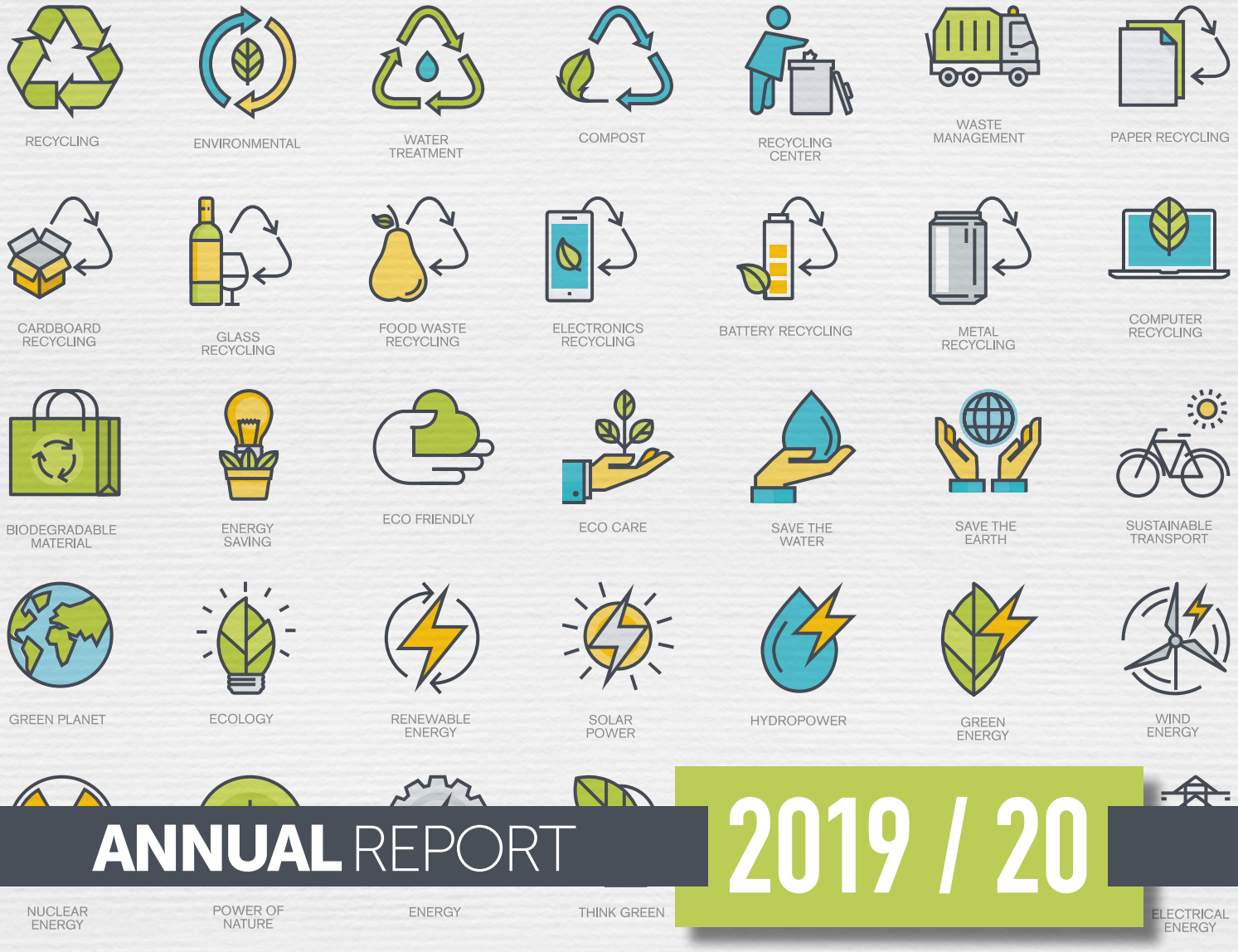

ANNUAL REPORT 2019 / 20

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Vision

Creating Innovative Solutions for a Sustainable Future

Mission

Tackle issues of concern to Indian society, and the world at large, and develop innovative and cost effective solutions

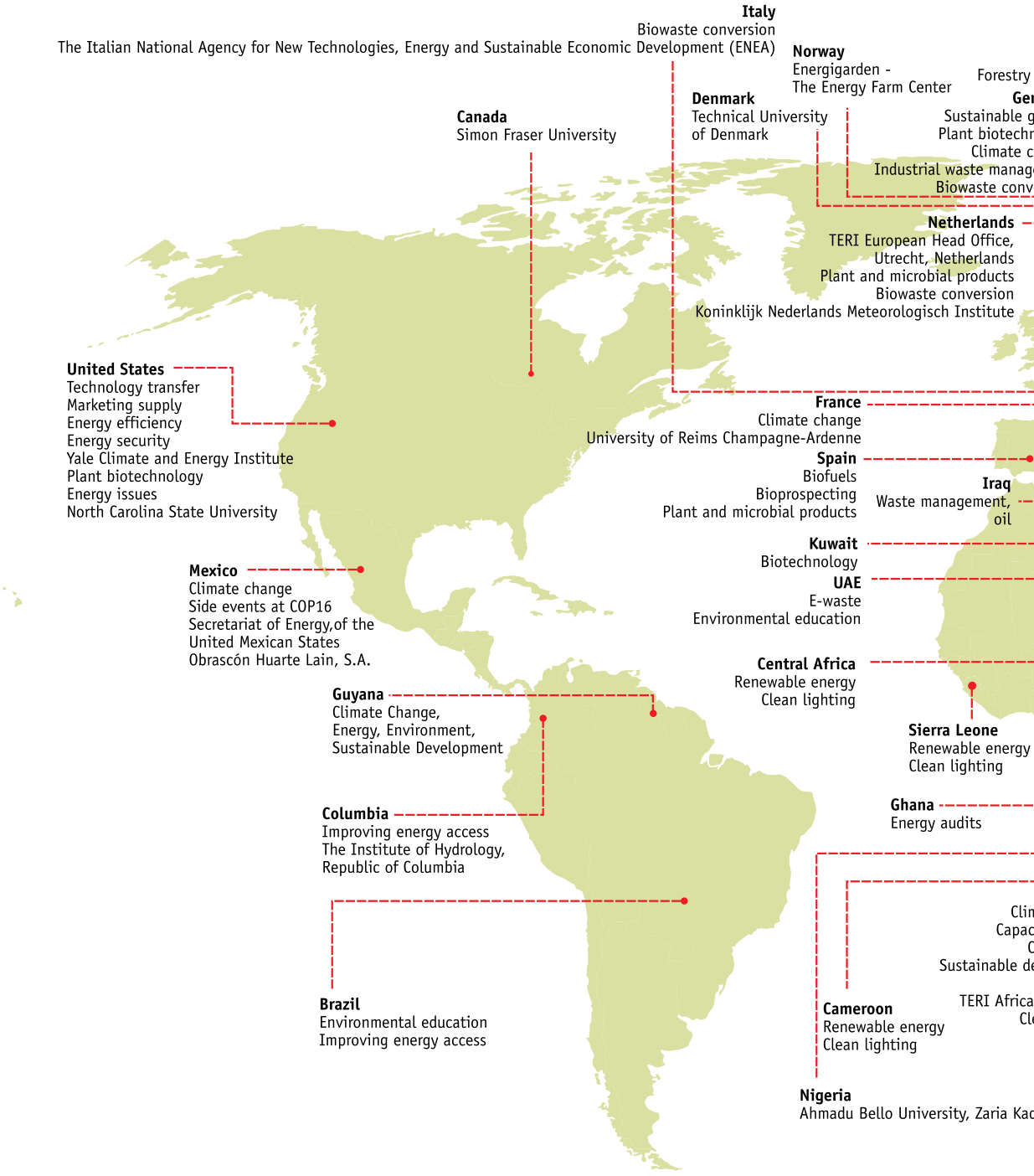
Enhance networking for sustainable interventions

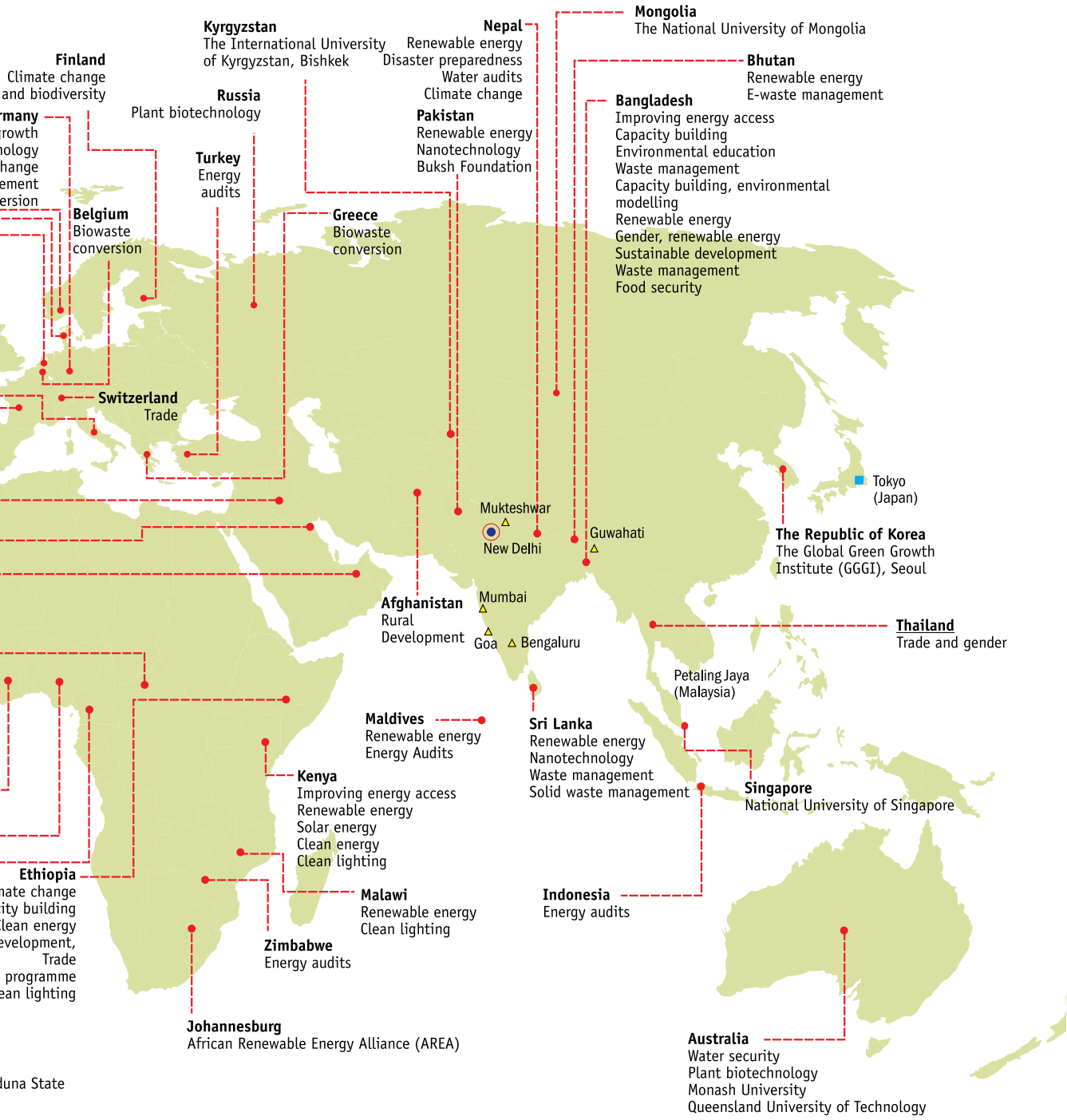
Realize potential for national and international leadership as a knowledge-based agent of change in the fields of energy, environment, other natural resources, and sustainable development

Inspire and reach out to diverse stakeholders for realizing a shared vision of global sustainable development, which could be translated into action

Our growing commitment to a sustainable future

Research and outreach activities in over 50 countries




Mongolia
The National University of Mongolia
Nepal
Renewable energy
Disaster preparedness
Water audits
Climate change
Kyrgyzstan
The International University of Kyrgyzstan, Bishkek
Bhutan
Renewable energy
E-waste management
Bangladesh
Improving energy access
Capacity building
Environmental education
Waste management
Capacity building, environmental modelling
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Gender, renewable energy
Sustainable development
Waste management
Food security
Pakistan
Renewable energy
Nanotechnology
Buksh Foundation
Finland
Climate change
and biodiversity
Russia
Plant biotechnology
Turkey
Energy audits
Belgium
Biowaste conversion
Greece
Biowaste conversion
Switzerland
Trade
Tokyo
(Japan)
Mukteshwar
New Delhi
Guwahati
The Republic of Korea
The Global Green Growth Institute (GGGI), Seoul
Afghanistan
Rural Development
Mumbai
Goa
Bengaluru
Thailand
Trade and gender
Petaling Jaya
(Malaysia)
Maldives
Renewable energy
Energy Audits
Sri Lanka
Renewable energy
Nanotechnology
Waste management
Solid waste management
Singapore
National University of Singapore
Kenya
Improving energy access
Renewable energy
Solar energy
Clean energy
Clean lighting
Ethiopia
Malawi
Renewable energy
Clean lighting
Indonesia
Energy audits
Zimbabwe
Energy audits
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Water security
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Centre
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Annual Report 2019/20

DIRECTOR **GENERAL'S MESSAGE**

The year 2019/20 has been both daunting and awakening. Daunting because of the outbreak of the COVID-19 global pandemic, and awakening since it heralded a paradigm shift in the overall outlook of the human race. Worldwide, COVID-19 cases have surpassed 100 million and while vaccinations are underway, we must not underestimate the powers of the invisible virus, especially when its mutations are emerging in several parts of the world. This year, however unprecedented, has taught us to revive, be resilient, and restore, that too, efficiently.

The Energy and Resources Institute (TERI), despite obstacles and challenges, has grown as a multidisciplinary and polyphonic firm through a synthesis of its Division-based areas and Programme-driven work culture. Enabling work from home in an era of the new 'normal', the Information Technology and Services Division facilitated most of our colleagues to work from home across the regional centres. Microsoft Teams ensured excellent experience of online meetings or collaborations and integrated people, contents, and tools. The harmonious integration of our institute's diverse research programmes with the corresponding units and areas – energy, integrated policy analysis, natural resources and climate, sustainable habitat, social transformation, environmental and industrial biotechnology, and sustainable agriculture – through concerted efforts, have brought us closer to realize the goal of adopting energy-efficient choices for a sustainable, greener society and future. In its research endeavours, TERI was ably assisted by the support services – communication outreach and advocacy unit, project management unit, knowledge management, growth diversification, commercialization unit, and corporate social responsibility unit. The support units – administrative services, human resources, and of course information technology also provided anchorage to TERI's research efforts. Energy is the pillar of our country's socio-economic development, and over the years, the growth in the energy sector has been monitored and sustained through changes and variations in both the demand and supply sides.

During unprecedented times of the COVID-19 outbreak, the adoption and promotion of clean-energy solutions has acquired a whole new meaning and dimension. In this regard, the Energy Transitions Commission (ETC) India project aims to develop a narrative for policymakers for adopting low-carbon pathways to enable smooth transition towards a carbon-neutral or zero-carbon energy sector in India. This requires a study of various options of supply of clean power to match the estimated demand for the country till 2050. The work includes a holistic assessment of demand, supply, grid-balancing, investments, and policymaking for the energy sector.

During 2019/20, a detailed study with hourly despatch model for production cost optimization using open-source software, namely PyPSA (Python for Power System Analysis), was given a final shape. The study charted a cost-effective and feasible pathway for India's power system to achieve high levels of wind and solar electricity generation by 2030. Additionally, three studies highlighting the challenges and the ways forward with regard to open-access, cost of supply, and electric vehicles duly taking into consideration the distribution companies' (DISCOMs) and stakeholders' perspectives through consultative workshops were successfully completed.

Within the paradigm of renewable energy (RE), India is moving steadily to achieve its targets with wide-ranging policy initiatives at the level of central and state governments. The RE sector is evolving and generating opportunities for working on its various aspects. And in order to support the national vision of RE, TERI's Renewable Energy Technology (RET) Division has maintained its focus on R&D, project implementation, policy research, and consultancy services, besides select training and capacity-building activities. Further, the Division took charge of setting up of one of the most advanced solar water pump test facilities in collaboration with M/s Maxop Engineering Company Private Limited, besides completing a number of studies with exemplary support from the MacArthur Foundation, Energy Transition Commission India, and Norwegian Framework Agreement.

Presently, TERI in association with GERMANWATCH is working on MAP (Multi-Actor Partnership) project to identify and map the risks involved in the solar sector. The project is sponsored by the German Ministry (BMZ). Under this initiative, TERI organized two stakeholder consultation workshops, including a workshop titled 'New Business and Investment Opportunities in Solar Sector' conducted in November 2019, at INTERSOLAR 2019, Bengaluru. One of the several accomplishments in this area was that Innovate UK awarded a contract to TERI titled 'CORES: Collaboration to Optimise Renewable Energy Systems' to introduce affordable, reliable, portable energy solutions to remote communities in India and Africa.

Among other laurels, TERI and Society for Energy, Environment, and Development (SEED) won prize money under Indo-US Science and Technology Forum for an innovative concept, that is, a solar dryer-based self-employment model for rural tribal communities, women, and differently abled persons. TERI hosted the SEED India Hub for delivery of customized enterprise support and promotion of eco-inclusive entrepreneurship for sustainable development. During 2019/20, TERI worked on international- and local-level projects addressing waste management issues in different spheres and worked on-ground to demonstrate the impact. In 2020, programmes

included the Training of Trainers (ToT) and cocreation sessions for Business Development Support (BDS) providers, practitioner's lab for climate finance targeted at the needs of growing 'missing middle' eco-inclusive enterprises, and SEED replicator programme matching proven business models with aspiring entrepreneurs.

