main Distribution Frame (MDF) where the core switches are located and used for managing the entire TERI network. IT infra team also maintains magnetic LTO 7 tape library that is used to archive data onto magnetic tapes.



To provide uninterrupted connectivity across and within all centres of TERI, we have an extensive network with 70+ network switches, 7 firewalls, 40+ Wi-Fi access points with a minimum link speed of 1 Gbps, and internet link speed of 250 Mbps. All centres are connected to each other through MPLS or VPN links to IHC and network security is ensured by Sophos XG series Firewall and all the endpoints are secured by TrendMicro endpoint security.

A HPC (Supercomputing) infrastructure with a maximum capacity of 11.82 teraflops of speed, 308 cores of processing power, and 250 TB of storage is implemented to meet the future requirements in the areas of climate, air, and water modelling.

Microsoft Office 365

Our office 365 suite also works on hybrid infrastructure, and most of the services, such as mail and OneDrive, work on hybrid infrastructure, keeping your files and emails both secure and available most of the time. OneDrive is one of the important tools that enable people to access their data/files from anywhere, anytime, and on any device. The automatic syncing backup of files ensures that you will never lose your files even if your computer crashes. It has seamless integration with Microsoft Windows operating system and it appears as one of the folders in file explorer.

Other Office 365 apps such as Excel, Word, and PowerPoint also have online version that can be used anywhere and on almost any device.

Digital Library on Green Mobility

[https://greenmobility-library.org]

This is the Digital Library on Green Mobility (DLGM) portal for Low Carbon Transport, especially electric mobility, in India. The DLGM aims to provide a platform for sharing ideas, knowledge, and draft documents among the different stakeholders of various organizations

and institutions from India and abroad involved in low carbon transport in India. The portal aims at educating the researchers, academicians, citizens, and businesses with access to information such as policy instruments, reports, articles, books, standards, and case studies.

The content of the portal is the result of the collaborative effort of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and TERI. Also, an attempt has been made from this portal to highlight the latest news related to low carbon transport in India, with special focus on electric mobility. It is our endeavour to enhance and enrich this portal in terms of its content, coverage, design, and technology on a regular basis. The DLGM will source, provide links, and highlight latest news, policies, reports, interviews, documents, research papers, government notifications, etc., on low emission transport issues in general and e-mobility in particular with reference to India. It will also cover relevant important reports, news, and publications of the world. The DLGM will develop and maintain a set of searchable databases and links to various stakeholder organizations, accessible through different devices such as PCs, mobile phones, and tablets. One of the key components of this portal is allowing the stakeholders to share relevant resources, which can be uploaded on the website.

Stakeholders

Government ministries, departments and agencies, Civil Society Organizations (CSOs), academia, citizens, research community, industry, business houses, consultants, etc.

Green Olympiad Online Examination

[http://goexam.teriin.org]

IT has developed an online platform for Go Exam, which is a pan-India examination that tests the knowledge, aptitude, and attitude of students on the environment. Subject-based questions with a core range of issues related to water, waste, energy, air, agriculture, urban landscapes, biodiversity, climate change, and sustainable development are included in the examination. In addition to these, questions to assess student's environment quotient related to personal choices and behaviour are included.

Features

Online Paid Registration: School/university students pursuing any stream are eligible to register for the examination.

Student Dashboard: Each registered student is provided with login details to access the platform, where student can access sample questions and get a simulated environment before the real examination.

Online Examination: Through an online secure platform, students can attempt the examination consisting of 50 multiple choice questions to be completed in an hour.

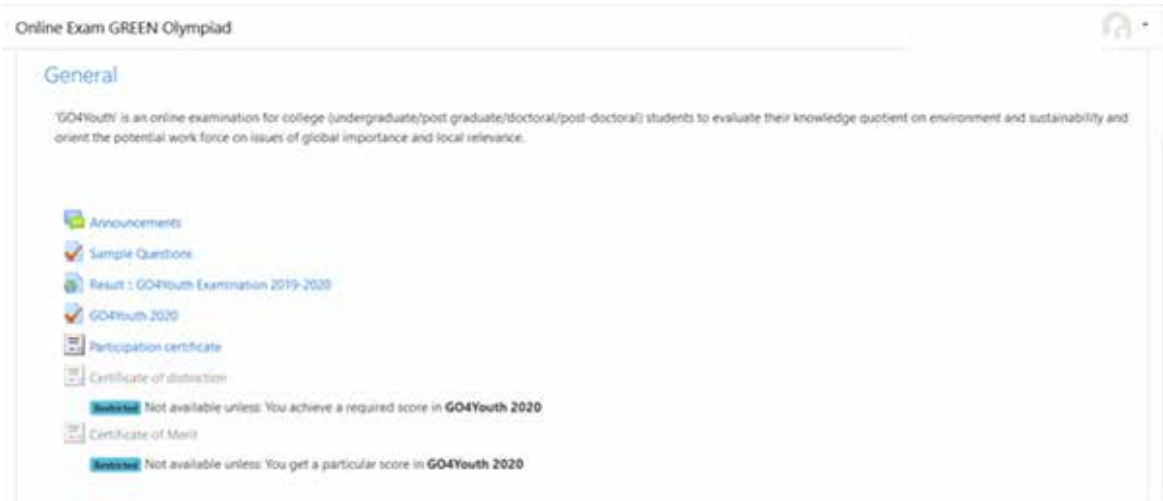
Publish Result: The result pertaining to the examination can be viewed online by the student. The student can also get to know the correct/incorrect answers.

Grade-wise Certificates: Students are awarded grade-wise certificates based on their level of performance in the examination, ranging from distinction, merit, and participation.

Special Incentives: Special incentives and rewards are given to suitable candidates for promotion of 'GO4Youth' within their network.

Stakeholders

Students, schools, and colleges



Sustainable Urban Freight Coalition

[https://sufcoalition.org/]

SUF Coalition is a growing consortium of public and private stakeholders of urban freight in India to bring together industry, academia, and civil society for knowledge creation and dissemination and sharing for sustainable urban freight (SUF) practices. SUF Coalition includes urban local bodies, vehicle manufacturers, research institutions, central and state government agencies, civil society members, and all other stakeholders of Urban Freight in India. This Coalition aims to act as a guidance facility for cost and emission reduction of urban freight in India.

Key Features

Develop national support structure for cost and emission reduction of urban freight. SUF Coalition aims to provide:

- A knowledge portal for SUF research and practice
- A forum to network industry, academia, and civil society stakeholders of UF
- A platform for sharing of experiential knowledge and best practices
- A platform for facilitating partnerships for low carbon initiatives in UF

Stakeholders

Sponsors – Government agencies, private organizations, original equipment manufacturers, etc.

GRIHA Learning Centre

[https://glc.grihaindia.org/]

As Albert Einstein once said, "Problems cannot be solved at the same level of awareness that created them." With this thought in mind, the GRIHA Learning Centre is developed as a massive step towards bridging the gap between green rating and sustainability integration.

Design, development, and propagation of the 'green infrastructure' demand a large pool of qualified professionals in all parts of the country. To enable the active dissemination of knowledge and skills necessary for designing green buildings, GRIHA Council is switching its training programmes to the e-learning platform.

The primary aim of the learning centre is to enhance the outreach and ensure that it is easily accessible to every individual across the nation.

Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort for All

[https://sheetalalliance.com/]

The SHEETAL programme is a CSO initiative led by TERI and partners AEEE and CEEW supported by Children Investment Fund Foundation to provide the opportunity for strategic actions to put forward the sustainable cooling agenda in India by facilitating the implementation of ICAP (India Cooling Action Plan). Aligning with ICAP, the consortium proposes a multidisciplinary, integrated approach along with technical solutions to enhance access to energy efficient cooling across multiple target sectors, such as space cooling, cold chain, transport air conditioning and servicing sector, etc.

The project also involves different stakeholder groups at the national and international levels that can assist with providing cross-sectoral discussion and knowledge sharing around emerging pieces of analysis and conclusions. This would provide a place for assembling different line ministries and international and domestic cooling policy experts to come together and synergize the actions to facilitate the implementation of the ICAP.

Stakeholders

Different line ministries and international and domestic cooling policy experts to come together and synergize the actions to facilitate the implementation of the ICAP.

Clean Air Project (Cap India)

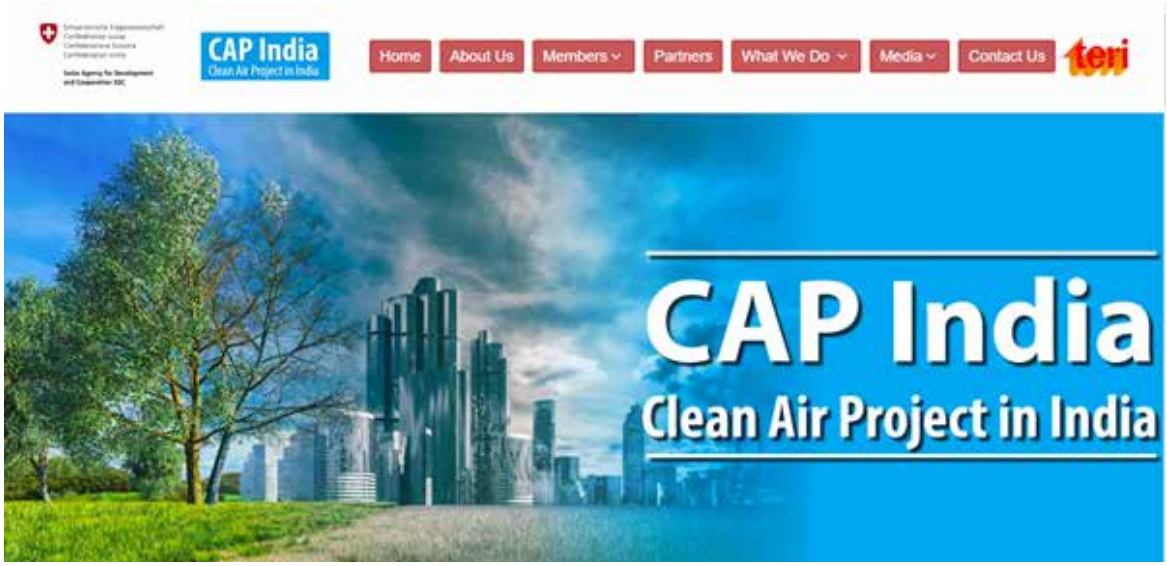
[http://52.76.109.165/cap-india/index.php]

In view of supporting India's efforts for improvement of air quality and reducing impacts on human health, ecology, and climate, CAP India project was conceived by the Swiss Agency for Development and Cooperation in 2019.

The project has two components, namely, research and implementation. A network led by Paul Scherrer Institute (PSI), Switzerland leads the activities on the research front, while The Energy and Resources Institute (TERI) is responsible for leading the implementation consortia focussing on overall project management. The research team is introducing state-of-the-art monitoring and modelling equipment and techniques to assess different species of particulate matter concentrations and their respective sources in cities. The implementation team takes inputs from the research team and from emission inventories and modelling based assessments to strengthen the air quality management plans in selected cities in India. The implementation consortium also envisages demonstrating the effectiveness of selected interventions through pilot projects, which can then be scaled up by the city, state, or central government at the larger scales in the four selected cities or elsewhere in the country.

During the course of the project, the capacity of local stakeholders, including government officials, academic groups, NGOs, and industries, is built through specifically designed training programmes on data measurement, emission inventories, air quality modelling, preparation of air quality action plans, MRV framework, and pilot projects. In order to achieve Outcome 3, the project team will also focus on spreading awareness in different sections of local communities. Specific awareness generation workshops will be carried out with different stakeholder groups, including school/college students, general public, media, etc.

The project is fully aligned with the objectives of NCAP and is supported by the MoEFCC, MPCB, and UPPCB. The project is also in line with several other international initiatives of WHO, UNICEF, UNEP, and CCAC that aim to contribute towards air quality improvement in Indian cities.



GRIHA V. 2019 Tool

All new construction projects with a built-up area more than 2500 m2 (excluding parking, basement area, and typical buildings) are eligible for certification under GRIHA v.2019 tool.

Rating Process

- Online registration: By registration and successful payment of registration fee through GRIHA website, login credentials are provided to the project team for submitting the documentation on the GRIHA online panel.
- All successful registrations through GRIHA website are provided with the login credentials to submit the documentation on the GRIHA online panel.
- Orientation workshop: After the registration process, an orientation workshop is conducted by GRIHA Council officials, which helps to provide the detailed information on the rating along with an explanation of all the criteria.
- Due diligence: The site visit is scheduled in two phases: once when the project has reached its plinth level and the other scheduled after the completion of the building structure work to validate the sustainable measures adopted.
- Submission of documents: When project reaches the phase of completion, the project proponent will upload the documents for all the criteria on the online panel.
- Preliminary evaluation: Preliminary evaluation is carried out by a team of professionals from GRIHA Council and external evaluators, who are experts in their respective fields recognized by the GRIHA Council.
- Final due diligence: Once the project is completed and all the equipment and systems are installed and commissioned, a final site visit is done by the GRIHA Council.
- Final evaluation: The final rating is given based on the final evaluation and is valid up to 5 years.
- Additional due diligence Green awareness drive: The GRIHA Council conducts an additional due diligence visit after the final rating for green awareness and education amongst project occupants.
- Rating renewal: The rating can be renewed in two ways: (i) By submitting an audit data report (over a span of three consecutive years) comprising energy, water, and waste (report to be prepared by BEE-certified energy auditor) and (ii) by enrolling the project for GRIHA EB rating to maintain its certification for the next cycle of 5 years.