The conversion of waste into a renewable resource is one of the fine examples to limit greenhouse gas (GHG) emissions for power generation. In a move towards waste management through methanation technology, TERI installed a first-of-its kind biomethanation plant in Udaipur city supported by the Udaipur Municipal Corporation. A two-tonne per day capacity plant based on the modified TEAM technology (anaerobic digestion) was installed to scientifically treat organic fraction of municipal solid waste. Branching out in this vision, the National Thermal Power Corporation Limited awarded a contract to TERI for setting up of a 100 kg per day biomethanation plant at NTPC-Farakka, West Bengal. At the global front, a UNIDO-sponsored project for setting up of a biomass power generation plant was implemented and the inauguration of rice husk in Cambodia was successfully done, while a bamboo waste-based project in Thailand is in installation and commissioning stage.

Within the Industrial Energy Efficiency Division, the pool of engineers, many of whom are accredited and certified energy auditors with the Bureau of Energy Efficiency (BEE), Government of India, regularly conducted energy audits in industries to identify options for energy conservation at the plant level. With expertise and in-depth knowledge of applicable technologies, TERI continues 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.

During 2019/20, the Division undertook energy audits in different kinds of industries in India in sectors, such as cement, power, chemicals, laminates, steel, automobile, food processing, and so on. It continues to provide support under the Perform, Achieve, and Trade (PAT) scheme of BEE to various Designated Consumers (DCs) with regard to Mandatory Energy Audit and Monitoring & Verification (M&V) services. TERI worked with 18 DCs during the FY2019/20. For the first time, M&V services were rendered to four electricity DISCOMs in Karnataka and Assam. Additionally, TERI undertook energy conservation studies in plants located in other countries, including – Cebu International Airport, which is the second largest airport in the Philippines; Dangote Sugars, Nigeria, which is the largest sugar refinery in the world; plants of Indorama Ventures in the USA and Germany; and Dabur Nepal Private Limited.

The Environmental and Industrial Biotechnology (EIB) Programme works towards contributing in advanced solutions for remediation of contaminated environments, minimizing waste generation, and creating sustainable environment by providing clean energy solutions. With the vision to increase community resilience, TERI implemented a project that aims to upgrade and develop key public spaces for schools and *Anganwadi* centres. The project focuses on strengthening health services by reducing vulnerabilities due to poor access to health facilities and providing a nurturing environment for children. Under the project, TERI upgraded sanitation infrastructure in 15 *Anganwadi* centres and 6 schools in Rani Block, Kamrup district, Assam.

With the objective to inform policy on the critical sustainability issues of our time, the Integrated Policy Analysis (IPA) Programme through an in-depth and interdisciplinary research seeks to answer the central question, 'How can policy be designed to scale up solutions that successfully decouple economic development from natural resource use and environmental degradation while enhancing livelihood opportunities and the quality of life?' In this regard, 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.

During 2019/20, the Division was engaged in providing inputs to the Ministry of Environment, Forest and Climate Change (MoEFCC), through its study on long-term low-carbon development strategies for India. The project focused on developing alternative energy-economy scenarios for India to examine the implications of India's development trajectories with varying focus on energy access, jobs and clean energy/sustainable urbanization objective. Additionally, the Division completed two projects supported by the Norwegian Ministry of Foreign Affairs (NFA). These projects focused on undertaking a detailed estimation (across five grid regions, various seasons) of energy (in particular electricity) requirements across various end-uses, particularly in the residential and commercial sectors at different times of day (ToD). Gathering detailed information on electricity use at the end-use level has remained a big data-gap in India. TERI's study focused on understanding the electricity use patterns in the residential/commercial sectors to better understand the variations in consumer behaviour, regional differences, and income-related variations towards ownership and use of various appliances.

TERI prepared a detailed report – 'Towards a Low Carbon Steel Sector: Overview of the Changing Market, Technology, and Policy Context for Indian Steel' – which was launched by Shri Dharmendra Pradhan, Hon'ble Union Minister of Steel, Petroleum and Natural Gas, during the World Sustainable Development Summit 2020, our annual flagship event. The report suggests a comprehensive package of measures that would keep the sector competitive while reducing its environmental impacts. We all know how the changing climate is posing new challenges to the sustenance of humankind. In the context of building climate resilience, 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, 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, Forest and Biodiversity, 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. Moreover, in the bygone year, TERI continued to support the Copenhagen-based Climate Technology Centre and Network (CTCN) through various technical assistance projects.

This year, TERI was set to co-host the Adaptation Futures 2020 with the World Adaptation Science Program (WASP), which is one of the four components of the World Climate Programme based on the World Meteorological Organisation Congress XVI Resolution 18. The 2020 edition would have been the sixth

in the international conference series on global adaptation and the first to be held in Asia. One of its several objectives was also to emphasize knowledge sharing and co-learning for actionable solutions across the Global North and the South. Owing to the unforeseen circumstances due to COVID-19 and the resultant travel restrictions, the Steering Committee took the decision to postpone the conference to 2021. TERI, through its multifaceted approach to issues and themes under the climate and environment paradigm, shall continue to strive through pioneering research and collaborations with our noteworthy stakeholders and beneficiaries.

TERI, being one of the 14 global partners, contributes to the climate transparency initiative, an international partnership project that examines and reviews G20 climate actions, finance and vulnerability. In this regard, our institution contributed to the 'Climate Transparency Report 2020', which was launched in November 2020. Linking Climate and Development Policies–Leveraging International Networks and Knowledge Sharing (CD-LINKS) is another milestone project, supported by the European Commission under the Horizon 2020 framework, which focuses on linking climate and development policies. The project evaluated several alternative scenarios indicating India's choices and challenges in undertaking more ambitious emission reduction targets that were compatible with global scenarios depicting the well below 2°C world.

Specific to the Paris Agreement, we have prepared a framing document to aid the formulation of a long-term mitigation and adaptation strategy for India (in line with Article 4.19). It identifies 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. Additionally, we have advocated on international partnerships on building capacities and implementing complementary work with other developing and industrializing nations. Under this ambit, TERI has also been contributing to Fiji's NDC implementation road map and the 'State of Environment Report'. Within the Centre of Excellence for Advanced Research in Agricultural Nanotechnology, TERI–Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India and Deakin University, Australia, in association with the Department of Biotechnology, Government of India formulated 'DBT–TDNBC–DEAKIN–Research Network Across continents for learning and innovation (DTD–RNA)'. The network was launched at TERI Gram, Gurugram, Haryana, on 3 September 2019.

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 Nainital district of Uttarakhand since its establishment in 2003. Our efforts encompass a strategy for enhancing land productivity by using sustainable biotechnological approaches and harmonizing modern technologies and traditional knowledge. In 2019/20, TRISHA promoted various high-altitude medicinal plants in the district of Nainital including Bageshwar, Pithoragarh, Tehri, Rudraprayag, and Uttarkashi on cluster basis for women farmers. As far as the Centre for Biodiversity and Ecosystem Services is concerned, TERI conducted the first-of-its-kind study – 'Economic Valuation of Ecosystem Services of National Zoological Park in Delhi' with a robust and refined methodology. The annual value of key ecosystem services comprising use and non-use values, such as carbon storage and sequestration, employment generation, recreation, education and research, biodiversity conservation, and the surrogate value of land has been evaluated in this study. Additionally, TERI also initiated a World Bank-supported consultancy on economic valuation of mountain forests and mangroves in the Kingdom of Saudi Arabia (KSA).

In the field of marine and coastal areas, multiple projects were successfully carried out for livelihood diversification, women empowerment, and entrepreneurship development, especially of artisanal fishing through a successful demonstration of crab cultivation, aquaponics, and fish cage culture, supported by National Bank for Agriculture and Rural Development (NABARD). Under the TERI–DBT Centre of Excellence, the project on aquafeed development from deoiled algae has been initiated.

TERI's Coastal Ecology and Marine Resources Centre (CEMRC) is a multidisciplinary research centre, which focuses 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. For instance, CEMRC, Goa worked on City Biodiversity Index (CBI) (also known as Singapore Index on Cities' Biodiversity) for the city of Panaji, a project funded by Imagine Panaji Smart City Development,Limited.

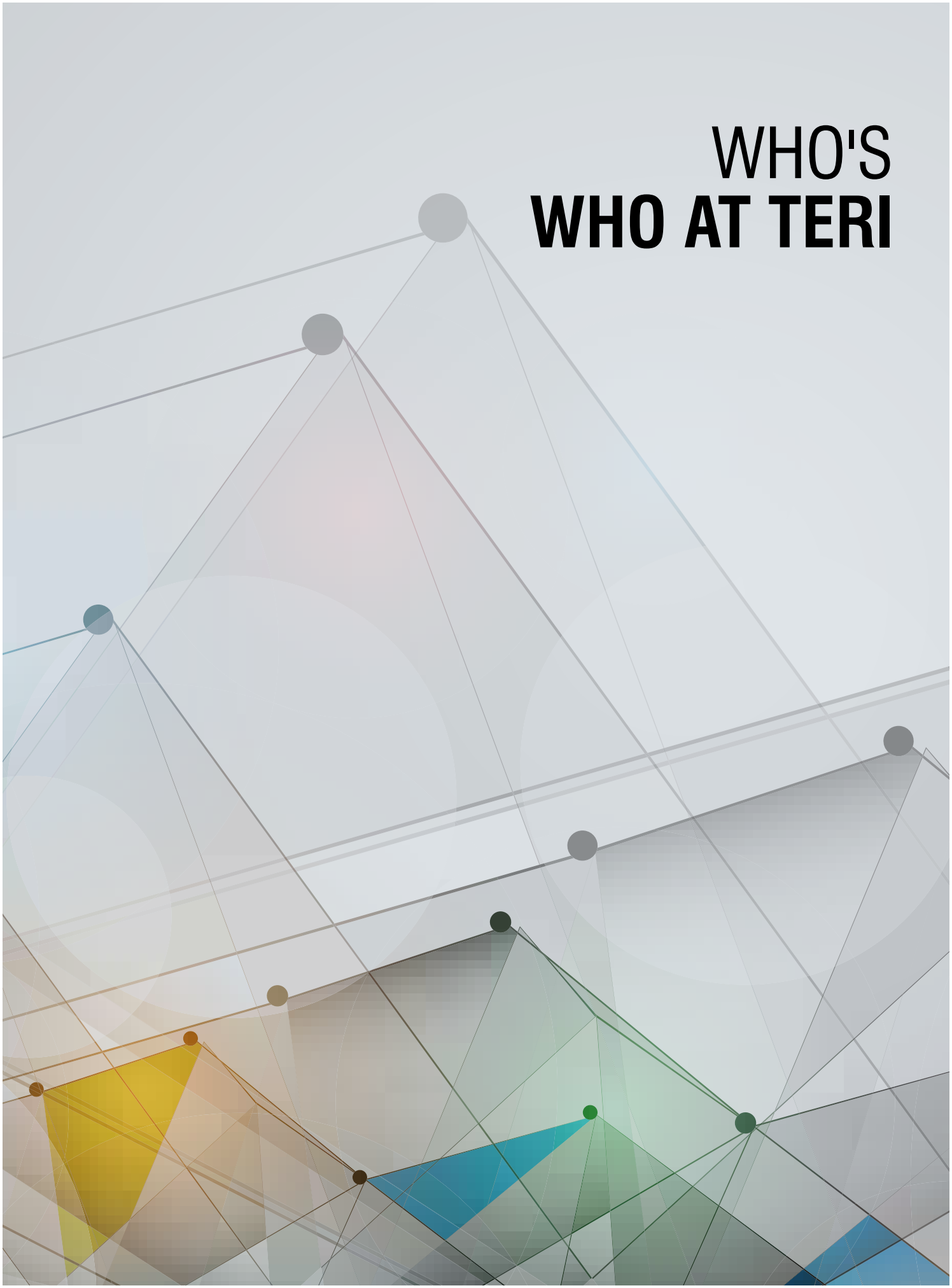
With respect to sustainable habitats, the 11th GRIHA Summit was organized in association with UNSW, Sydney, at the India Habitat Centre, New Delhi on December 17–18, 2019. The overarching theme was – 'Approach to Integrated Sustainability'. The event was supported by many premier international and national organizations, such as the 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). The Summit platform was leveraged to showcase collaborative research and development works between TERI, GRIHA, and UNSW in the built environment cutting across various thematic areas. The rating of 300 new and existing buildings for the Public Works Department, Government of Maharashtra under the landmark agreement signed in 2018/19 was undertaken. Three additional MoUs were signed with First Construction Council, Indian Institute of Architects (IIA), Northern Chapter, and National Real Estate Development Corporation (NAREDCO) at the Summit.

The Sustainable Buildings, Delhi, a part of the Sustainable Habitat Programme, promotes low-carbon and low-cost solutions to developmental concerns in the built environment. In light of the COVID-19 pandemic, the current projected GDP growth for India stands at 1.9% for FY21. It is critical at this juncture to envisage a 'new normal' for a post-lockdown scenario, which would integrate the principles of sustainable development with economic stability and social equity.

With the world reeling under the effects of the deadly virus, in December 2019, transportation was one of the worst affected sectors, as economies, including India, were put under severe lockdown. During 2019/20, TERI conducted detailed studies on analysing the future prospects of electric mobility in India. The Centre for Sustainable Mobility came out with a report – 'Faster Adoption of Electric Vehicles in India: Perspective of Consumers and Industry' – with a special focus on the two-wheeler sector. It also initiated a research study on the 'Road Map for Electrification of Urban Freight Sector in India' to understand, map, and recommend strategies for faster adoption of electric commercial vehicles across Indian cities.

The past year has been a lesson for us. While activities and achievements shall continue, we as a growing family must also continue to be motivated and prepared than ever before in our endeavour and pledge to move forward to a society that makes sustainable, energy-efficient choices and contributes to an environmentally secure future to ensure the well-being of successive generations, pandemic or no pandemic.

Ajay Mathur
Director General, TERI



WHO'S
WHO AT TERI

TERI'S **GOVERNING COUNCIL**

Shri Nitin Desai
Chairman

Shri Vijai Sharma

Dr Shailesh Nayak

Shri Nawshir H Mirza

Dr Ajay Mathur

Dr Naushad D Forbes

Prof. (Ms) Basabi Bhaumik

Prof. (Ms) Laurence Tubiana

THE MANAGEMENT TEAM

Dr Ajay Mathur
Director General, TERI

Mr Girish Sethi
Industrial Energy Efficiency

Mr Sanjay Seth
Sustainable Habitat

Dr Annapurna Vancheswaran
Communications Outreach and Advocacy Unit

Dr Ashvini Kumar
Renewable Energy Technologies

Dr Alok Adholeya
Sustainable Agriculture

Dr Ashvini Kumar
Environmental and Industrial Biotechnology

Mr A K Saxena
Electricity and Fuels

Mr Amit Kumar
Social Transformation

Dr Vibha Dhawan
Advanced Biofuels

Dr Syamal Kumar Sarkar
Natural Resource and Climate

Dr G Rudra Narasimha Rao
Industrial Energy Efficiency

Dr Sumit Sharma
Earth Science and Climate Change

Debajit Palit
Rural Energy and Livelihoods

Colonel (Retd) Sanjai Joshi
Administrative Services

Dr Dipankar Saharia
Agricultural and Rural Extension

Dr Jitendra Vir Sharma
Land Resources

Mr Jagdish Mutharia
Information Technology

Mr D N Narasimha Raju
TERI-SRC

Dr Ritu Mathur
Integrated Assessments and Modelling

Dr Suneel Pandey
Environment and Waste Management

Ms Shabnam Bassi
Sustainable Buildings

Mr Anshuman
Water Resources

Mr Sunil Dhingra
Renewable Energy Technologies

Ms Rishu Nigam
Creative Content

Mr Prosanto Pal
Industrial Energy Efficiency

Dr Reena Singh
Sustainable Agriculture

Ms Anupama Jauhry
TERI Press

Dr Livleen K Kahlon
Environmental Education and Awareness

Mr Souvik Bhattacharjya
Resource Efficiency and Governance

Dr Anjali Parasnis
Nutritional Security

Dr P K Bhattacharya
Knowledge Resource Centre

TERI'S **DISTINGUISHED FELLOWS**

Mr C Dasgupta
Distinguished Fellow Emeritus

Mr Dipak Dasgupta
Distinguished Fellow, Earth Science and Climate Change

Dr Vibha Dhawan
Distinguished Fellow & Senior Director, TERI

Dr Prodipto Ghosh
Distinguished Fellow, Earth Science and Climate Change

Air Commodore (Retd) M M Joshi
Distinguished Fellow, Administrative Services

Ms Preeti Madan
Distinguished Fellow, Director-General's Office

Mr S Vijay Kumar
Distinguished Fellow and Lead, Food and Land Use Coalition, India

Mr Ajai Malhotra
Distinguished Fellow and Senior Advisor (Climate Change), Project Management Unit

Mr Shri Prakash
Distinguished Fellow, Transport and Urban Governance

Mr K Ramanathan
Distinguished Fellow, Electricity and Fuels Division

Mr R R Rashmi
Distinguished Fellow and Programme Director, Resource Efficiency and Governance