PRAMAAN – https://pramaan.org.in

Background

Commercial and industrial (C&I) sector is the largest electricity consumer in India and is envisaged to play a pivotal role in India's National Action Plan on Climate Change (NAPCC). Although a lot of interest is seen from the C&I sector for procurement of renewable energy, this existing RE potential is still to be tapped. As part of its commitment to the Paris Agreement, India has set the ambitious target of achieving 175 GW of RE capacity by 2022. The C&I sector has an opportunity to contribute to these national goals while also achieving long-term self-sustainability.

Benefits of PRAMAAN

- Environmental sustainability
- Regulatory compliances
- Reduced business risks
- Reduced energy costs
- Boost to market reputation

National Advisory Committee (NAC) and National Technical Committee (NTC)

The NAC members bring unique governance skills and experience to the board and the NTC members bring on board essential technical experience and knowledge related to RE implementation and both governs the PRAMAAN rating system.

Knowledge Resource Centre

The Knowledge Resource Centre (KRC) supports TERI's research activities on energy, environment, and sustainable development by developing automated library system and managing innovative knowledge services and products. TERI KRC has set up many specialized information centres on thematic areas, such as transport, renewable energy, mycorrhiza, and climate change. Through a well-designed, state-of-the-art Intranet-based knowledge management system, KRC strives to capture and disseminate TERI's vast knowledge and research data.

The Centre caters to the knowledge needs of TERI researchers and external users through collecting, collating, and disseminating knowledge-based products and services using subscribed and open-access resources, which include books, reports, periodicals, and e-resources. Besides providing research and project assistance to TERI researchers, the KRC professionals are also engaged proactively in multi-stakeholder research projects, developing international-/national-level relationship and networking, conducting capacity-building programmes for research and information professionals, web content and database development, bringing out peer-reviewed publications and knowledge products on contemporary issues.

During 2020–21, the KRC executed many knowledge-based projects from government and international organizations consisting of online database on R&D equipments, digital repository of S&T publications and National S&T Survey supported by the Department of Science and Technology, Government of India, and Mycorrhiza Information Centre supported by the Department of Biotechnology, Government of India.

The KRC implemented the project on 'Access to Energy Efficiency Technology Information for Indian Industries', supported by the Department of Scientific and Industrial Research, Government of India, which involved collection, compilation, and dissemination on energy-efficiency improvement technologies and carbon dioxide reduction technologies that are being used and practiced in Indian industry sub-sectors, viz. Iron and Steel and Pulp and Paper.

The KRC hosts the ENVIS Resource Partner (RP) on Renewable Energy and Climate Change supported by the Ministry of Environment, Forest and Climate Change, Government of India, which maintains a highly viewed website and works relentlessly towards knowledge development and dissemination for policy-making, organizing workshops and skill development programmes, and conducting environmental surveys. Under the Green Skill Development Programme (GSDP) of the government, the RP initiated the course on 'Sustain and Enhance Technical Knowledge in Solar Energy Systems' for skill development to enable India's youth to get gainful employment and/or self-employment. Over 330 students have been trained and engaged so far in various capacities under this programme. TERI ENVIS RP and Department of Environment & Forests, Lakshadweep ENVIS Hub jointly organized a one-day annual seminar on 'Impact

of Climate Change in Lakshadweep Mitigating Climate Change Using Sustainable Sources', which received overwhelming responses from the stakeholders.

Corporate Social Responsibility

Corporate Social Responsibility (CSR) has evolved over time and has been gaining more importance for businesses in the context of sustainability and sustainable development. CSR and business were interpreted separately by the Corporates and the linkage between the two was missing. Business houses used to see CSR as one of many activities under social work. Gradually over time businesses realized that CSR and business cannot be conducted in isolation. The concept of CSR has gained increased significance in recent years. The growing focus on CSR has changed the attitude of businesses all over the world, and India is not an exception. The concept of CSR is not new to India; historically speaking, social responsibility of companies is a well-established phenomenon in India, and the country has one of the world's richest traditions of CSR. Various development-led initiatives through CSR in developing countries post Companies Act 2013 have provided platform for social development and has created opportunities for business to create value proposition for businesses and stakeholders.CSR department of TERI has formulated several programmes related to CSR and Sustainability to achieve Sustainable Development in the following areas:

- Policy inputs and awareness generation on CSR
- Planning and baseline study on CSR projects
- Implementation of the CSR projects based on the policy and Schedule V11
- Monitoring evaluation and impact assessment of project
- Outreach and dissemination

Community based CSR project

Stakeholder meetings on CSR projects

- Achieving sustainability in CSR projects

TERI's Expertise on CSR

- A proven history of working on wide-range of projects within the domain of provision of CSR, sustainability, and sustainable development
- More than a decade of experience of implementing and providing CSR and sustainability-driven projects
- Strong capability of implementing CSR projects based on Schedule V11
- Major themes on CSR include education, integrated development, community development, water and sanitation, environment sustainability, clean energy
- State-of-the-art facilities, laboratories with latest sophisticated instruments, software and experienced manpower
- Wide experience of implementing CSR projects across India
- Conducting training and awareness programmes, workshops, stakeholder's consultation, and participatory approaches to project implementation in CSR and sustainability.

TERI has received several awards related to its CSR programmes, which include the following:

- Best CSR organization on Rural Development Project for Coal India CSR project in Purulia in West Bengal
- Mahatma Award for Best CSR Project on Environment and Sustainability for Coal India Project
- Best CSR Project for CSR and Environment Sustainability for CONCOR CSR Project implemented in Himachal Pradesh
- Many prominent awards on themes of Education, Water, Clean Energy CSR projects

Ecotourism

The Ecotourism Group of TERI has a specific plan to promote tourism in the country in a responsible and sustainable manner whilst involving the local community leading to the overall economic development of the area.

The Group's key role is to conduct 'Eco-educational Programmes' for educational institutions, sensitizing youth about various environmental issues with respect to the existing social structure, cultural norms, economic realities, and contemporary global trends. In the past years, the Group has conducted numerous programmes for thousands of students coming from various institutions across the globe. As part of the programme, the Ecotourism Group places maximum effort to minimize the gap between urban and rural India and develop a sense of responsibility amongst the participants towards nature and the local community. Another key activity of the Group is to sustainably run and manage all day-to-day activities at TERI's Himalayan Centre, nestled in Mukteshwar, Nainital. The Group actively encourages private and public organizations to look for an escape from their metro life and explore suitable income-generation opportunities for the local community in the hills of Uttarakhand. In order to promote Mukteshwar as a destination and upscale market of TERI's herbal products, the Group has organized and also participated in numerous events and exhibitions in different parts of the country for an overall economic and social development. The Group has also joined hands with local government bodies and NGOs to encourage ecologically sustainable and financially viable ecotourism.

Project Management Unit

Projects are the mainstay of TERI. At any given time, more than 300 projects, ranging from research to implementation, would be underway. The Project Management Unit (PMU) is the institute's central hub and the objective of this Unit is to efficiently manage the projects—from their inception through to their conclusion. The PMU ensures that TERI's projects meet their budgetary and performance obligations and that at all times, the lines of communication between the donors/sponsors, implementation teams, and beneficiaries are well maintained and accessible. PMU, which functions as a nerve centre of the institute, is responsible for responding to the needs of projects in a timely and an effective fashion. The PMU's key responsibilities include:

- Identifying funding opportunities and areas of dissemination and coordination
- Facilitation for the preparation and submission of bids
- Team and relationship management, including the ongoing communication of duties and responsibilities within the project teams
- Ensuring a timely delivery of all contractual obligations
- Interim, mid-term, and project completion reporting
- Contract administration and budget control
- Quality control
- Research and editorial assistance. Logistical support
- Facilitating effective utilization of resources
- Generation of MIS reports
- Maintenance of knowledge repository

TERI's PMU uses sound project management techniques and customized software tools to facilitate deliverables on time and within strict quality guidelines, thereby ensuring that the desired outcomes of the projects are met. However, PMU's role does not end here as it also ensures that all the projects are well documented and catalogued in TERI's knowledge repository.

Human Resources Division

The Human Resources Division aims to engage the workforce to ensure a growth enabling, progressive working environment, which facilitates the realization of the vision and mission of TERI. The Human Resources Division has been instrumental in facilitating learning and development initiatives for staff to keep them in sync with the changing business environment. Online learning modules and live training sessions were introduced to ensure that learning doesn't stop even when employees are not physically present in office. We have initiated wellness programmes that focused on improving Mental Health and well-being of employees. We also focused on providing right remote working tools that enable employees to connect and collaborate while working from home. Flexible work from home policies were introduced to ensure employees are safe at home and effectively contribute to ongoing project activities. Regular internship opportunities facilitated by the Human Resources Division give TERI first pickings of the crème de la crème of the pool of fresh graduates from the best of institutes in the country who assist researchers on various research projects.

Our employee-friendly policies for higher studies provide an opportunity to researchers to pursue PhD programmes from the top universities across the globe.

At TERI we give utmost importance to the topic of diversity and sensitivity towards issues of harassment at the workplace. All the colleagues at TERI are familiarized and trained on the topic.

We aim at providing cross-divisional work and career opportunities to professionals to contribute to and gain knowledge and expertise in areas other than their primary research area, thereby improving interdisciplinary capabilities and offerings to the sustainable world. We give high attention on employee wellness programmes that focus on training and guiding our employees towards living a healthy lifestyle and enhancing their productivity at work. There are organizational programmes that provide platforms for employees to be a part of organization building and play a key role in building an inclusive workplace by participating in cross-functional team projects. TERI, through the Human Resources Division, encourages a culture and environment that is transparent and enhances employee engagement.

Administrative Services Division

The Administrative Services Division
The Mission of the Administrative Services Division of TERI is to ensure that research in TERI is carried out smoothly. In doing so, it provides the necessary administrative and maintenance support services to all the facilities located at the TERI headquarters at the India Habitat Centre; its regional centres located at Bengaluru, Goa, Guwahati, and Mumbai; and the campuses at TERI Gram in Gurugram and TERI Himalayan Centre in Mukteshwar, Uttarakhand. The strength of the Division lies in its well-motivated, dedicated, and qualified staff that supports all operations of TERI round-the-clock.

It maintains and runs all amenities and utilities meeting international standards. TERI's Quality Management System (QMS) is certified as per ISO 9001:2015 standards, its Health and Safety Management System as per ISO 45001:2018, and its Environment Management System as per ISO 14001:2015.

The Administrative Services Division also looks after The RETREAT (Resources Efficient TERI RETREAT for Environmental Awareness and Training). The RETREAT centre is a training and conference facility at TERI Gram. It provides organizations an opportunity to use its facilities for holding training programmes, workshops, and conferences with an objective of linking the process of corporate growth and training with the expression of corporate responsibility towards protecting the environment. The facility provides a unique experience of doing things in an unconventional yet viable way.

TERI's growing reach and visibility make it an integral part of the itineraries of many international dignitaries and delegates, including Heads of Governments. The professional coordination and conduct of all such visits continues to receive appreciation from the Heads of Missions in New Delhi.

PARTNERSHIPS AND NETWORKS

Partnerships and Networks

When trying to link policy, research, and practice, TERI recognizes the need to build collaborative partnerships and networks with the objective of sharing knowledge. enhancing technological capabilities, fostering innovation, building local capacities, and strengthening competitiveness. The institute continues to team up with local, international and bilateral institutions, and research and acedemic institutions to promote sustainable interventions. Our research collaborations MoUs, and partnerships, along with their areas of interest, through the year 2020/21, are listed in this section.