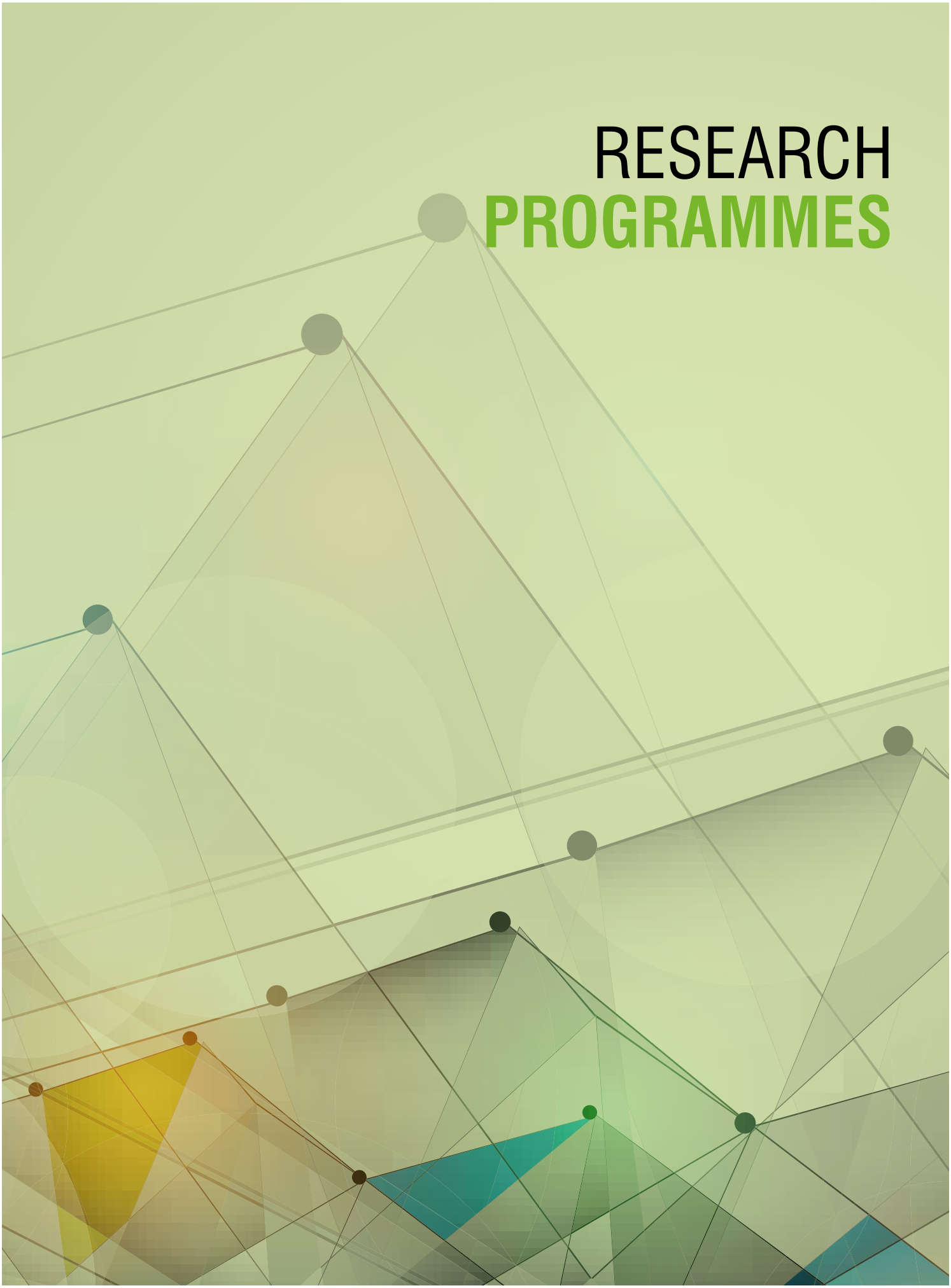
Prof. S L Rao
Distinguished Fellow Emeritus

Mr Ajay Shankar
Distinguished Fellow, Director-General's Office

Mr S Sundar
Distinguished Fellow, Transport and Urban Governance

Mr Sanjay Mitra
Distinguished Fellow, Transport and Urban Governance

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:

The Electricity and Fuels Division (EFD) carries out policy and regulatory analysis related to the energy sector (electricity, coal, oil, and gas). 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. 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 technological 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 on a range of activities to public, corporate, and international clients. It offers invaluable expertise in the fields of power and coal, and has extensive experience on regulatory and tariff issues and policy and institutional issues. EFD 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 2019/20, the Division continued its core area of work on energy transitions, demand-side management and energy efficiency, smart grids, energy storage, 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, 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. The work is being carried on a theme-based platform under the aegis of the Energy Transitions Commission (ETC) India, which was established during 2017/ 18 with the objective to foster deployment of low-carbon pathways in the country. TERI is engaged in a multi-stakeholder project for the Energy Transitions Commission, headquartered in the UK. TERI hosts the secretariat of the ETC India and EFD, as the nodal Division, in co-ordination with other divisions of TERI, leads a diverse group of stakeholders to facilitate a smooth transition towards low-carbon pathways in the energy sector through a collaborative approach. The activity is largely funded by Hewlett Foundation, Bloomberg Philanthropies, Oak Foundation, and Shakti Foundation with support from corporates including NTPC, Siemens, CLP India, BRPL, and Giriraj Renewables. Major new activities in this project include development of modelling and scenarios of India's power sector by 2050 with extremely high shares of renewables, and development of state-level models of high renewables penetration.

The ETC India project aims to develop a narrative for policymakers for adopting low-carbon pathways to enable smooth transition towards a carbon-neutral or zero-carbon energy sector in India. This requires a study of various options of supply of clean power to match the estimated demand for the country till 2050. The work included a holistic assessment of demand, supply, grid-balancing, investments, and policymaking for the energy sector. During 2019/20, a detailed study with

Power quality study for chilling plant with ALM 32 instrument at Dabur Nepal Private Limited

hourly despatch model for production cost optimization using open-source software, namely PyPSA (Python for Power System Analysis), was given a final shape. The study charted a cost-effective and feasible pathway for India's power system to achieve high levels of wind and solar electricity generation by 2030.

Smart Distribution, Electric Vehicles, and Battery Energy Storage: The Division continued to work on the 5-year (2017–22) Indo-US research project on smart distribution with storage. Installation of grid-scale battery energy storage systems (BESS) on distribution feeders, catering to three categories of consumers including institutional premises, gated residential colonies, and apartments so as to demonstrate various use-cases of energy storage at distribution downstream continued in partnership with BSES Rajdhani Power Limited (BRPL). The study initiated in 2018 with West Bengal State Electricity Distribution Company Limited (WBSEDCL) under MacArthur Foundation's grant continued its 3 years journey focusing on the pilot-scale implementation of BESS at both distribution transformer (DT) and feeder levels. A study was also undertaken for CESC Limited for conducting a techno-economic analysis of implementing BESS for overload management of a DT and managing load in critical facilities.

The Division worked with the Central Electricity Authority (CEA) and the Bureau of Indian Standards (BIS) to draft charging standards for electric vehicles (EVs) in India and prescribed appropriate charging standards that India can adopt in future. The Division is also working with utilities for supporting and managing EV integration by performing system impact studies including EV-charging harmonic measurements for assessing power quality issues. A case study for Kolkata E-bus operation was done for IEA Global EV Outlook 2020. The engagement with the West Bengal Transport Corporation (WBTC) continues with the assistance for developing another case study of their electric bus fleet for the Clean Energy Ministerial (CEM) Global EV City Casebook and policy guide. TERI was appointed by WBSEDCL, which is at present the nodal agency for the state of West Bengal for EV implementation, to assist the state in working towards infrastructural development and EV tariff modelling. The Division further spearheaded TERI's work on EV charging infrastructure under funding from CIFF, as part of an over-arching project on zero-carbon transition, and under the MacArthur Foundation-funded project on Smart Community Road Map Preparation for New Town Kolkata Green Smart City. The impact analysis of EV charging on the electricity demand curve of the NCT of Delhi for different types of vehicles, that is, buses, four-wheelers, three-wheelers, and two-wheelers including battery swapping was taken up during the year. Similar work was undertaken for the New Town Kolkata Green Smart City in Kolkata with additional focus on location planning of EV charging infrastructure using GIS and the work on last-mile connectivity.

Demand-side Management and Energy Efficiency: For over a decade, TERI has been working with various utilities and stakeholders across the country for demand-side management (DSM) and energy-efficiency-related studies, starting from development of load research methodology to preparation of DSM action plan for utilities as mandated by DSM regulations notified by the concerned State Electricity Regulatory Commission and project implementation support. EFD continues 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, capacity-building programmes on DSM and energy efficiency for utilities in the north-east zone under a Bureau of Energy Efficiency project, Load research study for BRPL, etc.

Implementation support was provided to Jamshedpur Utilities & Services Company Limited (JUSCO) for executing six DSM initiatives, namely, implementation of focussed energy efficiency 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.

Demand Forecasting and Integrated Resource Planning: Apart from the demand-and supply-side forecast, modelling activities were carried out under the umbrella of ETC India. The Division also carried out functional R&D projects to develop demand profile forecasting tools for distribution utilities or planning organizations to assess the changing pattern of electricity demand among their consumer categories in the medium term (three years). A web-based tool – the 'DISCOM Electricity Forecast Tool' (DEFT) – was developed to forecast load profiles for a distribution utility in India with the support of Shakti Sustainable Energy Foundation (SSEF). The tool is handy for any utility to carry out load research on their historical load data and also aids to understand the changing pattern of electricity consumption under various scenarios

including consumer category-wise energy efficiency, renewable energy, and electric vehicles penetration for the next three years (www.electricitydemandforecast.in).

Technical Studies on Grid Integration of Renewables: In the domain of electricity distribution, system studies for assessing the technical impacts of integration of rooftop solar systems on the distribution system were continued by the Division. After the successful completion of the studies for Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL) in the previous year, projects for the distribution utilities – BRPL in Delhi and WBSEDCL in West Bengal – were completed during 2019/ 20 and possible mitigation measures were suggested. These studies were undertaken with support from MacArthur Foundation.

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. During 2019/20, the Division initiated work on the preparation of AT&C loss reduction road map for a distribution utility in the north-eastern grid region, gauging human capital challenges in an Indian DISCOM and identifying strategies for developing human capital through learning and development programmes, and other activities.

Emerging Technologies and Innovations: In the emerging domain of smart grids, the Division works on the development of effective control systems for battery storage systems and solar photovoltaic (PV) inverter integration with distribution networks using hardware including emulators and real-time control hardware/embedded systems in TERI's in-house Smart Controller Laboratory.

A road map for strengthening power distribution infrastructure in New Town Kolkata Green Smart City is under preparation with the support of MacArthur Foundation. One of the innovative components under the project is the pilot implementation of block-chain technology-enabled P2P sharing of rooftop solar energy to demonstrate scaling-up of distributed renewable energy in the smart-city's energy mix through local energy markets and digital technology interventions.

Environmental and Economic Studies: TERI conducted a study with the support of Bloomberg Philanthropies in the area of emission control in thermal power plants. The study suggested measures for addressing key issues and challenges in implementation of new environmental norms, which were gathered through stakeholder interaction. A study for the assessment of economic and environmental impact of coal washing in India was also initiated for NITI Aayog.

Release of Energy Conservation Guidelines for MSMEs during National Conclave on 'Enhancing Energy Efficiency in MSME Sector' 22 September 2019

Capacity Building and Stakeholder Interactions: The division lays great emphasis on training and capacity building of utility officials in various spheres of the power sector through tailor-made learning and development 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 flagship programme, capacity building of DISCOMs was initiated in four DISCOMs in the north-eastern region of India (namely, 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 by TERI. A programme for capacity building of senior officials of Kerala State Electricity Board Limited on grid management and power market development was conducted during the year.

Distribution Utilities Forum: 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. During 2019/20, three studies highlighting the challenges and way forward with regard to open-access, cost of supply, and electric vehicles duly taking into consideration the DISCOMs and stakeholders perspective through consultative workshops were successfully completed (http://dufindia.com/).

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 2018/19 stands at 78.3 GW, with additional capacities of solar and wind power at various stages of development. The increasing growth trend in RE capacity installations is witnessed due to high level of interest in solar and wind power, though biomass power has also become highly relevant on account of environmental concerns caused by unregulated disposal of agricultural and municipal wastes. The RE sector is evolving rapidly and generating a lot of opportunities for working on its various aspects, such as, R&D, promotion, and dissemination of technologies at the utility scale and decentralized level.

In order to support the national vision of RE, the Renewable Energy Technology (RET) Division has maintained its focus on R&D, 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, users and various manufacturing industries, and consumers. There is a strong team of more than 30 research professionals with a diverse group of experts in biomass, solar, wind, and hybrid technologies. Special efforts were devoted to conceptualize and develop state-of-the-art infrastructure for testing solar water pumps and solar lighting systems. In the spirit of showing by doing, TERI campus at Gwal Pahari was solarized by setting up a rooftop solar system of an aggregate capacity of 222 kWp on various buildings and car parking areas. The major projects and achievements under various segments of activities are given in the following sections.

Research and Development

The Division's R&D initiatives included R&D partnership with International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Punjab State Council for Science and Technology (PSCST) for the development of advanced briquetting machine for paddy straw utilization, technical collaboration with Indian Institute of Technology Delhi, Delhi College of Engineering, ENEA, Italy, and Energy Farm, Norway under Mission Innovation for a joint R&D project on development of a biomass–solar electricity and cooling solution for rural areas. The Division took charge of setting up of one of the most advanced solar water pump test facilities in collaboration with M/s Maxop Engineering Company Private Limited, besides completing a number of studies with support from the MacArthur Foundation, Energy Transition Commission India, and Norwegian Framework Agreement. NABL-accredited test lab infrastructure facilities including solar water pump and solar lighting lab and smart grid and inverter testing lab give the RET Division unique advantage of market connectivity. The following are some of the key R&D projects pursued during the year:

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

Project Implementation

During the year, the Division continued its implementation of field projects within the country as well as abroad. The marketing of the biomass gasifiers and biogas (TEAM) technologies expanded through concerted efforts and a network of licensed partners. Some of the key projects pursued during the year are as follows:

- Innovate UK awarded a contract to TERI titled 'CORES: Collaboration to Optimise Renewable Energy Systems' to introduce affordable, reliable, portable energy solutions to remote communities in India and Africa.
- TERI and Society for Energy, Environment, and Development (SEED) won prize money under Indo-

US Science and Technology Forum for an innovative concept, that is, a solar dryer-based self-employment model for rural tribal communities, women, and differently abled persons.

- National Thermal Power Corporation Limited awarded a contract to TERI for setting up of a 100 kg per day bio-methanation plant at NTPC-Farakka, West Bengal.
- Implementation of a UNIDO-sponsored project for setting up of a biomass power generation plant. Inauguration of rice husk in Cambodia was successfully done, while a bamboo waste-based project in Thailand is in installation and commissioning stage.
- A waste-to-energy plant of capacity 2 TPD was inaugurated at Udaipur Municipal Corporation, Rajasthan. The plant treats the municipal solid waste collected from the city to generate electricity. This project was supported by ICLEI.

Specialized Studies

The RET team conducted the following specialized studies during the year with support from the Energy Transition Commission of India:

- **Potential assessment of floating solar PV in India**: It targets mapping of potential waterbodies for setting up of floating solar PV power plants using GIS mapping to assess the floating solar potential in India.
- **Accelerating deployment of rooftop solar PV in India**: This study has four sub-components, namely, analysis of policies of central as well as state governments, developing business models, establishing a rating system, and developing a corporate RE consumption index for accelerating deployment of rooftop solar in India.
- **Reports under a framework agreement between the Norwegian Ministry of Foreign Affairs and TERI**: Three reports were completed covering topics related to biomass gasifier coupled with CHP engine based on organic Rankine cycle for rural applications; solar micro-grid controller and waste management of solar PV, and electrical storage batteries in technical collaboration with the University of Agder, Norway. The findings of the project were shared through a stakeholder consultation workshop.

Policy Research

The Division worked with various governments and other agencies to contribute on policy aspects specific to RE dissemination.

- TERI has been associated with Power Roll in carrying out testing of the third-generation flexible, ultra-low weight, and very low-cost PV technology, which is being developed by Power Roll, UK. The research project is sponsored by Innovate UK.
- TERI in association with GERMANWATCH is working on MAP (Multi-Actor Partnership) project to identify and map the risks involved in the solar sector. The project is sponsored by the German Ministry (BMZ). Under this initiative, TERI organized two stakeholder consultation workshops, including a workshop titled 'New Business and Investment Opportunities in Solar Sector' conducted in November 2019, at INTERSOLAR 2019, Bengaluru.
- The Division conducted thematic track on 'De-risking Investments in Decentralised Solar Solutions' conducted on January 29, 2020 in WSDS 2020.
- Two reports supported by The MacArthur Foundation were prepared. The first report was on technical analysis of setting up a decentralized solar PV near to its rural users to minimize distribution losses. The second report focused on large-scale RE power integration and stabilized grid operation in Andaman and Nicobar Islands.
- A new study was initiated to support the implementation of Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan (PM-KUSUM) scheme for the power sector utilities in India. Technical assistance to the selected DISCOMS for the implementation of PM KUSUM Scheme was initiated.
- Energynautics GmbH engaged TERI to develop a policy and regulatory framework on power generation control and ancillary services from wind and solar generators.
- The policy papers supported by Energy Transitions Commission (ETC) India on 'Solar PV Manufacturing in India: Silicon Ingot & Wafer PV Cell - PV Module' and 'Report on Floating Solar Photovoltaic (FSPV): A Third Pillar to Solar PV Sector?' were prepared and launched. A discussion paper on 'Crop Residue Management: Solution to Achieve Better Air Quality' was launched.

With Support from the World Bank, Chandigarh Renewable Energy Science and Technology Promotion Society (CREST), Surat Municipal Corporation, We Mean Business, Global Methane Initiative (GMI), Global Methane Initiative, Energynautics GmbH, International Energy Agency (IEA), Oil India Limited, North Delhi Municipal Corporation, Adani Green Energy Limited, GIZ, and ETC, the Division conducted the following activities during the year:

- Study on the potential of floating solar PV in India; third-party inspection of an aggregate capacity of 520 kWp (400 kWp [4 x 100 kWp and 120 kWp]) grid-connected rooftop solar PV power plants at Chandigarh; preparation of tender documents; technical and financial bid evaluations; selection of appropriate bidders; third-party inspection; dialogues with state government to develop strategies to increase the RE footprint in the corporate sector; workshops on enabling biogas projects were conducted; training on pre-screening tools, risk analysis, and technical review checklist for biogas projects was also carried out. The RET Division developed an anaerobic digestion-biogas projects database for selected states in India. It conducted a study on the 'Role of Discoms in Using Grid Support Services from Solar Rooftop PV Systems and Storage'. A study for measuring biofuels potential in India was also undertaken. It also conducted biomass assessment studies in the northeast region of India with an objective to assess the biofuel production (biodiesel, ethanol, and CBG) in the region. TERI was the third-party quality assurance audit agency for the project 'Solid Waste Management in Delhi'. The Division also generated best practice and prepared the Guidelines of Structures for Ground Mounted SPV Projects in India.
- TERI in association with CADMUS, USA implemented a project titled 'Indian Solar Market Aggregation for Rooftops (I-SMART) Programme', sponsored by GIZ, for the rooftop solar demand aggregation in residential, commercial, industrial, and government buildings in Gujarat, Himachal Pradesh, Uttarakhand, Dadra and Nagar Haveli, Daman and Diu, Jammu and Kashmir, and Ladakh. The project targeted demand aggregation of rooftop solar systems in the aforementioned states/UTs.
- PRAMAAN – Portal for Renewable Energy Action Assessment Metrics for corporates in India was launched with the intent to accelerate India Inc.'s efforts in transitioning to renewable energy and corroborate its alignment with the nation's commitments under the Paris Agreement. The platform captures the renewable energy footprint in the commercial and industrial sector and recognizes its contributions to India's Sustainable Development Goals. This activity is supported by Energy ETC India.
- The Indian Chamber of Commerce has appointed TERI as an acknowledge partner for Green Urja Awards 2020 edition. The overall objectives are to recognize the clean transition efforts, that is, RE leaders in variety of sectors including DISCOMs, MSMEs, manufacturers, the corporate sector, etc.

Training Programmes

With support from the National Institute of Urban Affairs, International Centre for Integrated Mountain Development, KFW, and Institute of Energy Economics, Japan, TERI conducted the following training programmes:

- Municipal solid waste management for the officials of ULBs and elected representatives under Swachh Bharat Mission (Urban).
- Regional workshop on air pollution and health in Nepal and the Hindu Kush Himalayas.
- Surya Samvad on 'Floating solar plants – opportunities, challenges, and way ahead'.
- Workshop on Hydrogen and Fuel Cell 2020.

The Division created three policy briefs, titled 'Floating Solar Photovoltaic (FSPV): A Third Pillar to Solar PV Sector?', 'Solar PV Manufacturing in India: Silicon Ingot and Wafer PV Cell – PV Module Launch of Report on

Shri Trivendra Singh Rawat, Hon'ble Chief Minister of Uttarakhand launched the unified solar rooftop portal.

Shri Bandaru Dattatreya, Hon'ble Governor of Himachal Pradesh, flagged off 16th MTB Himalaya. The team members of Mission Smile and TERI visited 27 schools to spread awareness on renewable energy and sensitized 2700+ students

Floating Solar Photovoltaic (FSPV): A Third Pillar to Solar PV Sector?', and 'Crop Residue Management: Solution to Achieve Better Air Quality'. The Division also organized community discussion with tribal women self-help group in Bilaput village, Koraput district, Odisha. The self-help group will be the beneficiary of a biomass-solar PV electricity and cooling solution. The one-of-a-kind pilot system will provide electricity to the households and the refrigeration system running on waste heat from an engine exhaust of a biomass gasifier will be utilized to store perishable farm produce, thus augmenting income of the village community.

TERI installed a first-of-its kind biomethanation plant in Udaipur Municipal Corporation, Udaipur. A two-tonne per day capacity plant based on the modified TEAM technology (anaerobic digestion) was installed to scientifically treat organic fraction of municipal solid waste. TERI in partnership with The International Centre for Integrated Mountain Development (ICIMOD) organized a stakeholder consultation involving technology and solution providers, experts, developers, industries, and practitioners to discuss various *in-situ* and *ex-situ* technology options to identify and showcase available 'no burn' options and discuss the key challenges for adoption of these alternatives.

A total of 33 participants attended the workshop which comprised technology and solution providers, representatives from research institutions and industries, subject experts, project developers, and practitioners.

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 whom 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 over two decades.

During the year, the Division undertook energy audits in different kinds of industries in India in sectors, such as cement, power, chemicals, laminates, steel, automobile, food processing, etc. A few prominent groups where IEE rendered services included ACC, Neyveli Power, Garware, Jindal, Merino, ITC, Toyota Kirloskar, Grasim, etc. 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 and Monitoring & Verification (M&V) services. TERI worked with 18 DCs during the FY 2019/20. For the first time, M&V services were rendered to four electricity distribution companies (DISCOMs) in Karnataka and Assam. Additionally, TERI undertook energy conservation studies in plants located in other countries. These include:

- Cebu International Airport, which is the second largest airport in the Philippines
- Dangote Sugars, Nigeria, which is the largest sugar refinery in the world
- Plants of Indorama Ventures in the USA and Germany
- Dabur Nepal Private Limited

TERI continued to support the Copenhagen-based Climate Technology Centre and Network (CTCN) through various technical assistance projects. Implementation assistance to the National Designated Entity (NDE) of Pakistan is being provided for developing the national certification scheme for energy auditors, including preparation of draft rules and regulation for the scheme for large industrial consumers. Support was also provided to CTCN for organizing an event on 'Accelerating clean energy transformation in partnership with private sector' for NDEs in Asia-Pacific, network members and climate technology service providers, including private sector and international organizations. The matchmaking event took place at the margins of G-STIC 2019 during November 20–21, 2019 at Brussels, Belgium. Forty-three climate technology providers from 29 countries and 13 NDEs registered for the event.

During 2019/20, the IEE Division also initiated activities in the field of industry decarbonization, particularly the steel sector, which is globally perceived to be a 'harder-to-abate' sector. The work on steel sector was undertaken under the aegis of Energy Transitions Commission (ETC) India work programme and was primarily supported by Shakti Sustainable Energy Foundation (SSEF) and Children's Investment Fund Foundation (CIFF). Based on in-depth analysis and research, TERI prepared a detailed report 'Towards a Low Carbon Steel Sector: Overview of the Changing Market, Technology, and Policy Context for Indian Steel'. It was launched by Shri Dharmendra Pradhan, Hon'ble Union Minister of Steel, Petroleum and Natural Gas, during the World Sustainable Development Summit 2020, TERI's flagship event. The report suggests a comprehensive package of measures that would keep the sector competitive while reducing its environmental impacts. It recommends maximizing the use of domestic scrap and deploying energy efficiency measures, as well as facilitating greater resource efficiency throughout the economy. Other than that, it suggests establishing pilot and demonstration plants to test emerging low-carbon technologies such as hydrogen-based direct reduction, which are being explored in some of the European countries. The report mentions that measures such as these could put the sector on a pathway to reduce emissions to near-zero levels by the middle of the century or soon thereafter, making India the first country to industrialize while decarbonizing its steel production.

The activities in the MSME sector were primarily supported by BEE, KfW (through Enclude), United Nations Development Programme (UNDP), and SSEF. TERI continued to expand the knowledge collation and dissemination activities under the Small and Medium Enterprises Energy Efficiency Knowledge Sharing (SAMEEEKSHA) platform. Regional meetings of this platform were held in Rajkot (for Western Region) and New Delhi (for Northern Region). TERI also supported BEE in organizing the National Conclave on Enhancing Energy Efficiency in MSME sector on September 23–24, 2019 at New Delhi. During the conclave, 'Energy Conservation Guidelines for MSME sector' were launched jointly by Shri Nitin Gadkari, Minister of MSME and Minister of Road Transport and Highways; and Shri R K Singh, Minister of State (IC) for Power

and New & Renewable Energy and Minister of State for Skill Development and Entrepreneurship, Government of India. TERI had supported BEE in preparing these guidelines.

To build the capacity of the Small Industries Development Bank of India (SIDBI) in energy efficiency financing, KfW had provided SIDBI technical assistance (TA) support, which was implemented by a Consortium formed by Enclude, a Palladium company and TERI. During the year, TERI supported Palladium in updating the positive list, conducting loan reviews, identification of EE investments through energy audits, cluster-level awareness workshops, and development of a GHG emissions calculation tool. Recognizing the enormous potential for demand-side management (DSM) among industrial consumers, the IEE team undertook a detailed study to explore the scope of aggregation of DSM opportunities among SME industrial consumers. About 100 consumers were selected in consultation with Tata Power, spread across Delhi, Mumbai, and Ajmer. The study was supported by MacArthur Foundation. In addition, TERI continued its activities with the UNDP in Jharkhand with regard to preparation of investment-grade energy audit reports and providing implementation support to SMEs in adopting cleaner technologies. The SSEF-supported project on assessing opportunities for switching to electrification in industrial processes in small-scale industries entered its second phase.

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). During the year, a number of field visits of Japanese experts/ technology providers were facilitated to industrial end-users in India. TERI assisted and facilitated IGES to conduct awareness and capacity-building events in Mumbai, New Delhi, Ahmedabad, and Surat. 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.

The IEE team also undertook a few specialized studies and capacity-building programmes during the year, which included:

A study to identify and assess the potential for energy efficiency investments in five production units (PUs) of Indian Railways, with a view to quantify CAPEX requirements, which can be funded by KfW. The study revealed that there is a significant and sizeable energy-saving potential in all the PUs. An estimated 89 million units (MUs) electricity equivalent of annual energy savings can be saved in the PUs with an investment of INR 525 crore (US$ 76 million).

Need assessment study and upgradation of pump works in head house of Cauvery Stage I, II & III for Bangalore Water Supply and Sewage Board (BWSSB)

Water audit for Hindustan Aeronautics Limited and its entire township at Bengaluru

In-house energy management training programme for Haldia Petrochemicals Limited

A practical energy audit training programme for participants from industries in and around Bengaluru. More than 50 participants joined this programme.

ENVIRONMENTAL AND INDUSTRIAL BIOTECHNOLOGY

The Environmental and Industrial Biotechnology (EIB) Division works towards contributing in advanced solutions for remediation of contaminated environments, minimizing waste generation, and creating sustainable environment by providing clean energy solutions. The Division closely works with the oil and gas sector to improve their energy efficiency and to deal with their environmental concerns.

In order to maximize the reach of environment and Industry, its specialist teams synergize their capabilities and activities, both within and outside India. The EIB Division functions from the four areas: (i) Bioremediation Technology (BR) Area, located at TERI, New Delhi; (ii) Microbial Biotechnology (MB), located at TERI, New Delhi; (iii) Biotechnology Area, TERI-NE, Guwahati; and (iv) Agriculture and Rural Extension Area, TERI-NE, Guwahati.

Bioremediation Technology Area

Fermentation Technology Research Centre

With the state-of-the-art pilot-scale bioreactor facility, the Centre has successfully developed the best-selling technology – '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 by 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 the area grab a major project of Kuwait Oil Company (KOC) through a global competitive bid, for the bioremediation of 2.8 million tonne of oil-contaminated soil. After the successful completion of this project, the Oilzapper technology has bid for a second-phase mega tender (KERP Bioremediation in South Kuwait) for remediation of total petroleum hydrocarbon (TPH)-contaminated soil in the KOC oilfield and for clean-up of oil-contaminated sites.

Oilzapper product was developed after 7 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.

Industrial-scale and industrial bioreactor facilities were set up by TERI at Gwal Pahari. At present, there are bioreactors and utilities at Fermentation Technology Research Centre, as mentioned here:

Bioreactors

- 3.2 L and 100 L photo bioreactors
- 10 L, 30 L, 100 L, 200 L, 1000 kL, and 13,000 L bioreactors

***In-situ* and *ex-situ* Bioremediation of Oily Sludge/Oil-contaminated Soil of Various Production Pits in Assam Field**

The Bioremediation Technology Area was awarded a work order by Oil India Limited, Duliajan to provide services for *'In-situ* and *ex-situ* bioremediation of oily sludge/oil-contaminated soil of various production pits in Assam Field'. In this project, TERI focuses on site assessment and bioremediation of oil contamination that occurred due to a fire accident at gas well No. 5 at Baghjan oilfield. TERI adopted an aerial survey technique using a drone fly for the assessment of volume of land contamination. To treat the oil-contaminated field, a bioremediation process using microbes provided by R & D Department, Oil India Limited Duliajan, Assam has been undertaken. In this project, TERI is treating approximately 160,000 m^2 oil-contaminated area. The contaminated site shall be restored within 12 months and to reclaim natural vegetation native plant species will be introduced in the field.

Aerial view of the oil-contaminated site at Baghjan oilfield area

Research Activities of Bioremediation Technology Area

Development of Hexachlorocyclohexane-degrading Bacterial Formulation

Biostimulation and bioaugmentation are the two methods that are efficient for remediation of persistent organic pollutants. The area's studies have reported these methods as practically viable approaches for decontamination of hexachlorocyclohexane (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 the Umari land. In the Umari Village project, teams at the University of Delhi, TERI, CSIR-NBRI, CSIR-IITR, and Ramjas College, Delhi, who joined hands with complementary expertise, undertook a demonstration of the remediation of the large-scale HCH dumpsite. TERI produced a large volume of HCH-degrading Sphingobium B90A bacterial culture in a 13 KL bioreactor which was discovered and developed by the University of Delhi. TERI conducted bioaugmentation and biostimulation at the site. The bacterial formulation and specially designed nutrient

HCH dumpsite lying at Umari Village, Barabanki before bioremediation field trial

Application of microbes and tilling at the oil-contaminated site

mixture developed by TERI were applied into the field. The field trial assessment is continuing since last two years and the progress is satisfactory. Once the project is successful, demonstration of the technology for HCH decontamination can be used worldwide. The present study will also generate a new-of-its-kind technical skill in the bioremediation sector.

Consultancy Service for Assessment of Soil Fertility in Ankleshwar Asset, ONGC

The area involves bioremediation of oil-spilled environments and oily sludges from oil companies. The team had undertaken a study to ascertain the agricultural soil fertility of ONGC oilfields in Ankleshwar, Gujarat. In this study, 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 the soil samples of contaminated and uncontaminated reference sites.

Development of Up-flow Anaerobic Bioelectrochemical System

TERI in collaboration with Korea Maritime and Ocean University, South Korea developed a hybrid system called 'Up-flow anaerobic bioelectrochemical system' (UABE) for the production of enhanced methane from distillery wastewater. The UABE system is superior in methane production and chemical oxygen demand reduction in comparison to a conventional anaerobic digester.

UABE system (100 L)

Advanced Wastewater Treatment Process

The area recently completed an Indo-Hungary bilateral project which demonstrated the advanced wastewater treatment process called 'Biocatalytic membrane bioreactor system' for the treatment of emerging micropollutants in wastewater. A research expert from the University of Pannonia, Hungary visited TERI and demonstrated an enzyme-based system for the effective removal of pharmaceutical residues from wastewater.

Development of Eco-friendly Oil Well Drilling Fluid: XC Polymer (Xanthan Gum)

In 2015, TERI initiated a study to develop an XC polymer with a view to provide an eco-friendly technology to the oil industry, to be used for drilling fluid/viscosifier. The XC polymer was produced by the process of bacterial fermentation along with the addition of selective chemical additives to achieve the drilling fluid standards. The feasibility of the developed product was analysed and further tested at the Institute of Drilling Technology (IDT), ONGC Dehradun and Chemical Laboratory, Oil India Limited, Duliajan. The product is under field-level validation for the commercial application. The industrial applications will be done by ONGC TERI Biotech Limited (OTBL), a joint venture of TERI and ONGC which will also open up new opportunities.

Microbial Biotechnology Area

The Area is actively engaged in exploring sustainable approaches for the protection of environment, development of innovative technologies, and alternate renewable energy production for commercial application. The Area mainly focusses on a basic and applied research for exploring microbes towards the development of sustainable solutions for the industry.

Focus/thrust area

- Demonstration of microbial methane generation enhancement from poor to marginal-producing coal bed methane (CBM) wells (fields).

- Microbial Enhanced Oil Recovery (MEOR) for better 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 in oil/gas pipelines
- Prevention of paraffin deposition in oil well tubing.
- Sequestration of CO_2 with simultaneous production of commodity chemicals.
- Metabolically engineering for industrial-scale production of commodity chemicals.
- Exploitation of metagenomics for the production of biodegradable plastics.
- Development of potential probiotics from novel sources.
- Developing green corridor (plantation) on highways and greening of schools for environment sustainability.
- Application of a recombinant strain for the industrial-scale production of a commercial enzyme.
- Detection of bacterial drug resistance, AMR phenotypes through targeted nucleic acid via the CRISPR-CAS system.

Microbial Enhanced Oil Recovery

A technology for enhancing oil recovery in dead or abundant oil wells was jointly developed by TERI and Institute of Reservoir Studies, ONGC. The technology is currently commercialized by OTBL. Another customized thermophilic bacterial consortium was developed for the US oilfields in a joint venture with Glori Oil, and is being implemented in oil wells in Texas, USA. Carrying forward MEOR activities, the Area developed a highly effective bio-based technology for tackling viscosity reduction of heavy oil in flowlines. Currently, the Microbial Biotechnology Area is exploring the potential of biopolymers 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, the BcEOR process holds tremendous potential to be developed as a full-fledged technology for the production of residual oil in an economical, environment friendly, and sustainable approach.

Biological Enhanced Methane Production from Coal

India is the world's third largest producer of coal. The reserves in India were estimated at around 298.94 billion tonne, as on March 31, 2013. As per Directorate General of Hydrocarbons (DGH) database, India has 92 trillion cubic feet of CBM gas reserves; however, the commercial production of CBM is still at a very nascent stage in the country. ONGC is currently operating in four CBM blocks, which are in Jharia, Bokaro, North Karanpura, and Raniganj. It is estimated that on average only 15–20% of the coal is recoverable and the rest of it lies unexploited. Utilization of the 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 CO_2.

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

Therefore, microbially 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.

Online methane monitoring system set-up at the Jharia site

CBM site execution team

Carrying forward these research explorations, the Area is working towards the development of a microbial biosensor to detect oil and oil-derived compounds in the environment; 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 government and various industries, the Area is keen on finding a sustainable solution to climate change-related problems by identifying bacteria for the production of cleaner energy forms, for carbon capture and storage that would displace methane on coal seams with carbon dioxide, and for bioremediation of mine water treatments.