Energy

Industrial Energy Efficiency

Partner	Profile	Focus Area	Type of Association
Institute for Global Environmental Strategies	Research institute	Capacity building on climate change, energy efficiency	Collaborative research
New Energy and Technology Development Organisation	Research institute	Energy efficiency, smart grids	Partnership
Bureau of Energy Efficiency	Government agency	Energy efficiency	Funding
Shakti Sustainable Energy Foundation (SSEF)	Foundation	Energy efficiency, electricity sector	Partnership and funding support
The Energy Conservation Center, Japan	Research institute	Energy efficiency	Partnership and funding support
Climate Technology Centre and Network (CTCN)	International organization	Climate change	Collaborative partner
United Nations Development Programme	Multilateral organization	Energy efficiency	Funding partnership
Ministry of Micro Small and Medium Enterprises	Government of India	Energy efficiency in MSME sector	Knowledge support
United Nations Industrial Development Organization (UNIDO)	Multilateral organization	Energy efficiency, Renewable energy	Funding support and partnership
Gujarat Energy Development Agency (GEDA)	Government agency	Energy efficiency	Partnership
Maharashtra Energy Development Agency (MEDA)	Government agency	Energy efficiency	Partnership
The State Energy Conservation Mission, Andhra Pradesh	Government agency	Energy efficiency	Funding

Partner	Profile	Focus Area	Type of Association
World Bank	Multilateral organization	Energy efficiency	Funding
Global Green Growth Institute	International organization	Energy efficiency	Funding
International Energy Agency	International organization	Energy efficiency	Funding support and partnership
Snam S.p.A	Corporate	Clean energy and hydrogen	Partnership
Greestat Hydrogen India Private Limited	Corporate	Clean energy and hydrogen	Partnership
Stockholm Environment Institute/ Leadership Group for Industry Transition	International organization	Clean energy	Knowledge partner
ETIMAD Energy Company	Energy services company	Energy efficiency	Partnership

Environment and Industrial Biotechnology

Partner	Profile	Focus Area	Type of Association
Assam University, Silchar	University	Bioremediation area	Collaborative project partner
Nirma University, Ahmedabad	University	Bioremediation area	Collaborative project partner
University of Delhi	Institute	Bioremediation area	Collaborative project partner
ICAR-IISR, Indore	Institute	Bioremediation area	Collaborative project partner
CSIR–IITR, Lucknow	Institute	Bioremediation area	Collaborative project partner
CSIR–NEERI, Nagpur	Institute	Bioremediation area	Collaborative project partner
IASST, Guwahati	Institute	Bioremediation area	Collaborative project partner
CSIR-NIO, Goa	Institute	Bioremediation area	Collaborative project partner
IISER, Bhopal	Institute	Bioremediation area	Collaborative project partner
Dr Alxendre S. Kellichenkoo, Director of Polytechnic Research Institute, Belarus National Technical University	Research institute	Microbial biotechnology	Collaborative project partner

Partner	Profile	Focus Area	Type of Association
Department of Environmental Engineering, Korea Maritime and Ocean University, Busan, South Korea	Research institute	Microbial biotechnology	Collaborative project partner
University of Pannonia, Veszprem, Hungary	Research institute	Microbial biotechnology	Collaborative project partner
Helmholtz Centre for Environmental Research, Leipzig, Germany	Government of Germany	Microbial biotechnology	Collaborative project partner
Finnish Meteorological Institute, Helsinki, Finland	Government of Finland	Microbial biotechnology	Collaborative project partner
Temper University of Technology, Helsinki, Finland	Government of Finland	Microbial biotechnology	Collaborative project partner
Metropolia Institute of Technology, Helsinki, Finland	Institute	Microbial biotechnology	Collaborative project partner
Helsinki Environmental research, Helsinki, Finland	Institute	Microbial biotechnology	Collaborating project partner
Green Chemistry Centre of Excellence, Department of Chemistry, University of York, Heslington, York, UK	Government of United Kingdom	Microbial biotechnology	Collaborating partners and jointly organized Indo-UK Joint Workshop (granted by Government of UK)
Centre for Tropical Crops and Bio-commodities, Queensland University of Technology, Brisbane, Australia	Government of Australia	Microbial biotechnology	Collaborative project partner
Centre for Energy, The University of Western Australia, Perth, Australia	University	Microbial biotechnology	Collaborative project partner
Department of Chemical Engineering, for Process System Computations, Curtin University,-Perth, Western Australia	Government of Australia	Microbial biotechnology	Collaborative project partner
CSIRO Energy Transformed Flagship, North Ryde, New South Wales	Research institute	Microbial biotechnology	Collaborative project partner

Partner	Profile	Focus Area	Type of Association
NTPC (APCPL), Jhajjar	Public sector undertaking company	Microbial biotechnology	Partnership networking
NTPC (NETRA), Greater Noida	Public Sector undertaking company	Microbial biotechnology	Partnership networking
Cairn Oil and Gas, VEDANTA LIMITED	Public Sector undertaking company	Microbial biotechnology	Partnership networking
Department of Microbiology, Central University Of Rajasthan	Government organization	Microbial biotechnology	Collaborative project partner
Department of Biosciences and Bioengineering, Indian Institute of Technology Guwahati, Assam	Government organization	Microbial biotechnology	Collaborative project partner
Sardar Patel University, Bakrol, Anand, Gujarat	Research institute	Microbial biotechnology	Collaborative research
Indian Agricultural Research Institute, PUSA, New Delhi	Research institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
Indian Institute of Chemical Technology, Hyderabad, India	CSIR institute	Microbial biotechnology	Collaborative project partner
Indian Institute of Technology, Mandi, Himachal Pradesh	Research institute	Microbial biotechnology	Collaborative partner
Institute of Advanced Studies for Science and Technology, a Unit of DST, India	DST Unit	Microbial biotechnology	Collaborative project partner
Oil India Laboratory, Chemical Department, Duliajan, Assam	Research institute	Microbial biotechnology	Collaborative partner
DBT-ICT Centre for Bioenergy Research, Mumbai, India	Research institute	Microbial biotechnology	Collaborative partner
DBT-IOC Centre, Faridabad, Uttar Pradesh	Research institute	Microbial biotechnology	Collaborative partner

Partner	Profile	Focus Area	Type of Association
DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, Mumbai	Research institute	Microbial biotechnology	Collaborative partner
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	Research institute	Microbial biotechnology	Collaborative partner
DBT-ICGEB Centre for Advanced Bio-energy Research, Centre for Genetic Engineering and Biotechnology, New Delhi	Government organization	Microbial biotechnology	Funding support
DBT-IOC Centre for Advanced Research on Bioenergy, R&D Centre, Indian Oil Corporation, Faridabad	Research centre	Microbial biotechnology	Collaborative partner
Motilal Nehru national Institute of Technology (MNNIT), Allahabad	Research institute	Microbial biotechnology	Collaborative partner
Oil and Natural Gas Corporation (ONGC) Limited	Public sector enterprise company	Bioremediation, Consultancy for soil fertility improvement	Funding support
Bharat Petroleum Corporation Limited (BPCL)	Public sector undertaking company	Bioremediation of oily sludge, contaminated soil	Funding support
Hindustan Petroleum Corporation Limited (HPCL)	Public enterprise company	Bioremediation of oily sludge, contaminated soil	Funding support
Reliance Industries Limited	Private sector corporation	Bioremediation of oily sludge, contaminated soil	Funding support
Oil India Limited(OIL)	Public sector company	Bioremediation of oily sludge, contaminated soil	Funding support
ONGC-Teri Biotech Limited (OTBL)	Private limited company	Bioremediation of oily sludge, contaminated soil, MEOR	Funding support
SB Industrial Engineering Pvt Ltd	Private limited company	Bioremediation of oily sludge, contaminated soil	Funding support
Indian Oil Corporation Limited (IOCL)	Public sector company	Bioremediation of oily sludge, contaminated soil	Funding support

Partner	Profile	Focus Area	Type of Association
DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, Mumbai,	Research institute	Microbial biotechnology	Collaborative project partner
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	Government organization	Microbial biotechnology	Funding support
DBT-ICGEB Center for Advanced Bio-energy Research, Center for Genetic Engineering and Biotechnology, New Delhi	Research institution	Microbial biotechnology	Funding support
DBT-IOC Centre for Advanced Research on Bioenergy, R&D Centre, Indian Oil Corporation, Faridabad	Government organization	Microbial biotechnology	Funding support
Motilal Nehru National Institute of Technology (MNNIT), Allahabad	Institute	Microbial biotechnology	Collaborative project partner
Indian Institute of Chemical Technology (IICT), Hyderabad	CSIR institute	Microbial biotechnology	Collaborative project partner
Indian Institute of Technology (IIT), Delhi	Government of India	Microbial biotechnology	Collaborative project partner
Indian Institute of Technology (IIT), Madras	Government organization	Microbial biotechnology	Partnership network
Indian Institute of Technology (IIT), Guwahati	Research institute	Microbial biotechnology	Collaborative project partner
Institute of Reservoir Studies, ONGC, Ahmadabad,	Public sector company	Microbial biotechnology	Collaborative project partner
Oil India Ltd. R & D Centre, Duliajan, Assam	Public sector company	Microbial biotechnology	Funding support
ONGC Energy Centre, ONGC Laxmi Nagar, New Delhi	Public sector company	Microbial biotechnology	Funding support
Agarkar Research Institute, Pune	Government organization	Microbial biotechnology	Partnership network
Institute of Reservoir Studies, ONGC, Ahmedabad	Public sector company	Microbial biotechnology	Partnership network

Partner	Profile	Focus Area	Type of Association
NTPC Research Alliances (NETRA), Greater Noida	Government organization	Microbial biotechnology	Partnership network
Gail India Limited	Public sector company	Microbial biotechnology	Funding support
DBT-CIAB Center for Integrated and Applied Biosciences , Mohali	Government organization	Microbial biotechnology	Funding support
CAIRN Energy Limited, Gurugram	Public sector company	Microbial biotechnology	Funding support/ Partnership net work
Tata Steel Limited, Jamshedpur	Public sector company	Microbial biotechnology	Funding support
INBIGS, ONGC Jorhat	Public sector company	Microbial biotechnology	Funding support
Flood and River Management Agency of Assam (FREMAA)	Government of Assam	Livelihood enhancement	Funding support
State Level Nodal Agency (SLNA), WDC-PMKSY, Assam	Government of Assam	Monitoring, evaluation and documentation	Funding support
North Eastern Council	Government of India	Capacity-building programme	Funding support
Department of Biotechnology	Government of India	Sericulture and medicinal plants	Funding support
Ministry of Environment, Forest and Climate Change	Government of India	Livelihood enhancement	Funding support
Assam Science Technology and Environment Council (ASTEC)	Autonomous Council of the Department of Science Technology and Environment, Government of Assam	Post-harvest and possible collaboration for project	Funding support and Collaborative project partner
Nagaland University	Government organization	Biodiversity and bioprospecting	Collaborative project partner
Tripura University	Government organization	Biodiversity and bioprospecting	Collaborative project partner
Rajiv Gandhi University, Itanagar	Government organization	Biodiversity and bioprospecting	Collaborative project partner
Mizoram University	Government organization	Biodiversity and bioprospecting	Collaborative project partner
North Easter Hill University, Shillong	Government organization	Biodiversity and bioprospecting	Collaborative project partner

Partner	Profile	Focus Area	Type of Association
Institute of Bioresources and Sustainable Development, Imphal	Government organization	Biodiversity and bioprospecting	Collaborative project partners
Centre for Orchid Gene Conservation of Eastern Himalayan Region, Manipur	Research centre (NGO)	Biodiversity and bioprospecting	Collaborative project partner
Regional Centre of Institute of Bioresources and Sustainable Development (RCIBSD), Sikkim	Government organization	Biodiversity and bioprospecting	Collaborative project partner
Assam Agricultural University, Jorhat	Government organization	Microbial biotechnology	Collaborating project partner
Indian Institute of Technology (IIT), Guwahati	Government organization	Microbial biotechnology	Collaborating project partner
N.V. Patel College of Pure and Applied Sciences, Vallabh Vidyanagar – 388120, Gujarat	Government organization	Microbial biotechnology	Collaborating project partners
National Institute of Technology, Rourkela	Government organization	Microbial biotechnology	Collaborating project partner
Public Health Engineering Department, Assam	Government organization	Sanitation	Funding support
Nation Institute of Urban Affairs, New Delhi	Government organisation	Capacity building	Funding support
Assam State Council for Science and Technology, Assam	Government organization	Microbial research	Funding support
State institute of Panchayat and Rural Development, Guwahati	Government organization	Consultancy for detailed project report	Funding support
Ministry of Food Processing Industries	Government organization	Infrastructure support	Funding support
Chhatrapati Sahuji Maharaj Unversity, Kanpur	Government organization	Medicinal plants	Collaborating project partner
Biotechnology Industry Research Assistance Council (BIRAC)	Government organization	Research support	Funding support

Integrated Policy Analysis

Centre for Integrated Assessment and Modelling

Dr Ritu Mathur as:

- Member of Global Climate Policy Partnership Network
- Steering Committee Member, India Energy Modeling Forum, NITI Aayog

Resource Efficiency and Governance Division

Partner	Profile	Focus Area	Type of Association
European Union	Multilateral Association	Resource Efficiency - Phase II	Partnerships are established between European and Indian businesses and stakeholders on resource efficiency in sectors of interest.
NITI Aayog	Government Organization	Carbon neutral resource efficiency strategy	Engagement with UT of Ladakh government forest department, Institutes and various stakeholders.
Konrad-Adenauer-Stiftung (KAS)	Foundation	Security concerns in the global maritime and energy	Conducted background study and event on Addressing maritime and energy security issues
Konrad-Adenauer-Stiftung Regional Project Energy Security and Climate Change Asia-Pacific (KAS RECAP)	Foundation	Blue Economy	Organise webinar and bring out publication in the form of Policy Brief
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Government Organisation	Reducing Plastic waste	Research Collaboration for Reducing Plastic Waste and to develop new technologies and business models to innovate plastic supply chains
World Resource Institute (WRI)	Non-governmental Research Organisation	Sustainable food and land use systems	Research collaboration to influence and advocate for the reform of public policies through ground level engagements and coming out with research paper

Partner	Profile	Focus Area	Type of Association
IKEA Foundation	Foundation	Sustainable and Regenerative Rainfed Agriculture	Engagement with state level and national level government departments and civil societies to design a strong policy and development strategy
Department of Biotechnology	Government Organisation	DBT-CoE - Sustainability assessment of Biofuel Production Systems	Sustainability Assessment of Integrated Biofuel Production Systems - Sustainability assessment of Biofuel Production Systems
Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ) GmbH	International Organisation	NAMA - GIZ IKI Interface Project – Phase II	Indo German Bilateral project on Development and Management of NAMAs in India

Natural Resources and Climate

Environment and Waste Management Division

Partner	Profile	Focus Area	Type of Association
Norwegian Institute of Public Health	Norway Government	Air pollution and waste management	Funded project
The World Bank	International organization	Air pollution and health	Funded project
Thinkthrough Consulting	Private Indian organization	Climate change and health	Funded project
National Institutes of Health (NIH), USA	USA Government	Waste management, environment and health	Funding support
Shakti Sustainable Energy Foundation	NGO	Air pollution and health	Funded project
Government of Madhya Pradesh	Indian Government	Health and climate change	Funded project
Central Pollution Control Board (CPCB)	Indian Government	Air quality and health	Funded project
WHO – SEARO	International organization	Climate change and health	Funded project
All India Institute of Medical Sciences, New Delhi	Indian Government	Air pollution and health	Collaborative research
University of Illinois at Urbana-Champaign, USA	USA Government	COVID-19, Air pollution and health	Collaborative research

Partner	Profile	Focus Area	Type of Association
School of Technology and Management of Viseu (ESTGV)	Portugal Government	Chronic kidney disease in India	Collaborative research
Indian Council of Medical Research (ICMR)	Indian Government	Air quality and health	Collaborative research
Health Effects Institute (HEI) USA	USA Government	Air quality and health	Collaborative research
National Bank for Agriculture and Rural Development (NABARD)	Indian Government	Hydrochar from paddy straw	Approached for funding support
National Mission for Clean Ganga (NMCG)	Indian Government	Microplastics and phthalates in Ganga River and their health effects	Approached for funding support

Centre for Waste Management

Partner	Profile	Focus Area	Type of Association
Abt Associates	Research organization	SLCP reduction from MSW management	Partners
Adelphi Research, Germany	Not-for-profit research institute	Policy analysis and strategy consulting	Collaborative research and partner in field implementation
Children's Investment Fund Foundation	Foundation	Environment	Funding support
CSIRO	Government organization	Plastic waste management	Funding support
Delhi Municipal Corporations (EDMC, SDMC, North DMC)	State government	Waste management and sanitation	Collaborative support
Department of Biotechnology	Government organization	Environment	Funding support
Department Of Environment, Chandigarh	State government	Environment	Funding support
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	Not-for-profit organization	Resource Efficient and Cleaner Production (RECP)	Funding support
E SREE Foundation	Society	Solid waste management	Funding support
European Union	International organization	Circular economy and resource efficiency	Collaborative research

Partner	Profile	Focus Area	Type of Association
Norwegian Institute for Water Research	International Organization	Marine litter	Funding partner
Punjab State Council for Science and Technology	State government	Environment	Funding partner
United Nations Environment Programme	International funding organization	Waste management	Funding support

Resource-efficient Technologies

Partner	Profile	Focus Area	Type of Association
Austria Recycling Verein zur Förderung von Recycling und Umweltschutz in Österreich (AREC), Austria	Not-for-profit research institute	Research in resource efficiency and recycling	Collaborative research
Adelphi Research, Germany	Not-for-profit research institute	Policy analysis and strategy consulting	Collaborative research
STENUM Asia Sustainable Development Society (STENUM Asia), India	Not-for-profit society	Consulting in resource efficiency for industries	Collaborative research
National Cleaner Production Center (NCPC), Sri Lanka	Non-profit guarantee company	Consultancy and advisory services, information dissemination, training and capacity building, policy advocacy	Collaborative research
Central Power Research Institute	Government organization	Research and developmental studies EMI shielding nanocomposites for power sector	Collaborative research
Centre for fly ash research and management	Not-for-profit organization	Commercialization of fly ash-based flame retardant nanocomposites	Partners
NITK, Surathkal	University	Consultancy	Collaborative research

Partner	Profile	Focus Area	Type of Association
Krishi Rasayan Group, Kolkata	Not-for-profit organization	Research on development and field trials of encapsulation and sustained release of micronutrients	Collaborative research
Deutsche Gesellschaftfür Internationale Zusammenarbeit (GIZ) GmbH	Not-for-profit organization	Resource Efficient and Cleaner Production (RECP)	Collaborative research
Indian Institute of Technology, New Delhi	Academic institute	Consultancy	Collaborative research
National Environmental Engineering Research Institute (NEERI), Nagpur	Research institute	Consultancy	Collaborative research
Delft University of Technology, Netherlands	University	Consultancy	Collaborative research
Wageningen University & Research, Netherlands	University	Consultancy	Collaborative research
Netherlands Institute of Ecology (NIOO-KNAW), Netherlands	Research institute	Consultancy	Collaborative research
The Maldives National University	University	Research	Collaborative research
PARLEY Maldives	Not-for-profit organization	Research	Collaborative research
The Regional Environmental Centre for Central Asia (CAREC)	Not-for-profit organization	Research	Collaborative research
National Association of Small and Medium Business of the Republic of Tajikistan	Not-for-profit organization	Consultancy	Collaborative research
Chamber of Commerce and Industry of Uzbekistan	Not-for-profit organization	Consultancy	Collaborative research
Central Silk Board –CSTRI	Research institute	Research	Collaborative research

Coastal Ecology and Marine Resources Centre, Goa

Partner	Profile	Focus Area	Type of Association
Prof. Dr.-Ing. Thomas Grischek (principal PI/ coordinator) Dr.-Ing. Cornelius Sandhu (project manager)	University of Applied Sciences Dresden Faculty of Civil Engineering Division of Water Sciences Friedrich-List-Platz 1 01069 Dresden, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Hilmar Börnick	Technische Universität Dresden Faculty of Environmental Sciences Institute of Water Chemistry 01062 Dresden, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Martin Wagner	DVGW-Technologiezentrum Wasser Branch Office Dresden Wasserwerkstrasse 2 01326 Dresden, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Prof. Dr.-Ing. Jens Nowak	Fachhochschule Potsdam Fachbereich Bauingenieurwesen Kiepenheuerallee 5 14469 Potsdam, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dipl.-Ing. Heribert Rustige	AKUT Umweltschutz Ingenieure Burkard und Partner mbB Wattstrasse 10 13355 Berlin, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
M. Sc. Philipp Otter	AUTARCON GmbH Franz-Ulrich-Strasse 18 f 34117 Kassel, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Prof. Dr. Rudolf Irmscher	Stadtwerke Heidelberg GmbH Geschäftsführung Kurfürsten-Anlage 42-50 69115 Heidelberg, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Gopal Krishan Scientist-C	National Institute of Hydrology Groundwater Hydrology Division Jal Vigyan Bhavan Roorkee 247 667, India	Water treatment - RBF/Constructed Wetlands	Project partner
Er. Rajiv Saini Executive Engineer	Uttarakhand Jal Sansthan Pant Dweep Haridwar 249 401, India	Water treatment - RBF/Constructed Wetlands	Project partner

Partner	Profile	Focus Area	Type of Association
Dr. Medalson Ronghang Assistant Professor	Department of Civil Engineering Bineswar Brahma Engineering College Bijuleebari, Chandrapara Kokrajhar 783 370, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Virendra Mishra Associate Professor	Institute of Environment and Sustainable Development Banaras Hindu University Varanasi 221 005, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Lakshmi C. Narasimhan Assistant Professor	Department of Geology Anna University Sardar Patel Road, Guindy Chennai 600 025, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Ligy Philip Professor	Department of Civil Engineering Indian Institute of Technology Madras Chennai 600 036, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Priyabrata Banerjee Principal Scientist	Surface Engineering & Tribology Group CSIR – Central Mechanical Engineering Research Institute M. G. Avenue Durgapur 713 209, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Dhiraj Pradhananga	The Small Earth Nepal, 626 Bhakti Thapa Sadak, Naya Baneshwor, Kathmandu, Nepal	Multidisciplinary (NGO)	Project partner
Dr. Thomas Boving	Professor - Environmental Hydrology Director - Water E2S2: Engineering, Economics, Science, and Society Collaborative Contact - Hydrology Certificate Program Dept. Geosciences Dept. Civil and Environmental Engineering University of Rhode Island Woodward Hall Rm. 314 Kingston, RI 02881	Environmental Hydrology	Project partner

Partner	Profile	Focus Area	Type of Association
Dr. Lalat Indu Giri	Electronics and Communication Engineering National Institute of Technology Goa, Farmagudi, Ponda , Goa - 403 401, India	Electronics and Communication Engineering	Project partner
Dr. Anthony Kung	Sustainable Mineral Institutes, The University of Queensland, Australia	Deep Sea Mining	Project partner
Mr. Tom Mills	Two Oceans Strategy (TOS), UK/Delhi	Deep Sea Mining	Project partner

Sustainable Habitat

Centre for Impact, Evaluation and Energy Access, Bangalore (CIEEAB)

a. Governments and Public Sector Undertakings

Partner	Profile	Focus Area	Type of Association
Karnataka Evaluation Authority	State Government Agency	Evaluation and Policy studies	Project partnership
Karnataka Forest Department	State Government Department	Forest protection, management and conservation	Project partnership
Mazagaon Dock Ship Builders Limited, Mumbai	Public Sector Unit	CSR Activities	Project partnership

b. Governments and Public Sector Undertakings

Partner	Profile	Focus Area	Type of Association
National			
Department of Science and Technology	Government of India	Collaboration for research activities on enhancing energy performance and thermal comfort in Indian buildings	Funding support
Department of Bio-Technology	Government of India	Collaboration for research activities involving cold storage using innovative technologies in chiller and envelope	Funding support

Partner	Profile	Focus Area	Type of Association
MECON Limited	Public Sector Undertaking under the Ministry of Steel of the Government of India	Project client on project related to campus development for Indian Navy	Project client
Karnataka Trade Promotion Organization	Government of Karnataka	Client for development of new exhibition centre for KTPO	Project client
Power Grid Corporation of India Limited	Indian state-owned electric utility company headquartered in Gurugram, India	Establishment of campus for power supply and residential facility	Project client
National Academy of Customs Indirect Taxes and Narcotics	Government Training Institute, apex institute of Government of India	Project coordinator for campus development at Bangalore	Project client
NBCC (India) Limited	Government of India Navratna Enterprise	Project coordinator for campus development at Bangalore	Project client
Research and Academia Institution			
Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT	Academia	Partner in research activities involving cold storage using innovative technologies in chiller and envelope	Consortium partner for Research
Royal Haskoning DHV	Independent, international engineering and project management consultancy	Engineering and project management consultancy for new project for Government of India	Consortium partner for research
Domestic and Multinational Corporation			
Astra Microwave products limited	Private organisation into R & D of Microwave and RF products	Project coordinator for campus development at Bangalore	Project client
Integrated Environmental Solutions-Virtual Environment	Software Development Company	Supported in providing free license for participants during training workshop	Knowledge partner
Kanvinde Rai & Chowdhury	Private architectural firm	Project client for IIT Bhilai Campus development for GRIHA LD Certification	Project client
Karekar Associates	Private architectural and engineering firm	Project coordinator for campus development at Bangalore	Project client

Centre for Urban Planning and Governance

Partner	Profile	Focus Area	Type of Association
National			
Ministry of Housing and Urban Affairs, Government of India	Government of India	Empanelled Consulting Firm for Smart City Mission	Advisory
Ministry of Housing and Urban Affairs, Government of India	Government of India	Empanelled Training Agency for AMRUT, Government of India	Advisory
National Capital Region Planning Board (NCRPB)	Government of India	Expert Member of the study group on Environment for National Capital Region Planning Board (NCRPB)	Expert member
Royal Danish Embassy	Embassy	Partner for Urban Living Lab for Smart and Sustainable Cities in India	Knowledge partner
Research and Academia Institution			
Asian Cities Climate Change Resilience Network	International Network	National Partner to the Asian Cities Climate Change Resilience Network (ACCCRN)	Knowledge partner
Climate Centre for Cities, National Institute of Urban Affairs	Think Tank	Climate Alliance Partner, Climate Smart Cities Assessment Frame Work	Alliance partner
Global Resilience Research Network (GRRN), pioneered by Global Resilience Institute(GRI), at North Eastern University, Boston, MA	International Network	Member of Global Resilience Research Network (GRRN), pioneered by Global Resilience Institute(GRI)	Network member
International Urban and Regional Cooperation (IURC) and Global Compact of Mayors, South Asia, funded by European Union	Multilateral organisation	Network Member for International Urban Cooperation (IURC)/Global Compact of Mayors, South Asia	Regional network member