The Microbial Biotechnology Area has also started a number of projects under its CSR initiatives, such as green corridor development with environment awareness programmes engaging schools, community, government, and other stakeholders, for a mass movement towards sustainability.

Biotechnology Area, TERI-NE, Guwahati

The biotechnological research of the Area includes treatment of wastewater using potential algal strains and phototrophic biofilm-facilitated adaptation conditioning of algal and bacterial association leading to easier harvest of biomass. In the molecular biology facility, research was initiated for transcriptome-driven isolation of unculturable bacterial strains for mitigation of drought stress in tea plantations. In the field of improved sanitation, the Area installed 100 prefabricated biotoilets with glass FRP (fibre-reinforced polymers) material in 100 schools of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. Researches on fungal pectinase for banana fibre extraction and citrus aphid biocontrol were also initiated by the area.

The Area 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 average sludge depth in an anaerobic digester for a day school was 0.004 m/month and sludge volume was 0.0075 m^3/month whereas for a hostel, sludge depth was 0.007 m/month and sludge volume was 0.0137 m^3/month. The projected sludge coverage of an effective volume of the digester installed in a day school was 213.3 months or 17.8 years and for hostels, it was 116 months (9.7 years). Therefore, frequent de-sludging of a digester is not required which is an added advantage in rural areas where de-sludging is a major challenge. Besides reducing BOD, COD, and faecal coliform in discharge, the anaerobic digester also yielded biogas, which was 32.58 NL per day in Meghalaya and 31.48 and 32.89 L per day in Tripura. The average biogas yield in Meghalaya was 0.523 NL/g COD removed and in Tripura 0.625 NL/g COD and 0.610 NL/g COD removed. The methane yield in Meghalaya was 15.96 L per day and in Tripura 15.43 L per day and 16.11 L per day. The methane composition of biogas was 49%. The average methane yield in Meghalaya was 0.256 NL/g COD removed and in Tripura 0.306 NL/g COD and 0.299 NL/g COD removed against the theoretical methane yield of 0.350 L per COD.

Learnings from the experience of a capacity-building exposure workshop held last year for senior officials of urban local bodies were consolidated and implemented in this year's activities conducted in Assam, Arunachal Pradesh, Manipur, Nagaland, and Tripura.

This year, capacity-building workshops for elected representatives of Assam, Manipur, and Tripura were conducted in Jamshedpur and Imphal.

With the vision to increase community resilience, TERI implemented a project that aims to upgrade and develop certain key public spaces for schools and *Anganwadi* centres. The project focuses on strengthening health services by reducing vulnerabilities due to poor access to health facilities and providing a nurturing environment for children. Under the project, TERI upgraded sanitation infrastructure in 15 *Anganwadi* centres and 6 schools in Rani Block, Kamrup district, Assam.

The Area initiated a research study on citrus aphid biocontrol. The insect cuticle is made of a heterogeneous mixture of lipids, long-chain alkenes, esters, and fatty acids that evolve as a barrier to pathogenesis. Entomopathogenic fungi are considered as one of the safest methods to control pest due to their high target specificity. Performance of these entomopathogenic fungi varies considerably to a degree of pathogenicity and virulence. Pathogenic fungi penetrate into the host external surface and after utilization of nutrients, citrus aphids get killed. The study aimed to improve the effectiveness of entomopathogenic fungal bioformulation to control citrus aphids. So far, 29 fungal strains have been isolated from mustard aphid cadavers and soil samples, and their *in-vitro* pathogenicity assays revealed seven fungal strains having different degrees of virulence – *Verticillium lecanii* (>80% mortality), *Paecilomyces fumosoroseus* (100%), *Cladosporium oxysporum* (100%), *Beauveria bassiana* (70%), *Fusarium culmorum* (67%), and *Metarhizium anisopliae* (69.2%) against citrus aphids. *Cladosporium oxysporum* caused 100% mortality @ 1 x 108 spore loads after the fourth day of treatment and 100% mortality @ 1 x 109 spore load after the third day. *Paecilomyces fumosoroseus* caused 100% mortality @ 1 x 108 and 1 x 109 spore load after the third day.

Research on fungal pectinase for banana fibre extraction was undertaken by the area. Fibres in a biological material exist in a complex structure of ligno-cellulose that are not easily separated during a fibre extraction process, thus, degumming is required to dissolve them during the process. Banana fibres are extracted using either an alkali or an acid treatment for degumming which are neither eco-friendly nor user-friendly. Pectinase are a group of enzymes that break down pectic polysaccharides of plant tissues, thus loosening of the pseudo stem tissue thereby facilitates the extraction of banana fibres efficiently. Therefore, the exploration of pectinolytic enzymes from native fungal strains on banana pseudo stem and evaluation of their efficiency was attempted for eco-friendly extraction of a quality banana fibre. So far, 17 fungal strains have been isolated, of which 9 isolates showed pectinase activity, of which 6 strains had laccase-degrading properties. The Plackett–Burman design was followed for the optimization of pectinase production. The significant factors identified were peptone @10 g/l, pH@4, and $MgSO_4$ @ 0.8 g/L for *Phoma herbarum*. Among the strains studied, *Phoma herbarum* and *Aspergillus niger* showed higher enzymatic production efficacy. Mechanical, chemical, and biological treatments are followed for the extraction of banana fibres. The Young's modulus and tensile strength decreased with increasing banana fibre diameter. The enzyme synthesised by *Phoma herbarum* (ENZ-5/2 h-treatment) showed better results with higher tenacity (201.407/den) and toughness (3.974 g/den) which was followed by *Aspergillus niger* (ENZ-4/2 h treatment) with tenacity (149.278/den) and toughness (2.252 g/den). The chemical treatment showed poor response [commercial soda (CHEM-2/24 h)-tenacity (131.953/den) and toughness (1.570 g/den)] in comparison to enzymatic treatment.

In another study, rubber wastewater discharge was remediated with a biofilm developed by microalgal and bacteria consortia isolated from waste. Lead findings were microalgae/bacteria either in planktonic or biofilm environment. The wastewater pH rose from 4 to 12 in a week with substantial reduction of N, PO_4, COD, and TDS. The alkaline water requires neutralization before recycling/disposal to environment to avoid creating sludge. To neutralize the pH and avoid sludge, TERI initiated a research proposal of caption addition in the form of Ca or Na after algal/bacterial optimum growth. The carbonate salt compound for precipitation of $CaCO_3$ or $NaHCO_3$. $CaCO_3$ can be applied to the rubber plantation as a soil binder to reduce soil erosion in high rainfall sloppy areas. $NaHCO_3$ can be utilized locally as a cleaning agent for low-cost hygienic sanitation.

The Area participated in a Civic Outreach Programme jointly organized by 175 BN CRPF and UNDP at Rani Development Block, Kamrup, Assam on January 7, 2020. In this programme, TERI discussed about its bio-toilet project and its importance in sanitation and waste management in schools. About 1000 visitors comprising members of rural communities, CRPF personnel, and school children participated in the programme.

Biotechnology Area, TERI-NE, Guwahati

Agriculture and Rural Extension Area, TERI-NE, Guwahati

The research and development activities of the Agriculture and Rural Extension Area, TERI-NE centre include production of quality planting materials and demonstration; Eri silkworms; 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 the sericulture sector, the Area carried out a project titled 'Ericulture for upliftment of socio-economic condition of rural women in tribal villages of Assam' under the biotechnology-based programme of DBT for the societal development in Kamrup and Udalguri districts of Assam covering 120 direct beneficiaries from 22 tribal villages in Assam. Under this project, separate 60 rearing houses were developed and 60 improved Eri spinning machines were provided to the beneficiaries. Simultaneously, training programmes on Eri silkworm rearing, pest and disease management, issues related to the post-cocoon sector, and spinning were organized in the project villages. A total of 2040 DFLs were provided to the beneficiaries for rearing. The beneficiaries were able to get 479,400 cocoons by rearing 2040 DFLs, supplied under the project, and generated income to the tune of INR2350 per 10 DFLs per beneficiary from a single crop. The project activities created a positive atmosphere among the Eri rearers in the selected villages, as they witnessed the benefit accrued from the project interventions. Also, many women from the nearby villages showed interest in rearing of Eri silkworm, based on which some of them were provided DFLs to rear Eri silkworm.

The Area is involved as a Monitoring, Evaluation, Learning and Documentation agency for monitoring and evaluation of 47 Integrated Watershed Management Programmes in five districts of Assam.

In its efforts to promote horticulture in the region and improve the productivity, the Area 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. As a capacity-building initiative, TERI-NE organized various training programmes for key stakeholders of the projects to equip them with skills for ensuring sustainable livelihoods.

Considering the adverse environmental impact of plastics, it is desirable to promote alternative packing materials. In north-eastern states of India, as an alternative of plastic, the leaves of the plant *Phrynium pubinerve* are used as a wrapping and packing material. For the large-scale cultivation of *Phrynium pubinerve*, to enhance income among low-income scheduled tribe group in Meghalaya and to reduce environment pollution, a project titled 'Cultivation of Packing Leaves Plant for Livelihood Enhancement of ST Communities and Promotion of Packing Leaves as Substitute of Plastics in Meghalaya' was initiated. Under the project, baseline surveys were carried out in 17 villages in Ri-Bhoi and West Garo Hills districts of Meghalaya and FGDs were also carried out for awareness generation and understanding the perception of the communities. A total of 132 scheduled tribe beneficiaries were selected before conducting training and awareness programmes. Four net houses were developed and the cultivation of the plant was initiated covering 72 ha area.

Peptic Ulcer Disease (PUD) has been representing a major health problem in terms of morbidity and

mortality since hundreds of years. An estimated 15,000 deaths occur each year due to PUD. In the Indian pharmaceutical industry, antacids and antiulcer drugs share INR 6.2 billion and occupy 4.3% of the market share. The clinical evaluation of currently available drugs showed development of tolerance and incidence of relapses and side effects that make the drug's efficacy arguable. An indigenous drug possessing fewer side effects is the major thrust area of the present-day research, aiming for a better and safer approach for the management of PUD. There is a rich traditional medicine system in the north-eastern part of India. Through traditional methods, local communities in the region use indigenous plants to treat different types of ailments including ulcer. Screening of such plants is very important for drug development. In view of the mentioned facts, the project titled 'An ethnobotanical survey of indigenous plants of Assam and Arunachal Pradesh and their pharmacological screening for antiulcer potential' was initiated to inventorize anti-ulcer plant species from Arunachal Pradesh and Assam and to screen them for antiulcer activities. The present exploration will be effective for finding a novel lead from a number of standardized antiulcer plant species and their antiulcer activity, which might be of clinical significance. Under this project, 18 ethnobotanical surveys were carried out in 10 districts of Assam and 6 districts of Arunachal Pradesh. A total of 40 anti-ulcer plant species were collected from Assam and Arunachal Pradesh, and out of these, 33 samples of 31 plant species were submitted to the partner institute. Pharmacognostic studies were carried out for 13 plant species and physiochemical studies were carried out for 24 plant species. A total of 22 plant materials of different plant species were extracted. Fractionation of three plant samples, which showed antiulcer activity in the preliminary biological screening, was done. Acute toxicity studies of active fraction of *Garcinia morella* and *Phlogacanthus thyrsiflorus* were carried out.

In the north-eastern region of India, the Area also works towards the production of quality planting materials and provision of rural extension services. Carrying forward its activities, the Area focuses on commercializing its low-cost, highly effective bio-based technologies for tackling viscosity reduction of heavy oil in flow line, enhanced methane production from coal bed, and biological hydrogen production process. The biological hydrogen production process has prime importance in generating hydrogen in a sustainable manner from waste without relying on conventional fossil resources. The MEOR technology developed by EIBD with the aid of IRS/ONGC achieved substantial recognition across the public sector oil companies in India for enhanced oil recovery from oil reservoirs by tackling the worldwide problem of oil well stripping.

Currently, in partnership with various industries, the Area is working towards finding a sustainable solution to climate change-related problems by identifying bacteria for the production of cost-to-cost, cleaner energy forms, for carbon capture and storage which 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.

INTEGRATED POLICY ANALYSIS

The Integrated Policy Analysis (IPA) Programme aims to inform policy on the critical sustainability issues of our time through an in-depth and interdisciplinary research. The research seeks to answer the central question, 'How can policy be designed to scale up solutions that successfully decouple economic development from natural resource use and environmental degradation while enhancing livelihood opportunities and the quality of life?'

The Programme aims to provide an integrated perspective for policy design, with a focus on analysing the following issues:

- Demand and availability of resources from multiple perspectives and scenarios, including carrying-capacity assessments;
- Energy demand estimation and forecasting;
- Sustainable production including resource efficiency, waste management, and circular economy, and linkages with larger socio-economic issues;
- Sustainable consumption, with a focus on lifestyles, consumption patterns, and waste generation;
- Resource and environmental governance and its political economy at local, national, and global levels;
- Modelling and analysis of economy–energy–environment linkages and alternative development pathways;
- Biophysical interactions across land, water, air, and biodiversity.

Research on these issues is complemented by a range of publications and active participation of the programme members in training programmes, conferences, other events, and government working groups to enhance the outreach and impact of work. This work is carried out through two centres of the Programme—the Centre for Resource Efficiency & Governance and the Centre for Integrated Assessment & Modelling.

Centre for Resource Efficiency and Governance

Centre for Resource Efficiency and Governance (CREG) of Integrated Policy Analysis Division leads TERI's work on resource efficiency and circular economy, sustainable consumption and production, sustainable agriculture policy, resource governance, trade in natural resources, Sustainable Development Goals (SDGs), and sustainability assessments. The Division has a multidisciplinary team of experts drawn from the fields of economics, finance, agriculture science and policy, energy engineering, law and trade, and international relations and political science. The Division employs innovative data-driven analytical tools, monitoring and evaluation frameworks, and policy coherence tools for effective and efficient execution of projects.

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 demand forecasting studies, techno-economic analysis, and simulate alternative development scenarios to study the implication of alternative energy use pattern. 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 analyses of energy- and climate change-related data.

The CIAM was also engaged in providing inputs to the MoEFCC, GoI, through its study on long-term low-carbon development strategies for India. The project focused on developing alternative energy-economy scenarios for India to examine the implications of India's development trajectories with varying focus on energy access, jobs and clean energy/ sustainable urbanization objective.

ENGAGE Project Kick-Off Meeting, 18-20 September 2019 – IIASA, Laxenburg, Austria

During the year 2019–20, the CIAM completed two projects supported by the Norwegian Ministry of Foreign Affairs (NFA). These projects focused on undertaking a detailed estimation (across five grid regions, various seasons) of energy (in particular electricity) requirements across various end-uses, particularly in the residential and commercial sectors at different times of day (ToD). Detailed information of electricity use at the end-use level has remained a big data-gap in India. This study focused on understanding the electricity use patterns in the residential/ commercial sectors to better understand the variations in consumer behaviour, regional differences, and income-related variations towards ownership and use of various appliances. The understanding of detailed consumption of electricity patterns provides useful inputs for modelling study and was also examined through the development of an integrated energy demand–supply model (using TIMES platform) to examine a resource-efficient and sustainable energy development. The disaggregated analysis undertaken in this study can help analysts and policymakers better identify areas where intervention is required to manage demand and reduce demand–supply gap. This in turn will help India achieve low-carbon and resource–efficient growth.

In another project supported by NFA, CIAM has developed an integrated energy demand–supply model (using TIMES platform) to achieve a resource-efficient and sustainable energy sector. The development of the pilot TIMES model for India representing the enhanced understanding of future electricity demands across end-uses (especially in the residential and commercial sectors) can provide useful indications to planners and policymakers in furthering innovative policy and technology solutions for resource efficient development.

The CD-LINKS, supported by the European Commission under the Horizon 2020 framework focused on linking climate and development policies. This project aimed at conducting joint research and shared experiences, methods, and data between leading research institutions and key stakeholders from G20 countries. The main objectives of this project were to improve the scientific understanding of the linkages between climate change and multiple sustainable development objectives by broadening the evidence base in the area of policy effectiveness by exploring past and current policy experiences and develop globally consistent, national low-carbon development pathways to establish a research network and capacity-building platform in order to leverage knowledge-exchange among institutions from Europe and several non-European G20 countries. The project evaluated several alternative scenarios indicating India's choices and challenges in undertaking more ambitious emission reduction targets that were compatible with global scenarios depicting the well below 2°C world.

The flagship publication of the CIAM, *TERI Energy and Environment Data Diary and Yearbook* (*TEDDY*) is an annual publication, which 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.

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, address health impact, 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

Centre for Global Environment Research

The Centre for Global Environment Research (CGER) in TERI leads work on various dimensions of climate change and cross-cutting themes. At the CGER, our work 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 include coverage of research that spans the scientific aspects, covers technology, finance dimensions across areas and sectors, and policy on climate. Of late, in the impact and adaptation domain, the Centre has been aiming to build the gender narrative and 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. A focus on research that is applied and of interdisciplinary nature exists.

Globally, the Centre has tapped onto the work modulus under international commitments, such as the Paris Agreement and Montreal Protocol (MOP), 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 Nationally Determined Contributions (NDCs) implementation, transparency and MRV frameworks, climate finance and markets, adaptation and resilience, loss and damage, and global stocktake. 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 contributes 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' 2020, launched in November 2020. 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 also been contributing to Fiji's NDC implementation road map and the *'State of Environment Report'*.

Specific to the Paris Agreement, the Centre has prepared a framing document to aid the formulation of a long-term mitigation and adaptation strategy for India (in line with Article 4.19). It identifies 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 NDCs' implementation (Article 4), the Centre is carrying out research on understanding modalities, procedures and guidelines (MPGs) and its implications for developing countries such as India, tracking NDCs' implementation, and supporting the domestic institutional set-up in the country.