Coastal Ecology and Marine Resources Centre, Goa

Partner	Profile	Focus Area	Type of Association
Prof. Dr.-Ing. Thomas Grischek (principal PI/ coordinator) Dr.-Ing. Cornelius Sandhu (project manager)	University of Applied Sciences Dresden Faculty of Civil Engineering Division of Water Sciences Friedrich-List-Platz 1 01069 Dresden, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Hilmar Börnick	Technische Universität Dresden Faculty of Environmental Sciences Institute of Water Chemistry 01062 Dresden, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Martin Wagner	DVGW-Technologiezentrum Wasser Branch Office Dresden Wasserwerkstrasse 2 01326 Dresden, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Prof. Dr.-Ing. Jens Nowak	Fachhochschule Potsdam Fachbereich Bauingenieurwesen Kiepenheuerallee 5 14469 Potsdam, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dipl.-Ing. Heribert Rustige	AKUT Umweltschutz Ingenieure Burkard und Partner mbB Wattstrasse 10 13355 Berlin, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
M. Sc. Philipp Otter	AUTARCON GmbH Franz-Ulrich-Strasse 18 f 34117 Kassel, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Prof. Dr. Rudolf Irmscher	Stadtwerke Heidelberg GmbH Geschäftsführung Kurfürsten-Anlage 42-50 69115 Heidelberg, Germany	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Gopal Krishan Scientist-C	National Institute of Hydrology Groundwater Hydrology Division Jal Vigyan Bhavan Roorkee 247 667, India	Water treatment - RBF/Constructed Wetlands	Project partner

Partner	Profile	Focus Area	Type of Association
Er. Rajiv Saini Executive Engineer	Uttarakhand Jal Sansthan Pant Dweep Haridwar 249 401, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Medalson Ronghang Assistant Professor	Department of Civil Engineering Bineswar Brahma Engineering College Bijuleebari, Chandrapara Kokrajhar 783 370, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Virendra Mishra Associate Professor	Institute of Environment and Sustainable Development Banaras Hindu University Varanasi 221 005, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Lakshmi C. Narasimhan Assistant Professor	Department of Geology Anna University Sardar Patel Road, Guindy Chennai 600 025, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Ligy Philip Professor	Department of Civil Engineering Indian Institute of Technology Madras Chennai 600 036, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Priyabrata Banerjee Principal Scientist	Surface Engineering & Tribology Group CSIR – Central Mechanical Engineering Research Institute M. G. Avenue Durgapur 713 209, India	Water treatment - RBF/Constructed Wetlands	Project partner
Dr. Dhiraj Pradhananga	The Small Earth Nepal, 626 Bhakti Thapa Sadak, Naya Baneshwor, Kathmandu, Nepal	Multidisciplinary (NGO)	Project partner
Dr. Thomas Boving	Professor - Environmental Hydrology Director - Water E2S2: Engineering, Economics, Science, and Society Collaborative Contact - Hydrology Certificate Program Dept. Geosciences Dept. Civil and Environmental Engineering University of Rhode Island Woodward Hall Rm. 314 Kingston, RI 02881	Environmental Hydrology	Project partner

Partner	Profile	Focus Area	Type of Association
Dr. Lalat Indu Giri	Electronics and Communication Engineering National Institute of Technology Goa, Farmagudi, Ponda , Goa - 403 401, India	Electronics and Communication Engineering	Project partner
Dr. Anthony Kung	Sustainable Mineral Institutes, The University of Queensland, Australia	Deep Sea Mining	Project partner
Mr. Tom Mills	Two Oceans Strategy (TOS), UK/Delhi	Deep Sea Mining	Project partner

Centre for Impact Evaluation & Energy Access

New Partnerships and Networks

- Frederick Erbert Stiftung (FES), Vietnam
- Frontier Technical, UK

Centre for Sustainable Mobility

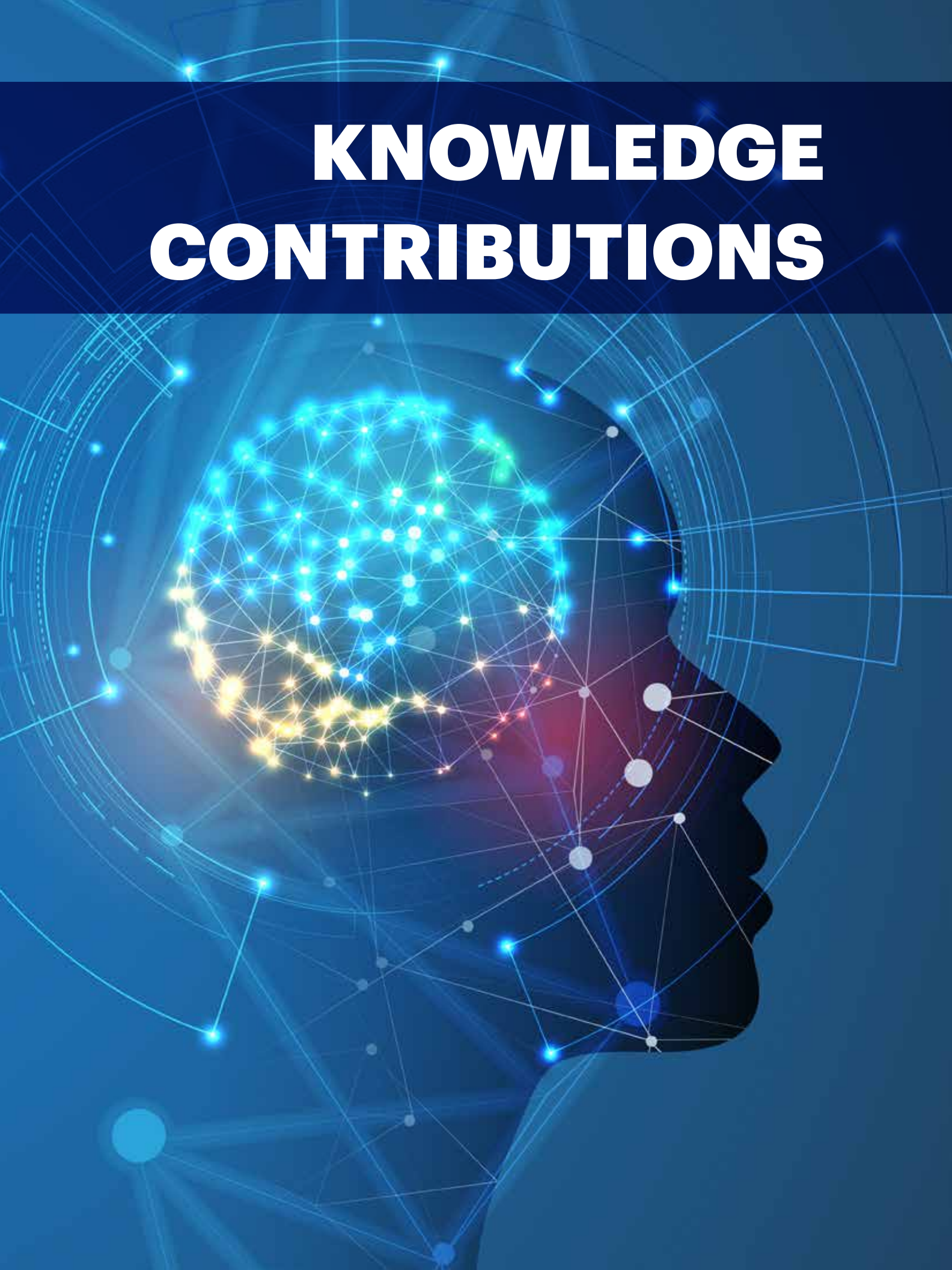
TERI completed the study on Roadmap for Electrification of Urban Freight in India, with the support of Shakti Sustainable Energy Foundation. The centre also undertook advisory assignments on the topic of sustainable mobility with the UK-headquartered Adam Smith International. We also initiated studies in the area or urban freight, railways, and modelling. A study titled Options for Enhancing Low-carbon Transport in India was also initiated in the year, looking at transport modelling for the road, rail and aviation sectors, and the associated emissions and fuel consumption. Another key project is the Strategies to Increase Railway's Share in Freight Transport in India. Both these projects are funded by the Children's Investment Fund Foundation (CIFF). TERI's CSM also initiated the project – Setting up the Urban Freight Cost and Emissions Reduction Guidance Facility (UFCERGF) - Phase 1, with the support of Environmental Defense Fund (EDF). Through the project, TERI successfully initiated discussions and deliberations with the vehicle manufacturing industry as well as city authorities in the city of Bengaluru and Surat. The Centre is also working with the Logistics Division, Ministry of Commerce and Industries and GIZ on developing an India-specific calculator for estimating emissions and freight costs for the logistics sector.

Climate Modelling

International: NORCE Research Center-Norway, BCCR-Norway, MPI-Germany, University of Reading, British Antarctic Survey-UK, Potsdam Institute for Climate Impact Research (PIK)-Germany

National: Ministry of Earth Sciences, Indian Institute of Tropical Meteorology (IITM)-Pune, Indian Meteorological Department (IMD), INCOIS, NRSC-ISRO, Andhra Pradesh State Development Planning Society, KL University, NIT-Warangal , SV University, Andhra University

KNOWLEDGE CONTRIBUTIONS



Representation in National and International Expert Group Committees

Centre for Climate Modelling

- NRSC-ISRO NICES program PMC member
- ICIMOD led Upper Indus Basin Network (UIBN) committee member
- IIASA-ICIMOD let Indus Basin Knowledge Forum (IBKF) - member

Centre for Waste Management

- Pandey S. 2019-till date. EAC-WMT Committee constitute by DST.
- Pandey S. 2019-till date. Solid Waste Management Sectional Committee, CHD 33.
- Pandey S. 2015–till date. Member, Expert Advisory Committee on Waste Management Under Technology Systems Development Programme of DST.
- Pandey S. 2007–till date. Member, Standard setting Committee on Waste constituted by Bureau of Indian Standards (BIS).
- Kapur S. April 2021-till date. Member. Circular Economy Committee constituted by the Ministry of New and Renewable Energy, Government of India on suggestion by Niti Aayog.
- Kapur S. 2019 - till date. Member. UN Habitat's Waste Wise Cities Campaign's Advisory Group.

Environmental and Industrial Biotechnology

- Dr Banwari Lal attended Technical Expert Committee on Environmental Biotechnology of Department of Biotechnology to review proposal and progress of ongoing project, 5 November 2020, organized at CGO Complex, Lodhi Road, New Delhi
- Dr Banwari Lal chaired the Session during the Annual International Conference of The Association of Microbiologists of India and Indian Network for Soil Contamination Research (INSCR), organized jointly by Indian Agricultural Research Institute (IARI), Department of Zoology, University of Delhi, Indian National Science Acadmey (INSA) and The Energy and Resources Institute (TERI), 3–5 February 2021
- Dr Banwari Lal delivered a lecture on Application of Microbial Enhanced Oil Recovery (MEOR) and Paraffin Degrading Bacterial (PDB) technology in oilfield of ONGC during the workshop on Petroleum Biotechnology and Oil Waste Management organized by ONGC, Jorhat, 1 July 2021
- Dr Banwari Lal delivered a lecture on Restoration of Oil Spill/Oil Contaminated Site in Kuwait Oil Company – a case study on the occasion of celebration of World Environment Day, 5 June 2021, organized by Institute of Advanced Study In Science And Technology, Guwahati

Industrial Energy Efficiency Division

- Kumar S, Member, CED-30, Sectional Committee, BIS
- Sethi G. Member, Screening Committee of Petroleum Conservation Research Association (PCRA)
- Sethi G. Member, Energy Management Sectional Committee of Bureau of Indian Standards (BIS)
- Sethi G. Member, Examination Advisory Committee for Energy Managers and Energy Auditors, Bureau of Energy Efficiency, Ministry of Power, Govt. of India
- Sethi G, Member, Refrigeration and Air Conditioning Sectional Committee MED 03
- Sethi G, Member, Policy Advisory Committee (PAC), Bureau of Energy Efficiency, Ministry of Power, Govt. of India

Environment and Waste Management Division

- Taskforce for setting guidelines for petrol pumps, CPCB, MOEFCC (2019-onwards)
- National Expert Group on Air Pollution and Health, NCDC, MOHFW (2018-onwards)
- Centre of Excellence for the NPCCHH (National Programme for Climate Change and Human Health) programme, National Centre for Disease Control, Ministry of Health and Family Welfare

Centre for Integrated Assessment and Modelling

- Lead author for IPCC AR6 Report
- Co-lead of Sustainable Growth Working Group of the U.S.-India Energy Dialogue led by NITI Aayog (formerly Planning Commission of India)
- Member of Board of Climate Strategies (CS) – An international research platform with its secretariat based in the UK

Resource-Efficient Technologies area

- Balakrishnan M. Principal Member, Chemical Division Council, Bureau of Indian Standards
- Balakrishnan M. Women Scientist Scheme (expert), Department of Science and Technology
- Sailaja R R N. Associate Member of the Institute of Engineers, India
- Sailaja R R N. Member (for life) of the Indian Society for Technical Education, India
- Sailaja R R N. Lifetime member of Society of Polymer Science India (SPSI)
- Sailaja R R N. Lifetime member for the Asian Polymer Association (APA)
- Sailaja R R N. Member of American Chemical Society (ACS) up to 2016 up to 2016
- Sailaja R R N. Lifetime member of Indian Society of Systems for Science and Engineering (ISSE)
- Roy P. Lifetime member of Indian Society of Systems for Science and Engineering (ISSE)

Renewable Energy Technology Division

- Dhingra S. Member, Project Appraisal Committee constituted by Ministry of New and Renewable Energy for evaluating and recommending proposals for biomass based power, bagasse based co-generation projects
- Dhingra S. Member, Study Steering Committee constituted by TIFAC for overall steering and guidance of the study on 'Biofuels – Current status and R & D Roadmap'.
- Dhingra S. Member, Project Appraisal Committee, Haryana Renewable Energy Development Agency
- Dhingra S, Member, Core Expert Panel for Solar Energy Research and Development: convergent solar solutions constituted by Department of Science and technology (DST)
- Garud S. Life member, Solar Energy Society of India since 1986, Member of Indian Standards Expert committee on Solar Energy
- Garud S. Member, Central Geological Programming Board, Committee No. XII- Geoscience for Sustainable Development
- Garud S. Member, Member of Committee, Electro Technical Division 42 on Wind Energy, Bureau of Indian Standards
- Kumar A. Member, Interim Administrative Cell of International Solar Alliance (ISA)
- Kumar A. Member, Governing Council of National Institute of Solar Energy (NISE)
- Kumar A. Member, Advisory Committee of ONGC Energy Centre for Appraisal of R&D Programme in Clean Energy

- Kumar A. Member, R&D Project Appraisal Committee of MNRE for solar thermal and solar PV projects
- Kumar A. Member, Expert Panels constituted by ONGC and IOCL for developing solar cooking solutions to suit all variety of Indian type cooking
- Kumar A. Life Member, Solar Energy Society of India
- Pant D. Resource Person, Swachh Bharat Mission by National institute of Urban Affairs, Ministry of Housing and Urban Affairs
- Ram N K. Member of Sub Group of Renewable Sector Energy Data Management, NITI Aayog Energy, Climate Change and Overseas vertical
- Ram N K. Member of Solid Mineral Fuels and Solid Bio Fuels Sectional Committee, Bureau of Indian Standards (Petroleum, Coal and Related Products Department)
- Dhingra S. Member, Project Appraisal Committee constituted by Ministry of New and Renewable Energy for evaluating and recommending proposals for biomass based power, bagasse based co-generation projects
- Dhingra S. Member, Study Steering Committee constituted by TIFAC for overall steering and guidance of the study on 'Biofuels – Current status and R & D Roadmap'.
- Dhingra S. Member, Project Appraisal Committee, Haryana Renewable Energy Development Agency
- Dhingra S, Member, Core Expert Panel for Solar Energy Research and Development: convergent solar solutions constituted by Department of Science and technology (DST)
- Garud S. Life member, Solar Energy Society of India since 1986, Member of Indian Standards Expert committee on Solar Energy
- Garud S. Member, Central Geological Programming Board, Committee No. XII- Geoscience for Sustainable Development
- Garud S. Member, Member of Committee, Electro Technical Division 42 on Wind Energy, Bureau of Indian Standards
- Kumar A. Member, Interim Administrative Cell of International Solar Alliance (ISA)
- Kumar A. Member, Governing Council of National Institute of Solar Energy (NISE)
- Kumar A. Member, Advisory Committee of ONGC Energy Centre for Appraisal of R&D Programme in Clean Energy
- Kumar A. Member, R&D Project Appraisal Committee of MNRE for solar thermal and solar PV projects
- Kumar A. Member, Expert Panels constituted by ONGC and IOCL for developing solar cooking solutions to suit all variety of Indian type cooking
- Kumar A. Life Member, Solar Energy Society of India
- Pant D. Resource Person, Swachh Bharat Mission by National institute of Urban Affairs, Ministry of Housing and Urban Affairs
- Ram N K. Member of Sub Group of Renewable Sector Energy Data Management, NITI Aayog Energy, Climate Change and Overseas vertical
- Ram N K. Member of Solid Mineral Fuels and Solid Bio Fuels Sectional Committee, Bureau of Indian Standards (Petroleum, Coal and Related Products Department)

Water Resources Division

Invited Speakers

- 2021: OTCB Program on Wastewater Reuse, held on March 10, 2021 organized by TERI and under the agesis of National Mission for Clean Ganga (NMCG), Ministry of Jal Shakti, GoI; Title: 'Advanced Treatment Technology to enhance treated wastewater reuse'
- 2021: National Science Day was organized by the Department of Pure and Applied Chemistry, University of Kota, Kota, Rajasthan on February 28, 2021. Title: 'TERI Advanced Oxidation Technology to achieve ZLD and enhance treated water reuse efficiency'

- 2020: Industrial Water Forum, Everything About Water Expo & Virtual Conference, 5th Dec. 2020; Organized by Everything About Water; Title: 'Integrating Advanced Oxidation to achieve ZLD and enhance treated water reuse efficiency'
- 2020: National Webinar jointly organized by Save the Environment Society and SRM University on September 26, 2020 from 4.30 pm – 6 pm. Title: 'Adequate treatment of wastewater: Necessity to meet SDG-6 and address issues of climate change'
- 2020: Virtual Conference on Innovative and Smart Technologies to manage Difficult Water, held on August 21, 2020; Organized by Everything About Water; Title: 'Advanced Oxidation Technology for treatment of difficult wastewater from industries'
- 2020: Webinar on Mainstreaming Demand Side Water Management in Indian Cities, held on July 28, 2020; it was organized by TERI and IWA-India Chapter

S K Sarkar

- Sarkar S K. 2019 – till date. Member, International Water Association
- Sarkar S K. 2021. Member, Expect Committee on Jal Jeevan Mission - Professor Chair. Department of Drinking Water and Sanitation, Ministry of Jal Shakti, GoI

Sonia Grover

- Member of Public Drinking Water Supply Services Sectional Committee of BIS

Representation in National and International Journals

Centre for Waste Management

- Pandey S. Member. Editorial Board, ICE: Waste and Resource Management.
- Pandey S. Member. Review Panel, Waste Management, Elsevier.

Environment and Waste Management Division

- Gupta V. Reviewer for BMC Public Health and Public Health Nutrition (Cambridge)
- Lal K. Reviewer for Journal of Hazardous Materials, Bioresource Technology, Journal of Environmental Management, Process Safety and Environmental Protection, Environmental Science and Pollution Research, Environmental Monitoring and Assessment

Renewable Energy Technology Division

- Darimani, H S and Pant D C. 2019. Biogas production from co-digestion of grass with food waste. Journal of Agricultural Chemistry and Environment (9) 1: 27–36
- Kotilainen, T, Aphalo P J, Brelsford C C, Böök H, Devraj S, Heikkilä A, Hernández R, Kylling A, A. V. Lindfors, and Robson T M. 2020. Patterns in the spectral composition of sunlight and biologically meaningful spectral photon ratios as affected by atmospheric factors. Agricultural and Forest Meteorology 291: 108041
- Ram N K, Singh N R, Raman, Kumar A, and Kaushal P. 2020. Experimental study on performance analysis of an internal combustion engine operated on hydrogen-enriched producer gas from the air steam gasification. Energy 205: 118029
- Performance assessment of institutional photovoltaic based energy system for operating as a micro-grid- Sustainable Energy Technologies and Assessments (ISSN 2213-1388) (Elsevier), Volume 37, pp. 1-13, article no. 100563, 2020. DOI: 10.1016/j.seta.2019.100563 (as per the Norwegian Register for Scientific Journals, Series and Publishers – Level 1)

Conference Papers and Magazines

- Performance Analysis of Institutional Hybrid Energy System for Electrical Energy Tariffs- DES Transactions, 3rd International Conference on Energy, Ecology and Environment (ICEEE). 2019. Pp.1-4. DOI:10.12783/dteees/iceee2019/31812 (as per the Norwegian Register for Scientific Journals, Series and Publishers – Level 1)
- Operational Analysis of Institutional Energy System for Developing a Micro-grid- IOP Conference Series. 2019. Materials Science and Engineering 605: 1–8, no. 012008. DOI:10.1088/1757-899X/605/1/012008 (as per the Norwegian Register for Scientific Journals, Series and Publishers – Level 1)

Policy Briefs

- Integration Study for Stabilized Grid Operation in Andaman and Nicobar Islands
- Decentralized Solar PV Near the Rural User End so as to Minimize Distribution Losses

Water Resources Division

Popular Articles in Refereed Newsletter & Magazines

- Nupur Bahadur*. 2020. Innovation in textile wastewater treatment: Integrating advanced oxidation to achieve ZLD and enhance water reuse efficiency. Everything About Water Magazine, Indepth, pp. 14–19, Issue August 2020. Invited article in the Special Issue on Water and Wastewater Projects
- Nupur Bahadur*. 2020. COVID-19 and water industry: Challenges and opportunities in the new normal. Everything About Water Magazine, Indepth, pp. 80–81, Issue June 2020. Invited article in the 20th Anniversary Special Issue on 2021: Road map for the Water Industry in post Covid Era.

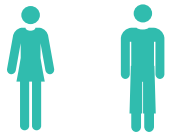
HUMAN CAPITAL AND INFRASTRUCTURE FACILITIES

Human Capital

At TERI, we consider all TERI-tes to be of utmost value and the key resource for success of the Institution. The synergy brought about by our human resources is a result of the freedom and flexibility that the Institute provides to its research professionals. TERI fosters a culture, which respects diversity in age, gender, and education, and realizes that each individual is unique and that each one brings a fresh perspective and their own skill sets to the table, which in turn helps TERI build a collaborative culture.

Our strength lies in the diversity of our people and we respect the fact that their different views and ideas help us stimulate our minds intellectually. TERI encourages its researchers to work on cross-functional and cross-divisional basis because it realizes that the interdisciplinary approach, the exchange of best work practices, and the concerted effort in thought and action leads to the desired outcome, which in turn enhances sponsor and client satisfaction.

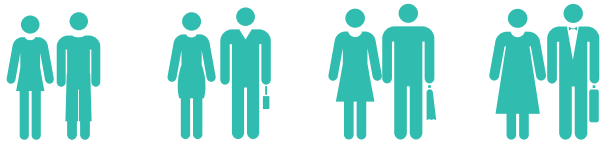
GENDER



32% Female

68% Male

AGE DISTRIBUTION



21% AGE 22-30 YEARS

33% AGE 31-40 YEARS

24% AGE 41-50 YEARS

22% AGE 51 AND ABOVE

QUALIFICATION

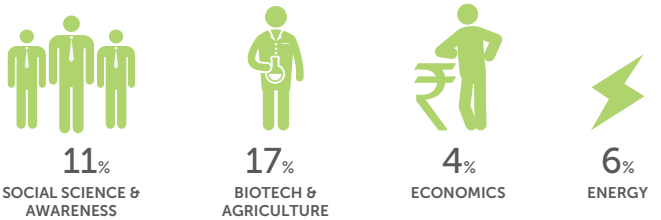
25% GRADUATE

47% POSTGRADUATE

12% PhD

OTHERS 15%

SPECIALIZATION

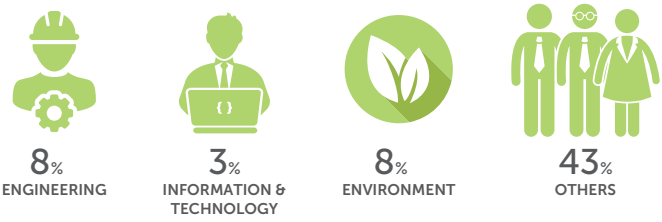


11% SOCIAL SCIENCE & AWARENESS

17% BIOTECH & AGRICULTURE

4% ECONOMICS

6% ENERGY



8% ENGINEERING

3% INFORMATION & TECHNOLOGY

8% ENVIRONMENT

43% OTHERS

Infrastructure Facilities

An Institute of the calibre and spread of TERI requires the presence of state-of-the-art, modern, and vital infrastructure facilities, which are instrumental in facilitating research and development on a large scale. TERI has developed a host of infrastructure facilities, across the length and breadth of the country, which continued to propel the Institute towards greater success and achievement in the year 2019/20.

CMCC Germplasm Bank

The Centre for Mycorrhizal Culture Collection is stepping into its second-generation level with an objective of supplying well-characterized mycorrhizal cultures to researchers and industry. The Bank has three temperature-controlled greenhouses at Gwal Pahari which house 2,800 isolates of Arbuscular Mycorrhizal Fungi (AMF) and 285 cultures of Ectomycorrhizal Fungi (EMF) collected from different soil types from India and around the globe. Our molecular biology and biochemical labs are equipped with avant-garde equipment which aid in characterizing each isolate and help in generating an information database which is available on the CMCC website (http://mycorrhizae.org.in/CMCC).

Solar Lighting Laboratory

The Solar Lighting Laboratory is involved in design customization, lab- and field-based performance assessment, and training on distributed generation-based systems for various applications. These include solar lighting systems, solar multi-utility charging stations for charging lanterns, mobile phones, and e-bikes.

Film and Television Unit

The Film and Television Unit has been producing some award-winning documentaries and owns the basic infrastructure to execute a film or television shoot end-to-end. It has been constantly producing high-quality DV output meant for television broadcast and theatre screenings.