Under the MoP and in the light of India's commitments within the Kigali Amendment, the Centre is carrying out research on understanding the global trends to meet the obligations under the Kigali Amendment, providing platform to the industry to share innovations measures on hydrofluorocarbons (HFCs) transitions and inform policymakers about developments in MoP, Open-ended Working Group (OEWG), and Ex-Com negotiations. The Centre is leading a civil society initiative, namely 'SHEETAL: Alliance for Sustainable Habitat, Energy Efficiency and Thermal Comfort for All' in collaboration with the Alliance for an Energy Efficient Economy (AEEE) and the Council on Energy, Environment and Water (CEEW) with the support from Children Investment Fund Foundation (CIFF). It aims at providing 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 governments of Union Territories of Chandigarh and Puducherry to revise their State Action Plans for Climate Change according to the new guidelines issued by the Ministry of Environment, Forest and Climate Change (MoEFCC), and thereby contributing to enhancing 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 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 development of MEL/MRV frameworks for buildings, transport, renewable energy, and agriculture sectors.

The year 2019/20 has been of eminence for the Centre as TERI was set to co-host the Adaptation Futures 2020 with the World Adaptation Science Program (WASP). Adaptation Futures is the flagship event of the WASP which is one of the four components of the World Climate Programme based on the World Meteorological Organisation Congress XVI Resolution 18. The 2020 edition is the sixth in the international conference series on global adaptation and the first to be held in Asia. Adaptation Futures 2020 will focus on the overall theme of accelerating science-based adaptation action and will serve to shine a spotlight on adaptation challenges and action in the Asian context. It will also emphasize knowledge sharing and co-learning for actionable solutions across the Global North and the South. Owing to the unforeseen circumstances due to COVID-19 and the resultant travel restrictions, the Steering Committee took the decision to postpone the conference to year 2021.

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 our noteworthy stakeholders and beneficiaries.

Centre for Environmental Studies

The Centre for Environmental Studies (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 various projects to examine environmental impacts associated with urbanization, industrialization, and other anthropogenic activities. Our research has focused on several aspects of the issue of air pollution, including regional-scale assessment of air quality, impact 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. CES has also been active in providing assistance to government bodies for the formulation of 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 focused on providing state-level policy recommendations through several source apportionment studies, which guided state-level regulatory authorities to develop local 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 N-CAP document and has also submitted emergency response plan to both state government 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 already ongoing in many cities and several new proposals are being formulated for 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 through application of biochar, etc.

Centre for Climate Modelling

The Centre for Climate Modelling (CCM) focuses 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, the first-of-its-kind TERI Climate Tool (TCT) is available at *tct.teriin.org* and assisted deployment of flood early warning system at urban scale, is 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. 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).

[1] CCSM–Community Climate System Model by National Centre for Atmospheric Research (NCAR-US)
[2] CESM–Community Earth System Model by NCAR
[3] GFS–Global Forecast System
[4] PRECIS–Providing Regional Climate for Impact Studies by UK Met Office
[5] WRF–Weather Research and Forecasting by NCAR
[6] NoRESM–Norwegian Earth System Model
[7] COAWST–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

Forest and Biodiversity Division

Centre for Biodiversity and Ecosystem Services

Biodiversity, upon which millions of people depend for myriad services, is under unprecedented pressure. This pressure is threatening to unravel and weaken the resilience of complex and fragile ecological systems, and endanger wildlife populations. TERI's Forestry and Biodiversity Division has focussed on the sustainable management of forest ecosystems and the conservation of biodiversity for over two decades. Realizing that loss of biodiversity has enormous implications for society, for poverty alleviation, and for meeting the Sustainable Development Goals (SDGs), the Centre for Biodiversity and Ecosystem Services (CBES) embedded within the Forestry and Biodiversity Division takes a broad view of biodiversity. The focus is not only on species or habitat loss but also on policies and 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, the involvement of a wide portmanteau of stakeholders, and a focus on valuing biodiversity and ecosystems.

1. Economic Valuation of Ecosystem Services

TERI conducted the 'first-of-its-kind' study 'Economic Valuation of Ecosystem Services of National Zoological Park in Delhi' with a robust and refined methodology. The annual value of key ecosystem services comprising use and non-use values, such as carbon storage and sequestration, employment generation, recreation, education and research, biodiversity conservation, and the surrogate value of land has been evaluated in this study. The total annual economic value of the ecosystem services (biodiversity conservation, employment generation, carbon sequestration, education, and research—recreational and cultural) is estimated to be INR 422.76 crore (2019/20). The total value of the one-time cost of services such as carbon storage and land value provided by the zoo is estimated to be INR 55,209.45 crore. This study highlights the importance of habitats such as zoos to human well-being and the need for replication across India.

Based on this work, TERI has now been awarded a study to conduct economic valuation of the ecosystem services provided by Sardar Patel Zoological Jungle Safari, Cactus Garden, Butterfly Garden, Ekta Nursery, Vishwa Van, Valley of Flowers, Arogya Van, Children Nutrition Park, and Statue of Unity in Kevadia, Gujarat.

In addition, TERI has also initiated a World Bank-supported consultancy on economic valuation of mountain forests and mangroves in the Kingdom of Saudi Arabia (KSA). The assignment looks to contribute to the KSA government's technical capacity for land-use planning through the assessment of forest degradation

Surveys conducted to estimate economic valuation of services such as livelihood (left) and carbon sequestration (right); picture credit: Siddharth Edake

Grassland (left) and wetland ecosystems (right) of Dudhwa Tiger Reserve

and important forest ecosystem services in actual and future development planning processes in order to promote the integration of ecological considerations into decision-making and planning policies.

2. Conservation of Protected Areas through Carbon Finance: Implementing a Pilot Project for Dudhwa Tiger Reserve

The project funded by the Royal Norwegian Embassy is in collaboration with the Uttar Pradesh Forest Department and CICERO—Centre for International Climate Research. The project aimed on developing an index to standardize the contribution of co-benefits of biodiversity conservation and livelihood enhancement in protected areas (PAs) of India such as Dudhwa Tiger Reserve. The key objectives of the project are to determine and develop a Climate, Community and Biodiversity alliance value (CCBA Value) and develop a mechanism for obtaining carbon finance from voluntary markets. The project also aims at improving the habitat and ecosystem services of the PA by addressing the issues of human–wildlife conflict and increase in income of the people living in and around PAs.

The methodology to understand the contribution of the ecosystem services was based on valuing services provided by DTR, such as firewood, minor forest produce, fodder and grazing, carbon sequestration, and recreation. The total economic value of DTR was estimated to be INR 10.58 billion in 2019 wherein the value of ecosystem services was found to be eight times greater than the value of carbon. Including these benefits in the carbon finance shall yield eight times more benefits as compared to the benefits from afforestation project.

3. Developing a Resource Mobilization Strategy for Implementing the State Biodiversity Strategy and Action Plan (SBSAP) of Uttarakhand and Demonstration of Select Financial Solutions for Conservation of Snow Leopard Landscape, Gangotri-Govind and Darma Byans Valley in Uttarakhand under the GOI–UNDP Project on SECURE Himalaya

Biodiversity finance is the practice of raising and managing capital and using financial incentives to support sustainable biodiversity management. It includes raising and mobilizing funds from private and public sectors, investments in commercial activities that produce positive biodiversity outcomes, and the value of the transactions in biodiversity-related markets. TERI carried out the BIOFIN project in the pilot state of Uttarakhand under GOI–UNDP SECURE Himalaya Project. Under it, Policy and Institutional Review, Biodiversity Expenditure Review, Financial Needs Assessment are carried out to formulate a biodiversity finance plan. The whole process is guided by BIOFIN Approach and synergized with global conventions and plans.

The results show that the total financial need assessment for implementing SBSAP is INR 12,874 crore (2018–30) while the biodiversity expenditure review is INR 15,787 crore (2018–30). Hence, the biodiversity expenditure is well above the finance needs assessed; thus emphasizing the need to just realign the current

Stakeholder consultation cum validation meeting to finalize SBSAP in Uttarakhand

expenditure through the existing legal and institutional framework. The Ministry of Agriculture and the Ministry of Rural Development are the major contributors towards biodiversity-attributable expenditure. Assessing their expenditures and allocations can help in mainstreaming biodiversity within these sectors.

4. Preparing a Detailed Project Report to Set Up a Centre of Excellence for Sustainable Land Management at ICFRE, Dehradun

Land degradation is one of the most serious environmental problems confronting the world today, including India. Hence, the Hon'ble Prime Minister of India, while addressing the High-Level Segment of COP 14 to the United Nations Convention to Combat Desertification (UNCCD) in 2019, made an announcement to set up an International Centre of Excellence at the Indian Council of Forestry Research and Education (ICFRE) in order to further develop scientific approach and facilitate induction of technology on land degradation issues. In response to this, the ICFRE has assigned the task to TERI and Ernst & Young jointly for preparing a detailed project report to set up a Centre of Excellence for Sustainable Land Management at ICFRE, Dehradun.

5. Traditional Agriculture for Sustainable Development: A Satoyama Approach

Traditional land use, such as shifting cultivation (rotational farming) that has been practised for generations, preserves an intellectual wealth that is found only locally. Land use in which nature and people's livelihood coexist can be a model for sustainable development in increasing human population and food demand. However, a wrong stereotype about shifting cultivation as environmentally damaging and low in productivity, combined with outflow of rural population to cities, raises a critical concern about the degradation and loss of local intellectual asset.

In this background, the 'JFGE-Satoyama Approach Project' was developed and approved by the Japan Fund for Global Environment (JFGE). 'JFGE-Satoyama Approach Project' is the shortened name of the formal project name, 'Traditional Agriculture for Sustainable Development: A Satoyama Approach'. It aims to address this problem by directing scientific research and collection of cases and re-evaluate and re-appreciate traditional agricultural practices of India as a model of sustainable development. In the JFGE-Satoyama Approach Project, the three main components include: (i) the production of an edited academic volume on traditional farming for sustainable development in North-East India; (ii) compilation of knowledge in Nagaland and elsewhere in India; and (iii) knowledge exchange with other regions. These components are inter-related sets of activities that complement each other. JFGE-Satoyama Approach Project is being implemented over a period of three years.

Traditional agriculture and associated folk dances from Zunheboto district, Nagaland

Centre for Forest Management and Governance

The Centre for Forest Management and Governance (CFMG) deals with a diverse range of issues related to socio-economic, institutional, policy and technical aspects of India's forest resources and rural development. The Centre is actively working to promote 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 CFMG 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. CFMG has also put considerable effort into documenting its research findings on the key issues involved in this sector. Major projects of the group are as follows:

1. 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 fuelwood-saving technologies and adopting alternative livelihood options.

Under 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 Chulha 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 cookstove. The entire process of deploying the Sukhad model needs about 15 days from casting of stove to operationalization and it 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 a range of INR 150–200. Also, 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 2018–20. 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-makers to decide on the

plantations models resulting in fuelwood production and also make 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 chulha, portable improved cookstove and LPG have been provided 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 reducing over 90,000 tCO_2e. It has also reflected in increment in forest carbon in the natural forests.

Implementation of NAMA Project

2. Development of Forest Governance Model in 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 forestry division conducted 26 Focussed Group Discussions (FGDs) in different areas of governance in the country (Schedule V, Schedule VI, and others). These FGDs were conducted 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 was submitted to the Ministry of Tribal Affairs (MoTA) and it would help

to issue the broad guidelines and principle 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 would issue similar guidelines in consonance with guidelines of MoTA and further develop plan of action, such as capacity building of local governments and communities.

As a continuation of this work, CFMG is currently 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 set-up of Panchayati Raj Institutions. The outcome of this work will help to evolve Gram Sabha-based forest governance and to effectively involve local communities including tribals and non-tribals in sustainable forest management.

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

3. 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 group has been organizing capacity building and training programmes for different states in the country for Forest Department to assess the carbon stocks of forests and also developed a manual on the carbon stock assessment of forests. As of now, the training has been conducted in the states of Chhattisgarh, Uttarakhand, Punjab, Assam, and Goa. 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 the current year, 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 our 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.

4. Nursery Activities at Gwal Pahari

The Division 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 acre and supports facilities such as mist chambers, shade houses, hedge gardens, and clonal orchards with the capacity to produce 3000 clonal plants annually. It also has open area of approximately 1.2 acre for shifting and grading of saplings. TERI's conserved gene bank has over 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 which supplies more than 5000 herbal plants annually to schools, the National Medicinal Plant Board, Resident Welfare Associations (RWAs), New Delhi Municipal Corporation nurseries, and various state forest departments.

Herbal nursery at Gwal Pahari

Centre for Sustainable Land Management

1. 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 with respect to the livelihood-dependent families and women.

Hence, a project awarded by the MoTA in 2020 will address the critical gap in existing literature on the outcomes of land acquisition on Scheduled Tribes (STs) and Other Traditional Forest Dwellers (OTFDs), post-2013. This study on land acquisition, rehabilitation, and resettlement is in tandem with the guidelines issued under RFCTLARR Act and various state land acquisition laws. It would include analysis of comprehensive processes prescribed under various legislations for acquisition of land for private purposes and efficiency of Social Impact Assessment (SIA) in consultation with Panchayati Raj Institutions. The SIA determines a project's impact on the people's land and livelihood.

The anthropological and the sociological perspective of the study will provide reference points to the policy-makers, administrators, practitioners, academicians, researchers, and civil society to gauge the inclusiveness and sustainability of safeguards for the Scheduled Tribes and Other Traditional Forest Dwellers incorporated in the Central Law.

Coastal Ecology and Marine Resources Centre, Goa

The Coastal Ecology and Marine Resources Centre (CEMRC) 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 were successfully carried out for livelihood diversification, women empowerment, and entrepreneurship development, especially of artisanal fish through successful demonstration of aquaponics and fish cage culture supported by the National Bank for Agriculture and Rural Development (NABARD). Under the TERI-DBT Centre of Excellence, the project on aquafeed development from de-oiled algae has been initiated. Under the National Cyclone Risk Mitigation Project (NCRMP) of the Government of India, Environmental and Social Impact Assessment (ESIA) studies in Goa were successfully completed for saline embankments in the two villages of Divar and Poinguinim. Impact assessment of underground electrical cabling in the village of Anjuna was also taken up and completed. Both the ESIA projects were funded by the World Bank through the Government of Goa. Projects related to mapping and inventorization of biodiversity of coastal villages have been carried out with support from Goa State Biodiversity Board (GSBB) for Velsao-Pale, Anjuna, Raia, Nuvem and other villages, covering a total of 23 villages of Goa. With the support of NABARD, the digitization of self-help groups from the six coastal talukas of Goa was carried out. The TERI Coastal Education Hub was inaugurated in February 2019. It conducts awareness programmes and provides live demonstration of coastal and marine resources, and sustainable aquaculture technologies through field trip to a greater number of schools and colleges. A newly initiated project is the study on 'Microbial-indicators of anthropogenic stress in the Mangrove Ecosystems of Goa', supported by DSTE, Goa. This study will determine the response of microbial communities in Goa's mangrove ecosystems to anthropogenic pressures and establish the relationship between the structure and specific microbial activities, which gives an uncertainty of microorganisms' role in the ecosystem formation.

Under Water Science and Technology area, river bank filtration (RBF) technology and groundwater exploration studies, hydrological modelling and activities for water quality testing have been initiated. RBF projects have been completed successfully by providing water for domestic usage and for irrigation purposes. The project funded by the Department of Biotechnology (DBT), wherein a horizontal flow filtration tank in combination with vertical wetland is used to provide clean water, is completed and the same has been patented. A new 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.

In addition, the Centre organizes workshops, training programmes, and seminars regularly. A joint workshop was conducted on international cooperation in research and development, the BEST Goa-Portugal 2019 (Blue Economy, Science and Technology, 2019) was held during September 2019, in Goa. The CEMRC in collaboration with the National Centre for Polar and Ocean Research (NCPOR), National Institute of Oceanography (NIO), IIT Goa, and NIT Goa along with 10-member team of scientists from INESC TEC–Portugal, including the University of Porto, the University of Minho, the University of Trásos Montes e Alto Douro, and the Polytechnic Institute of Porto attended the workshop. The Centre also regularly organizes educational trips for schools to connect students to science and inspire environmental action. Exposure to different coastal habitats and traditional practices and sustainable technologies is also given to students.