Mass Production Technology

In vitro mass production technology produces viable, healthy, genetically pure, and high-quality mycorrhizal propagules without any pathogenic contamination in a sterile environment.

DNA Fingerprinting and Molecular Breeding Lab

The DNA fingerprinting facility is a state-of-the art laboratory for varietal identification, mapping of genetic diversity, and marker assisted breeding. The facility harbours a LICOR 4300 DNA analyser and other molecular biology-related equipment. The facility is being used for providing DNA fingerprinting services to state horticulture departments and genotyping services to plant breeders for their breeding programmes.

Plant Genetic Transformation and Functional Genomics Laboratory

This laboratory has all the basic equipment such as Real Time–PCR, gel electrophoresis systems, and plant culture room. It works on developing genetically modified plants for better quality and productivity under changing environments.

Micropropagation Technology Park

Complete with infrastructural facilities ranging from modern laboratories and greenhouses to nurseries that are required for mass production of tissue-cultured plants, the facility has an annual production capacity of over two million plants.

Herbal Garden at Supi

The herbal garden is home to more than 60 different varieties of fresh and dry exotic vegetables, fruits, and herbs such as Broccoli, Pockchoy, Kiwi, Plum, Parsley, Rosemary, Thyme, Oregano, and Peppermint.

TERI–Deakin Nanobiotechnology Research Centre

The Centre bridges the gap between industry and academia through research and collaboration of leading international experts to generate effective solutions for a sustainable future. This Centre is working towards a greener and more advanced use of nanotechnology for resolving challenges in agriculture, biofuel production, and biomedical issues through nanoparticles, nano-biosensors, nanocarrier-formulations, nanodelivery of agrochemicals, and seed coating formulations (see http://tdnbc.teriin.org).

Fermentation Technology and Research Centre

The Centre is a state-of-the-art fermentation facility with a pilot-scale platform to carry out studies. It has a series of fermentors of working volume ranging from 3.5 litres to 13,000 litres. Apart from mass-scale production of indigenously developed oil degrading bacterial cultures, the facility has capacity to carry out research on anaerobic fermentation processes in pilot and large industrial scale. The facility also has the necessary analytical infrastructure for quality control and analysis of various fermentation products.

Supercomputer to Enhance Climate Modelling Capabilities

TERI has acquired supercomputing facility to boost its activities on climate modelling. The supercomputer consists of 512 cores that can draw a peak performance of 5.5 T Flops. Total RAM is 1000 GB with 32TB of storage space and about 24TB of backup storage. Models posted on the HPC system are CESM, CCSM, NorESM, WRF, and PRECIS.

TERI Water Laboratory

Recognized and certified under the Environment (Protection) Act of 1986 by the Ministry of Environment and Forest (now, Ministry of Environment, Forest and Climate Change), Government of India, the laboratory is equipped with field sampling, monitoring equipment, and analytical instruments. The laboratory provides multi-disciplinary water quality and quantity monitoring, testing, and related services.

Microbial Biotechnology Laboratory

The laboratory is an experimentation facility for the exploration of microbial diversity to provide biotechnological solutions in the field of environmental restoration and biofuels. The facility has state-of-the-art molecular biology set up with automated facility and real-time PCR systems. Infrastructure for both aerobic and anaerobic microbiology facility is available. The laboratory is supported by analytical facility that is equipped with necessary GC (with TCD and FID), GCMS, HPLC (with diode array and RI detector) systems with other requisite instrumentations.

TRISHA

TERI's Himalayan Centre at Latey Bunga exemplifies 'ideal' green environment. It is a symbol of optimum use of natural resources such as solar and other forms of renewable energy.

Solar Power Pack

It is an integrated solar multi-utility charging station for charging lanterns, mobile phones, and e-bikes.

TERI's Research Facility in Bengaluru

The TERI Southern Regional Centre building is a judicious blend of technology and tradition that promotes energy efficiency and sustainable development.

Library and Information Centre

The TERI library houses a wide array of resources on energy, environment, and sustainable development—from books, journals, and papers to the world's leading academic databases. A book digitization scanner — "Bookeye 4" — is installed in the Library and Information Centre.

TERI Gram

TERI Gram is located on the outskirts of Delhi. It is a sustainable habitat consisting of residential as well as conference facilities, powered by a specially designed renewable energy system to meet its energy requirements.

Test Bed Facility, Gwal Pahari

TERI and Somfy India Private Limited have came together to set up a Test Bed Facility at Gwal Pahari in the year 2015/16. The main objective of setting up this facility is to derive the benefits of Somfy Roller Blinds in test building.

APPENDICES

Contribution to Journals and Proceedings

Advanced Biofuels Program

- Kannan D C, Magar C S. Microalgal Biofuels – Challenges, Status and Scope. In: *Advanced biofuels technologies: present status, challenges and future prospects*. Eds.: Tuli DK, Kasture S, and Kuila A. (eds). Elsevier: in press
- Karthikeya K, Sharma S K and Subudhi S. 2020. Exploring optimal strategies for aquatic macrophyte pre-treatment: Sustainable feedstock for biohydrogen production'. *Biomass and Bioenergy Journal* 140: 105678. Elsevier Publication
- Miranda A F, Kumar N R, Spangenberg G, and Subudhi S, Lal B, Mouradov A. 2020. Aquatic plants, Landoltia punctata, and *Azolla filiculoides* as bio-converters of wastewater to biofuel. *Plants*, 9(4): 437. DOI: https://doi.org/10.3390/plants9040437
- Patel S and Kannan D C. 2021. A method of wet algal lipid recovery for biofuel production. *Algal Research* **55**: 102237. Elsevier
- Ramkumar N, Anupama P D, Nayak T, and Subudhi S. 2021. Scale up of biohydrogen production by a pure strain; *Clostridium butyricum* TM-9A at regulated pH under decreased partial pressure. *Renewable Energy*. Elsevier, Science Direct
- Ramkumar N, Mazumdar D, Mishra P, Subudhi S. 2021. Mixotrophic cultivation of *Chlamydomonas* for value added biomass production: Valorisation of organic acid rich spent effluent. *Current Research in Green and Sustainable Chemistry*. Elsevier, Science Direct **4**: 1001-26, companion to Current Opinion in Green and Sustainable Chemistry
- Sarma M K, Saha K, Choudhury R, Pabbi S, Madamwar D, Subudhi S. 2021. Development of a microwave assisted solvent extraction process for the extraction of high value carotenoids from Chlorella biomass. Biofuels, Bioproducts and Biorefining. John Wiley and Sons, Limited. DOI: https://doi.org/10.1002/bbb.2298. (Impact Factor: 4.5).
- Sarma, M K, Ramkumar N and Subudhi S. 2021. Biohydrogen production from aquatic plant and algae biomass by *Enterobacter cloacae* strain DT-1. *Chemical Engineering Technology*. Wiley-VCH GmbH publication. DOI: https://doi.org/10.1002/ceat.202000547
- Saha K, Mudgil D, Subudhi S., Srivastava A, and Adlakha N. 2021. Biological Production of Diols–Current Perspective. In: *Biomass for Bioenergy and Biomaterials*. CRC Press, Taylor and Francis, 1st edition, pp. 327-347, eBook: 9781003158486
- Verma D, Ramkumar N, and Subudhi S. 2020. Isolation and characterization of a novel photoheterotrophic strain '*Rubrivivax benzoatilyticus* TERI-CHL1': Photo fermentative hydrogen production from spent effluent''. *International journal of Hydrogen Energy*
- Verma D and Subudhi S. 2021. *Lactobacillus* sp. strain TERI-D3, as microbial cell factory for fermentative production of lactic acid: potential candidate to produce lactic acid from algae biomass. *Current Research in Green and Sustainable Chemistry*. Elsevier, Science Direct, companion to Current Opinion in Green and Sustainable Chemistry
- Salo L, Hyvärinen A, Jalava P, Teinilä K, Hooda R K, Datta A, Saarikoski S, Lintusaari H, Lepistö T, Martikainen S, Rostedt A, Sharma V P, Rahman M H, Subudhi S, Asmi E, Niemi J V, Lihavainen H, Lal B, Keskinen J, Kuuluvainen H, Timonen H, and Rönkkö T. 2021. The characteristics and size of lung-depositing particles vary significantly between high and low pollution traffic environments, 255: 118421. Science Direct

- Verma H., Phian S, Lakra P, Kaur J, Subudhi S, Lal R, Rawat C D. 2020. Human gut microbiota and mental health: advancements and challenges in microbe-based therapeutic interventions. *Indian Journal of Microbiology*, 60: 405–419. Springer

- Saha K, Mudgil D, Subudhi S, Srivastava A and Adlakha N. 2021. Biological production of diols-current perspective. In: Biomass for Bioenergy and Biomaterials. Taylor & Francis Group, LLC, USA

Biotechnology Area, TERI NE, Guwahati

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- Mainstreaming Urban Climate Action: Webinar Module I on Impacts of Climate Change on Cities, 10 September 2020
- Mainstreaming Urban Climate Action: Webinar Module II: Frameworks for Climate Change Adaptation and Mitigation, 17 September 2020
- Mainstreaming Urban Climate Action: Webinar Module III: Global and Indian Best Practices of Climate Action in Cities, 24 September 2020
- Mainstreaming Urban Climate Action: Webinar Module IV: Mainstreaming City-Level Climate Action, 1 October 2020
- WSDS 2021 Thematic Track: Private Sector's Role in Achieving Climate Resilience: Leading examples, 10 February 2021
- WSDS 2021 Thematic Track: Planning Cities for a Sustainable Future, 12 February 2021
- Impacts of COVID-19 on the Auto-rickshaw Community, 11 May 2020
- Future of Electric Auto-rickshaws, 18 May 2020
- Namma Auto Project, 30 May 2020
- Webinar on Impact of COVID-19 on Urban Mobility, 8 June 2020
- Webinar on Air Pollution and Transport, 1 October 2020
- Digital Library on Green Mobility (DLGM) in coordination with GIZ, 2 November 2020
- Workshop in Collaboration with the Surat Municipal Corporation (SMC), to facilitate electric vehicle pilots in municipal solid waste management in Surat, 25 November 2020
- Future of E-Mobility in India Strategies to Drive Demand' (in partnership with the British High Commission), 1 December 2020
- Launch of Report and panel Discussion on Roadmap for Electrification of Urban Freight in India, 18 December 2020
- WSDS Thematic Track: Is a Decarbonized Transport Sector Possible in India by 2050?, 11 February 2021
- Indo-German Workshop on Innovative Charging Technologies for Heavy Duty Vehicles – Technics, Strategy and Implementation; (Environmental Technologies; Energy, Innovation in Transport), 18 February 2021
- Roundtable Discussion on Mitigating Air Pollution in Pune: Urban Transport and Vehicle Fitness, 15 March 2021
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Centre for Rural Action

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Coastal Ecology and Marine Resources Centre, Goa

- Ganeshan, S and F. D'Souza. 2020. G20's Role in Marine Biodiversity—Policy Options and Best Practices for Enhancing Marine Protected Areas (MPA). Task Force 2 Climate Change and Environment,T20 Saudi Arabia
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- Sreekanth, G.B., T.S. Mayekar, A. Giriyan, F. D'souza S. Dourado, B. Ingole, and E. B. Chakurkar. 2021. Inventory of fishery resources using participatory research approach in Mandovi Estuary in Central western coast of India. *Journal of Environmental Biology* 42(5):1257-63

Centre for Impact, Evaluation and Energy Access, Bangalore (CIEEAB)

- 2 Day – Webinar on Climate Responsive Design Strategies for Sustainable Buildings by TERI, | 29 and 30 July 2020
- 4-Day - Webinar on "Natural Ventilation in Built Environment" under Training and Knowledge

Workshop Series on Sustainable Buildings

- Mr. Kiriti Sahoo made a Guest lecture and presentation to NIT on the Concepts of Green Buildings, 15 March 2021
- Karnataka Evaluation Authority
- Mazagon Dock Ship Builders Limited, Mumbai

Environmental and Industrial Biotechnology

- Basera P, Lavania M, and Lal B. 2020. Frequently used laboratory pathogenic bacteria and their effect on human health. *International Journal of Community Medicine and Public Health*. DOI: http://dx.doi.org/10.18203/2394-6040.ijcmph2020xxxx (Impact Factor–0.8)
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- Sharma N, Lavania D, Kukreti V, and Lal B. 2020. Instigation of indigenous thermophilic bacterial consortia for enhanced oil recovery from high temperature oil reservoirs. *PLOS ONE* **1**: 16 (Impact Factor–2.766)
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Environment and Waste Management Division

- Ghosh D, Sehgal M. 2021. Finding the sync between health and climate change. *EH News Bureau*, March 24, 2021. Details available at: https://www.expresshealthcare.in/news/finding-the-sync-between-health-and-climate-change/427897/
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- Gupta V, Uttreja M, Sehgal M. 2021. Developing vulnerability index to assess climate-related health impacts in Andhra Pradesh. In: Gupta AK, Barwal A, Madan A and Sood A (eds.). 2021. Health Adaptation and Resilience to Climate Change and Related Disasters – A Compendium of Case Studies. National Institute of Disaster Management, pp. 283