Marine and Coastal Research

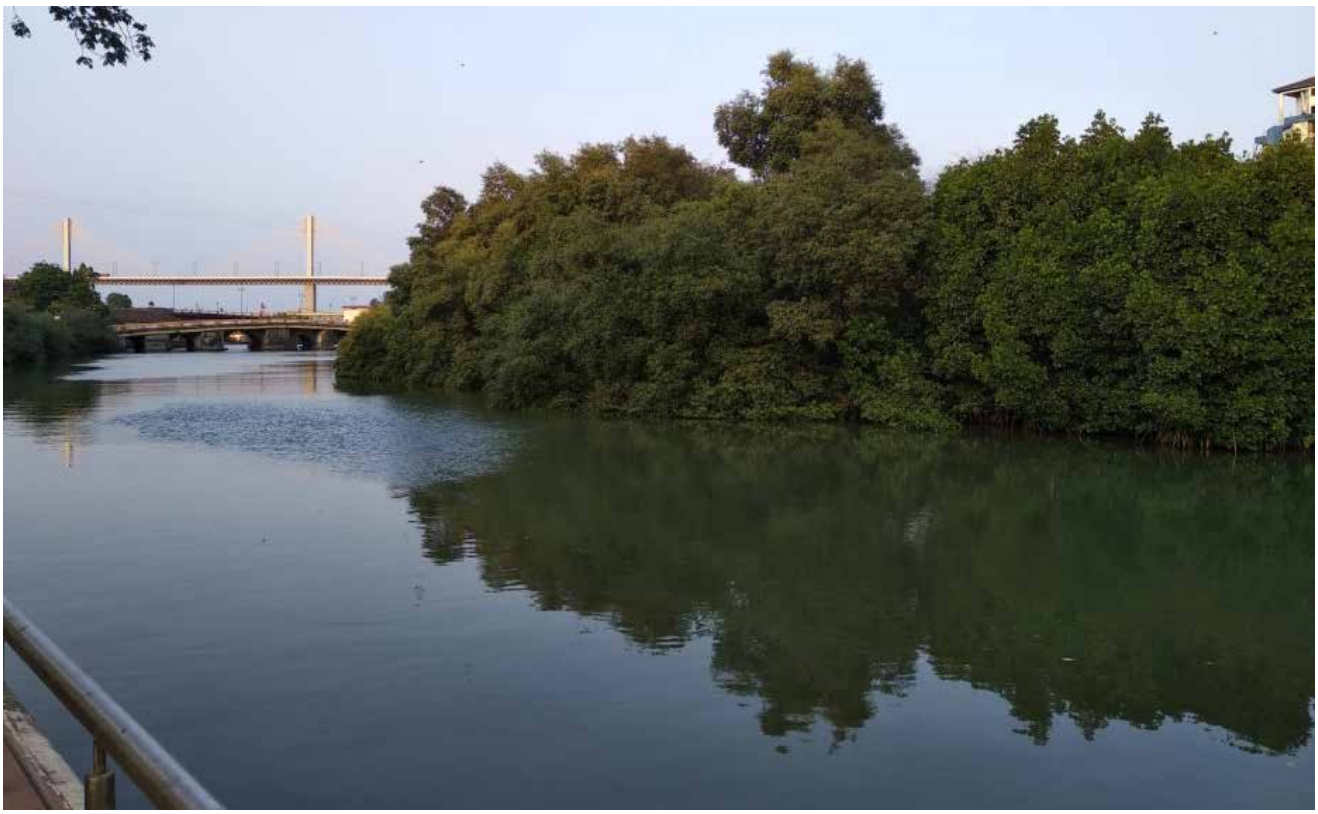
Project 1: City Biodiversity Index for the City of Panaji

In a rapidly urbanizing world with threat of climate change, it is important to understand how urban biodiversity is getting affected and how cities can have sustainable benefits by managing local biodiversity properly. CEMRC, Goa has worked on City Biodiversity Index (CBI) (also known as Singapore Index on Cities' Biodiversity) for the city of Panaji, a project funded by Imagine Panaji Smart City Development, Limited. The CBI is a dynamic self-assessment tool to know the status of urban biodiversity and how it can be improved over time with management and conservation efforts.

The assessment was primarily based on three core components, namely—(i) native biodiversity (plants, birds, butterflies, fish, and dragonflies), (ii) ecosystem services provided by biodiversity, and (iii) governance and management of biodiversity in the city. The ecosystem services provided by biodiversity had the highest city score. Native biodiversity component formed the baseline data. As the city of Panaji has several ecological niches ranging from hill to extended beautiful beaches, sand dunes, mangroves, lakes, creeks, and springs, and considering that this was the first assessment, the Panaji city CBI score turned out to be good. To improve the score in the next assessment, which will be due after three years, suggestions and recommendations are made which include implementation of more collaborative projects related to biodiversity and constituting a Biodiversity Strategy and Action Plan.

Project 2: TERI-DBT CoE Project—WP3.3 Aquafeed Development from De-oiled Algae

Fish is a valuable source of nutrition rich in protein and beneficial polyunsaturated fatty acids. Overfishing is a global problem with fish acquisition due to increasing fish consumption and insufficient recovery time for dwindling fish stocks in the oceans and seas.



Panaji city—Rua de Ourém creek with mangroves lined up along the creek edges

Experimental fish tank set-ups for aquafeed development housed in the aquaculture centre at the TERI Coastal Education Hub

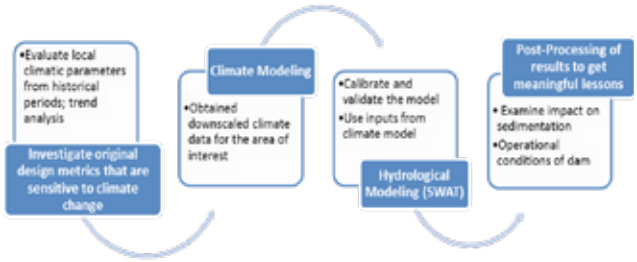
Aquaculture has quickly become an important source of fish and is now one of the biggest contributors to fish production. Although it provides nutritional security and gainful employment to millions in the sector, it is an expensive proposition with high consumption of fish meal and fish oil. Use of algae-derived products as alternative feedstuff is a cheaper option. Under TERI-DBT Centre of Excellence, the work package dealing with development of artificial fish feed using de-oiled algae has been initiated and tested. Small to large test set-ups are established for trial runs of aquafeed formulation with various combinations of ingredients in experimental feed diets for fish, such as tilapia, pearls spot, and common carp. Compositional analyses of formulated fish feed have shown to be rich in protein and essential for good growth of fish.

Water Science and Technology

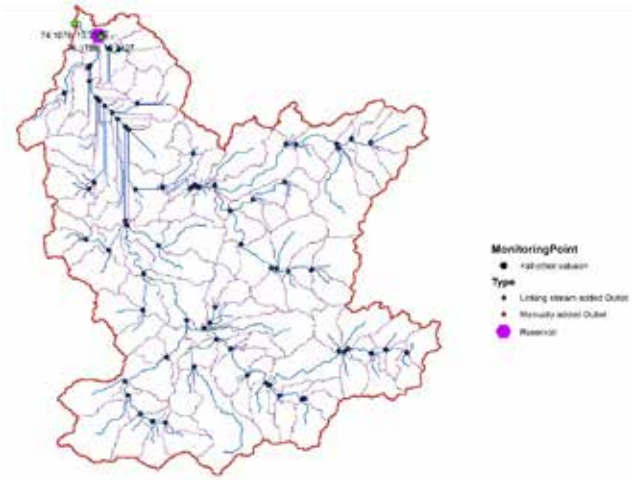
Project 1: Reservoir Sustainability: Evaluation of Climate Change Impact on Reservoir Inflows Using Climate and Hydrological Model—A Case of Salaulim Dam, Goa

The Research Question being addressed in this project is: How is reservoir performance affected under uncertainty included by impacts of climate change on hydrology? The study will provide policy inputs on how to manage multiple reservoir functions of supply of water on a reliable basis for domestic, irrigation, and industrial purposes.

The following methodology was adopted for the course of the study:



Project inception meeting with the Chief Engineer and other officials from Water Resources Department



Watershed delineation for Salaulim Dam using SWAT model

Project 2: Demonstration of River Sal Cleaning by Vertical Wetlands and River Bed Filtration

The river bank filtration technology works on the principle of creating pressure by pumping action which forces the polluted water in a river to travel to RBF well through river bed sediments, thereby removing contaminants, such as bacteria and heavy metals, by overlapping biological, physical, and chemical processes.

(a) *The triangular horizontal river bed filtration tank with different filter materials and the anti-microbial cage;* ***(b)*** *Solar panels (used for powering the pump) mounted on the BF tank;* ***(c)*** *Design of the cage with antimicrobial material (silver impregnated activated charcoal (left) and wood shavings with TPA (right)*

The project was initiated to treat Sal River, which is one of the most polluted rivers of Goa, along with the wastewater released by fish market at the project site that lies adjacent to the river. The site was not found to be suitable for installing a conventional RBF system, as planned originally because the region was a landfill area with highly contaminated topsoil. Hence, a horizontal, above ground bank filtration (BF) system with unique bioactive barrier (TPA soaked wood shavings and silver impregnated activated charcoal) for the effective removal of bacteria was designed and implemented. The system was designed to mimic processes taking place in natural wetland settings, such as straining, sorption, and biodegradation to filter water by passing it through several filter materials. A provisional patent is filled to protect the intellectual property of the innovative BF system design (Application No. IN 2019 11003694).

The BF system demonstrated on an average one log reduction (~90%) in total coliforms. With time, an increase in removal efficiency was observed with highest value of 99.6% (equal to 2.6 log reductions). Similarly, the mean *E. coli* removal efficiency for BF system was 91.7%. Further, the system also reduced the turbidity of the inlet water by removal of total suspended solids. The results demonstrated that simple design of the BF system makes it economically viable as pumps required for water movement were operated on solar panels and also most of filter material was locally available. This provides further scope to replicate similar model at other places for treatment of wastewater with necessary modifications.

Project 3: Off-the-grid Sensor Controlled Irrigation Using River Bank Filtration Technology

The WTI-DST 2018-funded project endeavours the demonstration of BF wells with off-the-grid solar pumping and sensor-controlled irrigation systems at Nauta Lake in Cortalim Village and river bank sites along Sal River in South Goa. The project, being unique to Goa, presents a model of sustainability for educating farming communities with small-land holdings. The project is ongoing and is carried out in association with the National Institute of Technology (NIT), Goa.

Drilling and installation of RBF wells at Cortalim

RBF solar panels installed for sustainable power supply for the functioning of the borewell pumps at Cortalim site

Other Projects

Goa State Strategy for Resource Efficiency and Circular Economy

Dr Pramod Sawant, Hon'ble Chief Minister of Goa, and Mr Ugo Astuto, Ambassador of the European Union to India launched the strategy for 'Fostering Resource Efficiency and Circular Economy in Goa', on February 24, 2020 making Goa a pioneering state to prepare such a strategy.

TERI was the knowledge partner in developing this strategy for Goa on resource efficiency (RE) and circular economy (CE). Funded by EU, other project partners were GIZ, CII, and Adelphi. For Goa, Directorate of Planning, Statistics, and Evaluation (DPSE) was the nodal agency. This strategy focuses on three sectors—tourism (plastic waste), construction (construction and demolition waste), and marine litter. The strategy recognizes the emergent need to use resources judiciously across life cycle in order to sustain Goa's long-term development and societal well-being. A day-long dissemination workshop was organized to share the main elements of Goa's RE&CE strategy with the stakeholders and identify ways and opportunities and potential challenges for the successful implementation of the strategy.

This workshop was attended by 90 people representing government, NGOs, businesses, banks (NABARD and European Investment Bank), other state government officials (Gujarat and Telangana), academia, research organization, and civil society organization.

TERI and GIZ team along with Dr Pramod Sawant, Chief Minister of Goa, and Mr Ugo Astuto, Ambassador of the European Union to India releasing the strategy document

Nutrition Security Division

TERI Western Regional Centre, Mumbai

TERI's regional centre in Mumbai was established in 2006 and has since been working to address the niche areas for the region. Food and nutrition security, environmental resource management, eco-city, and coastal issues are a few of the focus areas in addition to the cross-cutting themes, such as energy audit and renewable energy applications. It has a wide network of collaborations with diverse stakeholders belonging to both urban and rural communities, government, public sector and civil society organizations, academia, and corporate sectors. The highlights of the Centre for 2019/20 are as follows:

Food and Nutritional Security

1. Project 1: Partial Restoration of Village Pond and Introduction of Livelihood Avenues

Over the past six years, TERI has successfully implemented various interventions to improve food and nutritional security in Pathardi village of Palghar's Mokhada block and has also worked on improving water and energy access, along with introduction of livelihood avenues that would supplement nutritional security build capacity and empower youth and women.

Taking forward TERI's aim of transforming Pathardi village into a model village, the 2019/20 phase of the division's ongoing rural development project focused on increasing the availability of water in the village and the introduction of new livelihood avenues such as aquaculture through specialized training. The village of Pathardi in Mokhada block of Maharashtra's Palghar district faces extreme water shortage in the summer months making it difficult for the villagers to pursue any livelihood activity after the monsoon months, leading to migration for labour work. TERI thus planned to restore a pond within the vicinity of the village and increase its water holding and retention capacity to ensure water availability for longer periods of time. Once complete, the pond would greatly help villagers to adopt additional revenue generation activities.

TERI provided the villagers with training on Azolla cultivation to be used to improve the health of the livestock as well as for sale. Aquaculture training was provided to villagers with the help of experts from the Central Institute of Fisheries Education (CIFE). Training sessions by CIFE have also been planned for the future that would greatly benefit the villagers and help them obtain more in-depth knowledge about aquaculture and even specialize in it.

A pilot aquaculture unit constructed by a Pathardi villager

TERI team and experts from CIFE with the participants of an aquaculture workshop held on September 28, 2019 in Palghar district

2. Project 2: Participation of Tribal Beneficiaries in Aadimahotsav (Exhibition-cum-Sale) Held in Delhi

Carrying forward the activities of the previous phase, where villagers were provided with training and support to produce nutrient-fortified snacks and novel items, such as nutrient-rich spirulina chocolates, TERI continues to support the tribals to promote and sell their food products through exhibition-cum-sale events. In November 2019, facilitated by the division, two self-help group (SHG) representatives from Pathardi participated in a 10-day long exhibition organized in Delhi by the Tribal Co-operative Marketing Development Federation of India Limited (TRIFED) under the Ministry of Tribal Affairs, Government of India, earning good revenue through the sale of their nutritious food products during the event.

Pathardi representatives manning their stall at the TRIFED Exhibition in Delhi

Environmental Studies and Resource Management

1. Project 1: Air Quality Status of Maharashtra 2018–19

Sponsor: Maharashtra Pollution Control Board (MPCB)
Submission Date: June 2019

Sponsored by Maharashtra Pollution Control Board, this was the eighth consecutive annual report developed by TERI–WRC for MPCB. On June 4, 2019, *'Air Quality Status Report of Maharashtra 2018–19'* was unveiled, on the occasion of World Environment Day, by the then Chief Minister of Maharashtra, Hon'ble Shri Devendra Fadnavis in the presence of several other dignitaries.

The report documents the daily, seasonal, and annual trend in concentrations of air pollutants, such as SO_2, NO_x, RSPM, CO, CH_4, and ozone in Maharashtra across 72 active ambient and continuous air quality monitoring stations. More than 68% (6996) of the observations were found to be in the 'Good' and 'Satisfactory' categories, up from 65% found to be in the same category in 2017/18, thus recording an improvement.

2. Project 2: Water Quality Status of Maharashtra 2018–19

Sponsored by Maharashtra Pollution Control Board, the report entails information of Water Quality Index

Inauguration of Air Quality Status Report of Maharashtra 2018–19 by *(left to right) Shri E Ravendiran, Member-Secretary, MPCB; Shri Anil Diggikar, Principal Secretary, Environment; Shri Pravin Pote Patil, Minister of State; Shri Aditya Thackeray, Yuva Sena Chief; Shri Devendra Fadnavis, Chief Minister of Maharashtra; Shri Ramdas Kadam, Minister for Environment; Shri Sudhir Shrivastava, Chairman, MPCB; and Mrs Jyoti Thackeray*

(WQI) for surface water, which includes major basins (Tapi, Godavari, Krishna, and west flowing rivers) as well as the water samples representing saline (sea/creek) and groundwater. Performance of surface and groundwater quality in Maharashtra state is depicted in the form of illustrations and spatial representations.

Out of the total 228 Surface Water Quality Monitoring Stations (WQMS), around 150 WQMS were recorded under 'Good to Excellent' water quality as compared to 75 WQMS recorded in the previous year. The highest numbers of WQMS under the 'Good to

Excellent' quality category is observed for the west flowing rivers. The share of WQMS in 'Medium to Good' has decreased from 97 in previous year (2017/18) as compared to 43 WQMS in the current year.

3. Project 3: Environment Status Report 2018–19 of Navi Mumbai

This was sponsored by Navi Mumbai Municipal Corporation. It is mandatory for all urban local bodies (ULBs) under Class I cities of Maharashtra state to submit their annual environment status report to general body on or before July 31, as per Section 67A of the Maharashtra M unicipal Corporations (MMC) Act, 1949. The ESR is then submitted to the Ministry of Urban Development (MoUD). 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.

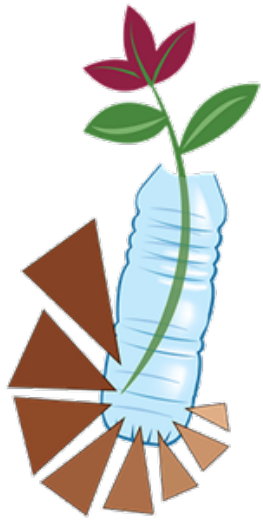
The highlights of Navi Mumbai ESR 2018–19 are as follows:

- Navi Mumbai ranked first on the basis of Citizen Feedback in the category 'Cities having population more than 10 lakh' during Swachh Survekshan 2019.
- There was an improvement in the Environmental Quality Index (EQI), Urban Infrastructure Index (UII), and Environmental Performance Index (EPI) as compared to the previous year (2017/18), owing to various pro-environment initiatives, such as effective waste segregation and management, closure of quarries, mangrove conservation initiatives, and development of roads within the city.
- To reduce air pollution levels in the city, NMMC has started Public Bicycle Sharing System (PBSS) to encourage citizens to use alternative, environment-friendly modes of transport.
- In 2018–19, NMMC planted 67,552 saplings of native trees, such as neem, bakul, kadamba, karanja, mango, and chikoo across the city to increase green spaces and minimize air pollution in the city.
- The NMMC developed Swachhta Park (Nisarg Udyan) at Koparkhairane. The park was a landfill site until 1999. It now serves as an open space for recreation purposes with amenities, such as jogging track, open gym, sitting areas, and public convenience facilities. The park has numerous interesting installations, such as a structure solely made out of e-waste to raise awareness about the importance of proper waste management.

Promotion of Counter-measures Against Marine Plastic Litter in South-East Asia and India – in Collaboration with the United Nations Environment Programme

The project focused on creating awareness about marine plastic pollution and plastic waste management in Mumbai Metropolitan Region (MMR). Activities including clean-up activities, stakeholder interaction, training of trainers, and awareness workshops were conducted under the campaign called 'Rethink Plastic' which was launched by TERI. The major highlights of this project are as follows:

- The project gave TERI a very important opportunity to connect and interact with a wide group of stakeholders, such as University of Mumbai and National Service Scheme unit, Government institutions such as Maharashtra Pollution Control Board (MPCB), Industry representatives (Thane-



Rethink Plastic logo

Belapur Industries Association – TBIA), Research institutions (Central Institute of Fisheries Education – CIFE, and Indian Institute of Technology, Bombay – IIT-B), and grassroots stakeholders (ferry boat owners association, waste dealers, NGOs).