- Lal K. 2021. Why kidney disease is increasing in Andhra Pradesh, study reveals. *Down to Earth* (Hindi), September 28, 2021. Details available at: https://www.downtoearth.org.in/hindistory/health/non-communicable-disease/why-kidney-disease-is-increasing-in-andhra-pradesh-study-reveals-79413
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- Sehgal M. 2020. Learning from tragedy. *Daily Pioneer,* May 2020. Details available at: https://www.dailypioneer.com/2020/columnists/learning-from-tragedy.html
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Industrial Energy Efficiency Division

- Hall, W., Spencer, T., and Kumar, S. 2020. Green Steel for a Green Economy. *Energy Future* **(8)** 3
- Hall, W, Spencer, T, Renjith, G, and Dayal, S. 2020. The potential role of hydrogen in India: a pathway for scaling-up low carbon hydrogen across the economy. New Delhi: The Energy and Resources Institute (TERI)
- Hall, W. 2020. Impact of Coronavirus on the Indian energy sector. *TerraGreen*. New Delhi: The Energy and Resources Institute (TERI)
- Hall, W. 2020. Policy brief: make hydrogen in India: driving India towards the clean energy technology frontier. New Delhi: The Energy and Resources Institute (TERI)
- Kumar, S and Sharma, P. 2021. Adoption of cleaner production innovations by micro, small and medium enterprises: lessons from the clay-fired brick

manufacturing sector in India. *International Journal of Management and Enterprise Development* **20** (1): 49–74. Inderscience Enterprises Limited

- Mangotra, K., Ahuja, R., Spencer, T., and Hall, W. 2020. Guiding framework for India's long-term strategy (LTS). New Delhi: The Energy and Resources Institute (TERI)
- Rissmana, J., Batailleb, C , Masanet E., Aden N, Morrow W R III, Zhou N, Elliott N, Dell R, Heeren N, Huckestein B, Cresko J, Miller S A, Roy J, Fennell P, Cremmino B, Blank T K, Hone D, Williams E D, Can S de la R du, Sisson B, Williams M, Katzenberger J, Burtraw D, Sethi G, Ping H, Danielson D, Lu H, Lorber T, Dinkela J, Helsethb J. 2020. Technologies and policies to decarbonize global industry: Review and assessment of mitigation drivers through 2070', *Applied Energy* **266**: 114848
- Sethi, G and Hall, W. 2020. Hydrogen-based steelmaking in India. SIMA Quarterly Newsletter, July Issue
- Rao, G R N. 2020. Let fresh air flow in: solar passive architecture can make buildings resilient to Covid 19. New Delhi: The Energy and Resources Institute (TERI)
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Invited speaker in workshops/seminars (selected)

- Mathur, R. 2021. Virtual Launch of the TERI-Shell Report India: Developing a Net-zero Emissions Economy, March 23
- Mathur, R. 2021. Engage – 3rd project meeting-capacity Building workshop, March 2
- Mathur, R. 2021. Speaker, IEA's India Energy Outlook – Exploring Energy and Emission Pathways to 2040, February 10
- Mathur, R. 2021. World Wind Energy Conference, January 27
- Mathur, R. 2020. General participation, Launch of the GridPath power sector modelling platform and panel discussion on the importance of modelling for power sector planning, November 23
- Mathur, R. 2020. General participation, Workshop on India's green ammonia opportunity, November 9
- Mathur, R. 2020. General participation, Webinar on the Potential Role of Hydrogen in India, 21 September
- Mathur, R. 2020. IPCC Third Lead Author Meeting, April 15–19 (joined online)
- Mathur, R. 2020. Shell project meeting, Netherlands, February 25
- Mathur, R. 2020. Expert Committee of TIASN, February 5–6
- Mahendra Waghray, K. 2021. BEIS-EESIT – First India community of practice workshop in Jan 2021
- Chaudhury, S. 2020, "Information and market based instrument to promote energy efficiency in residential sector" in webinar on "Behavioural Dimensions in Indian Power Sector", September 24, 2020

Nutrition Security

Published Articles

- COVID-19 and Nutrition: How the Pandemic Induced a Much Awaited Behavioral Change

Important link:

- COVID-19 and Nutrition: How the Pandemic Induced a Much Awaited Behavioral Change: https://www.teriin.org/article/covid-19-and-nutrition-how-pandemic-induced-much-awaited-behavioural-change

Important links:

- Online Wetlands Quiz: https://www.teriin.org/event/teri-nmeps-online-wetlands-quiz

Resource-Efficient Technologies (RET AREA)

- Srivastava N, Munnolimath A, Tewari P, Batra V, Balakrishnan M. 2021. Illustrating the significance of eco-inclusive enterprises in the buildings and construction sector. Annual GRIHA Magazine, *Shashwat 2021*
- Tewari P K, Batra V S, Singh R K, Balakrishnan M. 2021. Material Savings through Resource Efficient Manufacturing in Metal MSMEs Supplying to Automotive Sector. *Technical Reference Bulletin (TRB) Symposium on International Automotive Technology 2021 (SIAT 2021)*
- Doerpinghaus J, Hack J, Munnolimath A, Balakrishnan M, Batra V. 2021. Prevention of Marine Litter in India Policy Brief 2021
- Singh N, Gautam Y, Balakrishnan M, Basu S. Separation of lignin from pulp and paper mill wastewater using forward osmosis process. *Materials Today Proceedings*.
- Pervez N, Balakrishnan M, Hasan S W, Choo K-H, Zhao Y, Cai Y, Zarra T, Belgiorno V, Naddeo V. 2020. A critical review on nanomaterials membrane bioreactor (NMs-MBR) for wastewater treatment. *npj Clean Water* **3**, 43 (2020)
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- Sharma S S, Batra VS. 2020. Production of hydrogen and carbon nanotubes via catalytic thermo chemical conversion of plastic waste. *Journal of Chemical Technology & Biotechnology* 95(1): 11–19
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- Pramod T, Sampathkumaran P, Seetharamu S, Khan A M, Bhattacharya R R N S. 2020. Influence of betel nut concentration in the matrix of polycarbonate and abs on the mechanical characteristics. International Conference on Materials for Environment, Sustainable Society and Global Empowerment, Visvesvaraya Technological University, Muddenahalli, 2020
- Madhu B M, Balu R, Bhattacharya R.R.N. S. Water ageing effects on graphene nanoplatelets and multiwalled carbon nanotube reinforced epoxy glass fiber nanocomposites. International Conference on Advanced Materials and Technology (ICMAT-20) January 16–18, 2020
- Swathi M, Roy P, Deepthi M V, Sailaja R R N. 2021. Removal of toxic dyes from industrial waste water using chitosan grafted itaconic acid nanocomposites. *Advanced Materials Letters* 12: 1–10
- Pramod T, Sampathkumaran P, Puneeth N, Sailaja R R N, Seetharamu S, A Sathyanarayana Swamy, Kishore. 2021. Tribological response of polycarbonate and acrylonitrile butadiene styrene blends containing fixed amounts of kevlar fibre and molybdenum disulphide with varying quantities of betel nut powder, polymers and polymer composites. pp. 1–11. Details available at doi: https://dx.doi.org/10.1177/0967391121998823
- Balu R, Sailaja R R N, Madhu B M. 2021. Effect of hybrid fillers on GFRP epoxy composites with water immersion and thermal conditioning. *Macromolecular Symposia*. Details available at doi: https://dx.doi.org/10.1002/masy.202000090
- Simran F, Karumbaiah P, Roy P, Sailaja R R N. 2021. Removal of crystal violet dye using grafted guar gum along with nanoclay and MWCNT. (Accepted in Advanced Materials Letters)
- Rashmi, Sailaja R R N and Madhu B M. 2021. Analysis of epoxy nanocomposites characteristics by impedance spectroscopy. *Macromolecular Symposia* 398

Sustainable Agriculture

- Arya S S, Rookes J, Cahill D, and Lenka S K 2020. Next-generation metabolic engineering
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potential for agricultural applications. *Journal of Applied Microbiology* **129** (2): 199–211. DOI: https://doi.org/10.1111/jam.14609

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- Abraham, Mary and Dkhar, Nathaniel B. "Building Pandemic Resilient Cities in India", Terra Green, Cover story, pp 22-28, July 2020 http://terragreen.teriin.org/terragreen/TGJul20/TG_CoverStory/mobile/index.html

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Significant Achievements

- Having outstanding deliverables from DST Water Mission (WTI) Project, Ministry of Science & Technology, Government of India issued a Press Release on August 25, 2021, endorsing the successful development of TADOX® Technology. Also, DST published the findings of the project on its website: https://pib.gov.in/PressReleasePage.aspx?PRID=1748888 https://dst.gov.in/new-advanced-oxidation-technology-can-enhance-waste-water-reuse-lower-cost.

Research Papers in Refereed International Journals: Published

- Kumari P, Bahadur N*, Cretin M, Austin O'Dell L, Kong L, Merenda A, Dumee L*. 2021. Electrocatalytic membrane reactors for degradation of organic pollutants – A review. Reaction Chemistry & Engineering. Details available at: https://doi.org/10.1039/D1RE00091H. [I.F. 4.239]

- Kumari P, Bahadur N, O' Dell L, Kong L, Sadek A, Merenda A, Dumee L F*. 2021. Nanoscale 2D semi-conductors – impact of structural properties on light propagation depth and photocatalytic performance. Separation and Purification Technology 258(2021): 118011.[I.F. 7.312, Cited by 5]

- Bahadur N*, Das P, Bhargava N. 2020. Improving energy efficiency and economic feasibility of photocatalytic treatment of synthetic and real textile wastewater using bagasse fly ash modified Titania. Chemical Engineering Journal Advances 2(2020): 100012.[CEJ I.F. 13.273, Cited by 2]

- Invited article in the newly open access mirror journal of Chemical Engineering Journal with I.F. 13.273 Special Issue: Advanced Oxidation Technologies for Water and Wastewater Treatment: Advances, Gaps and Challenges

- Das P, Bahadur N*, Dhawan V. 2020. Surfactant modified titania for Cadmium removal and treatment of textile wastewater together being environmentally safe towards seed germination and plant growth of Vigna Radiata. Environmental Science and Pollution Research 27(2020): 7795–7811[I.F. 4.223, Cited by 8]

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Awards

- 2020: STE Meritorious Award for Excellence in Research & Academics: Conferred by the Save The Environment (STE)-Society for Research, Awareness and Social Development, Kolkata, West Bengal on December 20, 2020 in the 2nd Annual Meet of STE and International Conference on Environment, Water, Agriculture, Sustainability and Health (EWASH-2020): Expanding Our Vision Post COVID-19, held on virtual platform.

Students under Supervision /Advised:

- Paromita Das, Ph.D. (Bioresources & Biotechnology), TERI School of Advanced Studies, Delhi; Title: 'Eco safety studies of bare and modified Titania

Nanomaterials used as Adsorbents and Photocatalysts for efficient Wastewater Treatment'; Status: Thesis Submitted in May 2021, Viva –Voce Examination Completed and PhD Degree Awarded on December 8, 2021.

- Priyanka Kumari, Ph.D. (Material Sciences), Deakin University, under TERI-Deakin Nano Biotechnology joint Ph.D. Programme; Title: 'Development of Photo-electro Catalytic Membranes for treatment of fertilizers and pesticides found in agricultural runoffs'. Status: Thesis submitted on December 10, 2021
- Nipun Bhargava, Ph.D. (Water Science & Governance), Teri School of Advanced Studies, Delhi; Title: 'Design & Development of Photocatalytic Reactor for treatment of wastewater from textile & dyeing industry'; Status: Thesis to be submitted in June 2022.

Professional Recognitions & Honours

- 2020: National Mission for Clean Ganga (NMCG) and TERI signs an MoU to undertake TADOX Technology for possible intervention in Ganga cleaning programme.
- 2020: Member, Programme Committee, Water Convention 2020-22, Singapore International Water Week.

Session Chair

- International Conference on Environment, Water, Agriculture, Sustainability and Health (EWASH-2020): Expanding Our Vision Post COVID-19; Technical Session: 'Water management for agricultural and industrial applications', held on December 20, 2020 and organized by Save the Environment (STE), a society for Research, Awareness and Social Development, Kolkata.

FINANCIAL SUMMARY

FINANCIAL SUMMARY 2020/21

INFLOWS (₹ in Lakh)

81.70%
₹11512.35
INCOME FROM PROJECTS

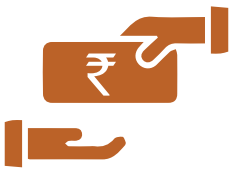
1.29%
₹181.12
INCOME FROM INVESTMENTS

0.66%
₹93.47
SALE OF PUBLICATIONS

16.35%
₹2303.85
INCOME FROM OTHERS

TOTAL **100%** (₹ **14090.79**)

OUTFLOWS (₹ in Lakh)



52.42%
₹7128.07
SALARIES

4.76%
₹647.77
EQUIPMENT

32.04%
₹4356.26
RESEARCH MATERIAL, TRAVEL

6.48%
₹881.34
RENTAL,UTILITIES, INFRASTRUCTURE AND MAINTENANCE

4.30%
₹585.03
ADMINISTRATIVE EXPENSES

TOTAL **100%** (₹ **13589.47**)

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