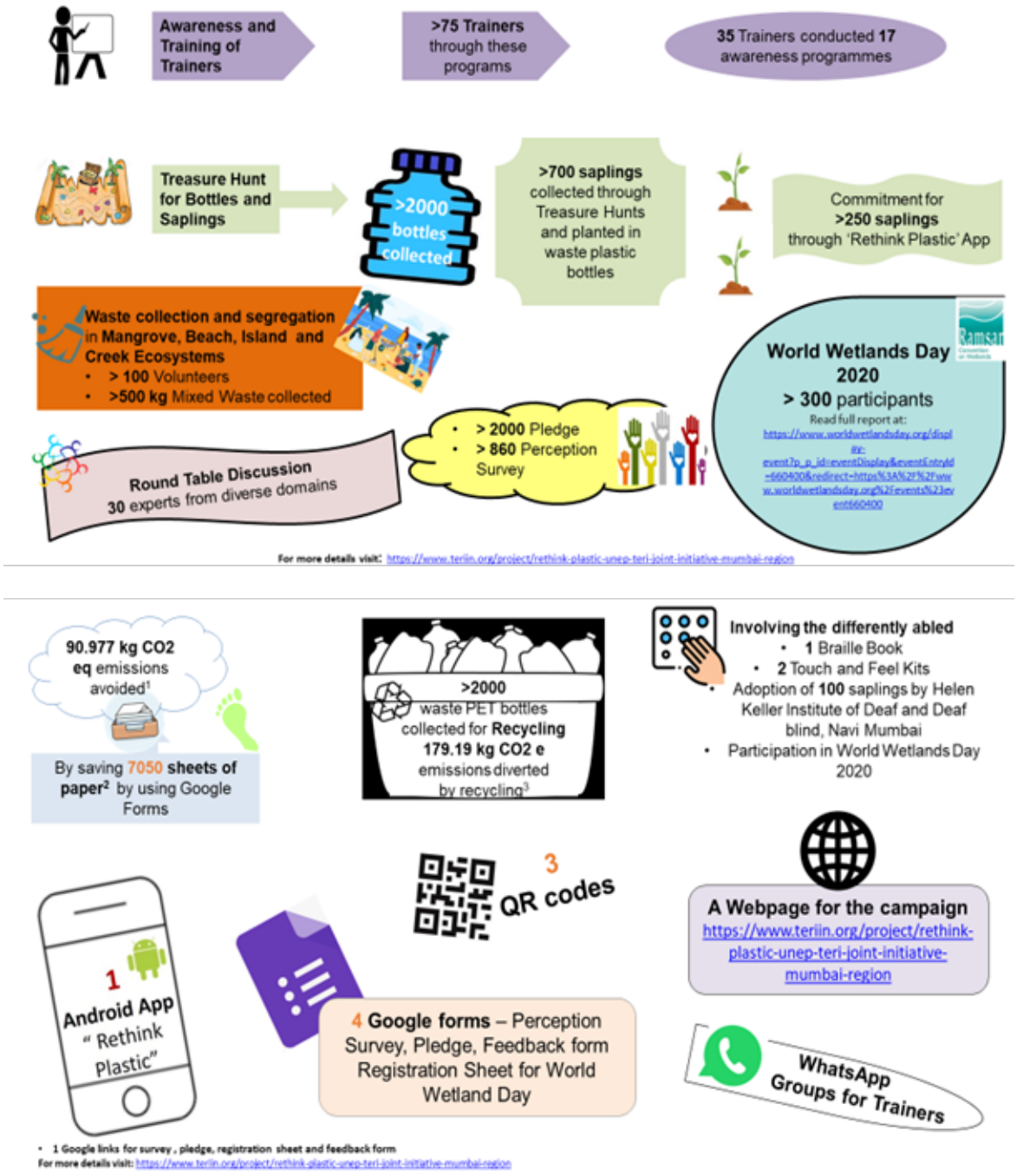
- A policy dialogue/roundtable discussion (RTD) was organized on December 23, 2019 at University of Mumbai Campus, Fort, Mumbai where more than 30 key stakeholders participated and provided valuable inputs.
- Interaction with Helen Keller Institute of Deaf and Deaf-Blind, Navi Mumbai for which TERI developed a Braille book, titled *'Introduction to Plastic Pollution'* and two touch and feel kits.
- Celebration of World Wetlands Day 2020 at Sagar Vihar, Vashi, Navi Mumbai on February 2, 2020. The main theme of this event was 'Save Wetlands from Plastic Litter'. The event was attended by prominent government officials along with more than 300 participants. Lot of plastic waste awareness-related activities were organized by TERI during this event.
- TERI adopted technology-driven approach such as *Rethink Plastic* android app Rethink plastic webpage, social media platforms (*WhatsApp, Facebook/ Twitter*), *Google Forms*, and scan code for conducting plastic waste perception survey, pledge and getting registrations, and feedback of stakeholders. By opting technology, TERI saved 7050 sheets of paper, thus avoiding 90.977 kg CO_2eq emissions.

Braille book and touch and feel kits (left); stakeholders in round-table discussion (right)

The overall summary of the report is represented here.

Important Links:

1. Rethink Plastic webpage: https://www.teriin.org/project/rethink-plastic-unep-teri-joint-initiative-mumbai-region
2. Rethink Plastic app: https://play.google.com/store/apps/details?id=com.teri.RethinkPlasticApp&hl=en
3. Short film by NDTV: https://www.youtube.com/watch?v=Y2TWHnWsL3E



Overall summary of the project

TERI's Algal Production Unit

TERI has set up a-100,000 L algal production system, as part of the DBT-TERI Centre of Excellence on Integrated Production of Advanced Biofuels and Biocommodities, at its Airoli site in Navi Mumbai.

It is aimed at integrated development of biofuels and commodities, such as food/feed nutritional supplements, bioplastics and platform chemicals to establish economic viability of the overall process.

The algal production system is based on an indigenous sunlight-distributed algal growth system that has been found to give 1.5 times the productivity of the standard raceway pond system. Microalgae are one of the promising renewable fuel options. The sunlight distributed system is a step in realizing the high lab yields of algae in outdoor conditions.

The project site includes inoculum systems, relevant downstream processing units, and a laboratory. The duration of the project is three years and it is expected to progress further upon validation at each stage. The scenario of value addition from aqua feed from deoiled algae presents a potential commercial viability scenario (INR 70–80/L of algal biofuel) in the near future.

100,000 L algal system at Airoli, Navi Mumbai algal project site

Environment Waste Management

The mandate of the Environment and Waste Management Division includes research on policies, regulation, governance, health, technological solutions for pollution control and management of solid and liquidwaste streams, and Resource Efficient Cleaner Production (RECP) assessment/implementation in wide range of industries.

As a part of RECP activities, the Division was actively engaged in RECP consulting in 400 enterprises in Bangladesh, Nepal and Sri Lanka as part of METABUILD project (https://www.metabuild-southasia.org). Currently, the activities are focused on 400 agri-food processing industries in Uzbekistan and Tajikistan as part of REAP project (https://reap-centralasia.org/) and 400 industries in tourism clusters along the Lakshadweep shorelines of the Maldives, Sri Lanka, and India to minimize marine litter. In addition, the Division is also hosting SEED (https://seed.uno), founded at the 2002 World Summit on Sustainable Development in Johannesburg by UN Environment, UNDP, and IUCN.

Work on water and wastewater treatment continued on membrane bioreactors, forward osmosis process, and resource recovery. Forward osmosis was examined for melanoidins concentration and water recovery in distillery wastewater as well as concentration of sewage. 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's work is spread across the country focusing on the capacity building for the health vulnerability assessment to climate change of all states and union territories; we are supporting build tracking and surveillance of air pollution-linked illnesses for the Ministry of Health and Family Welfare. We have undertaken health assessment in high exposure settings such as crop residue burning areas of India. We have also undertaken characterization of particulate matter ($PM_{2.5}$) and air pollution-related biomarkers in human samples. Efforts area to build resilience of the health care facilities for climate change across South East Asia region (11 countries) and examine strategies to improve the nutrition status of the country under the Food and Land Use Coalition (FOLU) project. Continued efforts are designed towards showcasing hot spots, which require special attention either because of extreme climatic events, persistent challenges from human activities or ineffective protective mechanisms, which may adversely impact health and well being. The Division is also working towards building resilience of population health through context-specific interventions by influencing a variety of pathways, such as pollution related, weather linked, or nutrition associated.

Our team as part of the Centre of Excellence initiative under the National Programme on Climate Change and Human Health, GoI, which is supporting development and implementation of National Health Adaptation Plan by providing guidance to states on vulnerability assessment and building resilience to climate change. For health relations, the area works on a broad spectrum of exposure-response relationship studies including air pollution studies in rural/urban hot spots; assessment of heavy metals; examining occupational risks and health effects in micro-environments. The area also hosts a secretariat on understanding Climate and Health Associations in India, particularly to bridge the knowledge gap in climate-linked health effect and have developed methodologies to rank districts of India on different health domains and health determinants.

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, and governance issues with respect to climate linkages of waste management; feasibility studies, audit, and performance assessment for waste generation and management. The studies focus on creating technologies and solutions to minimize waste generation and convert waste into useful products, with an objective of achieving 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 2019/20, the area grew to include international- and local-level projects addressing solid and plastic waste management issues in different spheres and worked on ground to demonstrate the impact.

During 2019/20, baseline assessment reports and IEC awareness reports and webinars for solid waste management were prepared for Varanasi and Panaji under the NAMA project sponsored by Deutsche Gesellschaft Fur InternationaleZusammenarbeit (GIZ) GmbH along with pilot demonstration of technological and policy solutions for waste management and recycling globally. In addition, workshops were organized in various localities to impart knowledge, to increase awareness about source segregation of municipal waste, and training session on decentralized composting in the two cities. The focus is on 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 the year 2019/20, the Division successfully conducted training programme Common Effluent Treatment Plants (CETPs) sponsored by Central Pollution Control Board and various e-training programmes and webinars on the 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, and governance issues with respect to climate linkages of waste management; 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 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 works on regulatory, policy, and governance issues with respect to climate linkages of waste management and has done 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. CWM has grown up with its capabilities to work with informal sector workers and implement projects for diverting waste streams back to 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 specialized curriculum's on waste management and recycling, environmental impact assessment and environmental management system. During 2019/20, the CWM grew to include international- and local-level projects addressing waste management issues in different spheres and worked on ground to demonstrate the impact.

Resource-efficient Technologies

Thematic Overviews

Resource Efficient Supply Chain for Metal Products in Buildings Sector in South Asia (METABUILD)

The METABUILD project (Resource Efficient Supply Chain for Metal Products in Buildings Sector in South Asia) (2016–20) (https://www.metabuild-southasia.org/resource-centre/showcases) was part of the European Union's SWITCH-Asia programme. The project, led and coordinated by TERI, was implemented in Bangladesh, Nepal, and Sri Lanka.

The project introduced resource-efficiency practices and technologies in 403 small and medium enterprises (SMEs) in the metal sector supplying to the buildings and construction industry. The project achieved overall energy saving of 33,953,817 kWh per annum, water saving of 48,978,140 L per annum, waste reduction of 700,436 kg per annum, and material saving of 4,434,782 kg per annum. The corresponding monetary saving was 2,943,875 Euros per annum along with CO_2 reduction of 13,222 tonne per annum.

membrane bioreactor with ash-based ceramic membranes developed by TERI will be piloted as part of this project. In addition, TERI is also working on socio-economic studies and programmes for educating school children on treated water reuse.

Testing of anaerobic membrane bioreactor at the Barapullah lab site

Resource Efficiency in Agri-food Production and Processing

The REAP project (Resource Efficiency in Agri-food Production and Processing industries) (https://reap-centralasia.org/) is being implemented under the European Union's SWITCH-Asia programme. The project aims to promote Sustainable Consumption and Production (SCP) practices in about 400 agri-food production and processing industries along the entire supply chain in Uzbekistan and Tajikistan. The project is implemented by a consortium led by The Regional

(a) *Policy dialogue event*

(b) *RECP implementation in companies*

(c) *Project closing event in Bangladesh*

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 are being 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 will be commissioned in 2021. The anaerobic

SCP Networking event held in Tashkent

REAP project team attended SCP event in Tashkent

Environmental Centre for Central Asia (CAREC), Kazakhstan with partners from India (TERI and STENUM Asia Sustainable Development Society); Central Asia (National Association of Small and Medium Business of the Republic of Tajikistan–NASMBRT), Chamber of Commerce and Industry of Uzbekistan (CCIU); and Europe (adelphi Research, Austria Recycling VereinzurFörderung von Recycling and Umweltschutz in Österreich (AERC)).

Prevention of Marine Litter in the Lakshadweep Sea

The PROMISE project (Prevention of Marine Litter in the Lakshadweep Sea) is part of the European Union's SWITCH-Asia programme. 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. The project consortium is led by Maldives National University, Maldives and is being implemented in partnership with Parley for the oceans (Maldives), adelphi Research (Germany), TERI (India), STENUM Asia Sustainable Development Society (India), and National Cleaner Production Centre (NCPC), Sri Lanka.

SEED India Hub Development (2020–21)

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 environmentally friendly and socially inclusive development and poverty reduction.

Launched during WSDS 2020, TERI hosted the SEED India Hub for delivery of customized enterprise support and promotion of eco-inclusive entrepreneurship for sustainable development. During 2020, programmes planned include the Training of Trainers (ToT) and co-creation sessions for Business Development Support (BDS) providers, practitioner's lab for climate finance targeted at the needs of growing 'missing middle' eco-inclusive enterprises, and SEED replicator programme matching proven business models with aspiring entrepreneurs.

Launch of SEED India Hub during WSDS 2020

Foreword by Dr Ajay Mathur

SEED Starter programme

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.

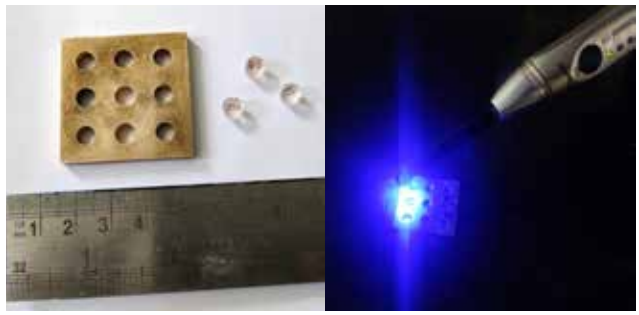
Slow release fertilizers reduce the rate of removal of the fertilizer from soil by rain or irrigation water, thus ensuring sustained supply of nutrition leading to improved efficiency of the fertilizer. The use of polysaccharide materials for controlled release of NPK fertilizer would be an eco-friendly 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 will be determined.

Pure sericin

Grafted sericin for encapsulation of NPK fertilizer

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 has been initiated.



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

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

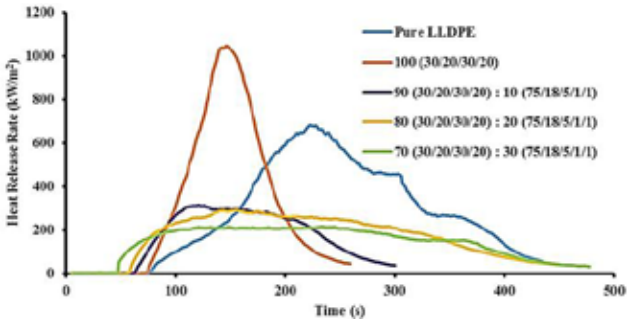
In this study, polyolefinic nanocomposites of HDPE/EVA/EPDM, LLDPE/HDPE/EVA/EPDM, and PP/EVA/EPDM have been developed with these following intumescent fire retardant additives to study synergism and improve fire-safety:

- Ammonium polyphosphate (APP) is used as an acid source as it is inexpensive and is also non-toxic. APP will be grafted with octasilane POSS to render it hydrophobic.
- A typical intumescent fire-retardant system (IFR) consists of an acid source, a char forming agent, and a blowing agent. The commonly used source for char forming is pentaerythritol. Thus, triazine-based hyperbranched polymer will be synthesized using piperazine and cyanuric chloride as they have a large

number of functional groups and thus can be used as a good charring-cum-foaming agent.

- The multi-walled carbon nanotubes (MWCNT) will be first acid treated to introduce carboxyl groups on the surface, which will be further treated with thionyl chloride using DMF as catalyst. Finally, aminopropyl isobutyl POSS will be grafted onto surface-modified MWCNT.

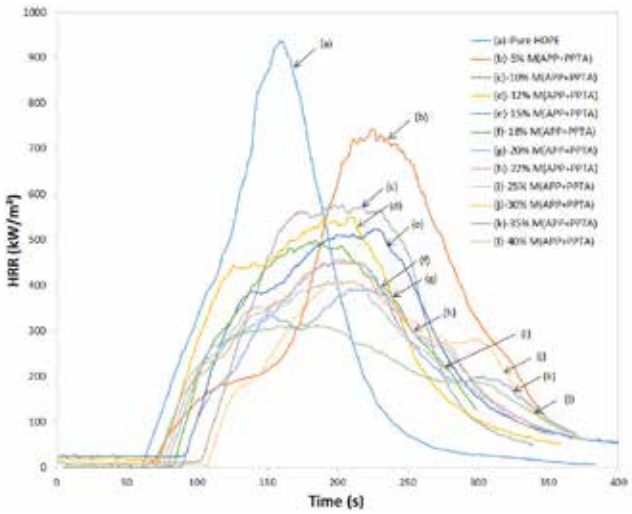
These additives have been optimized for both mechanical properties and fire-retardancy characteristics. Compatibilizing additives will also be added to enhance interfacial adhesion. The developed nanocomposites can be used as fire retardant for low- to medium-voltage cable sheaths.



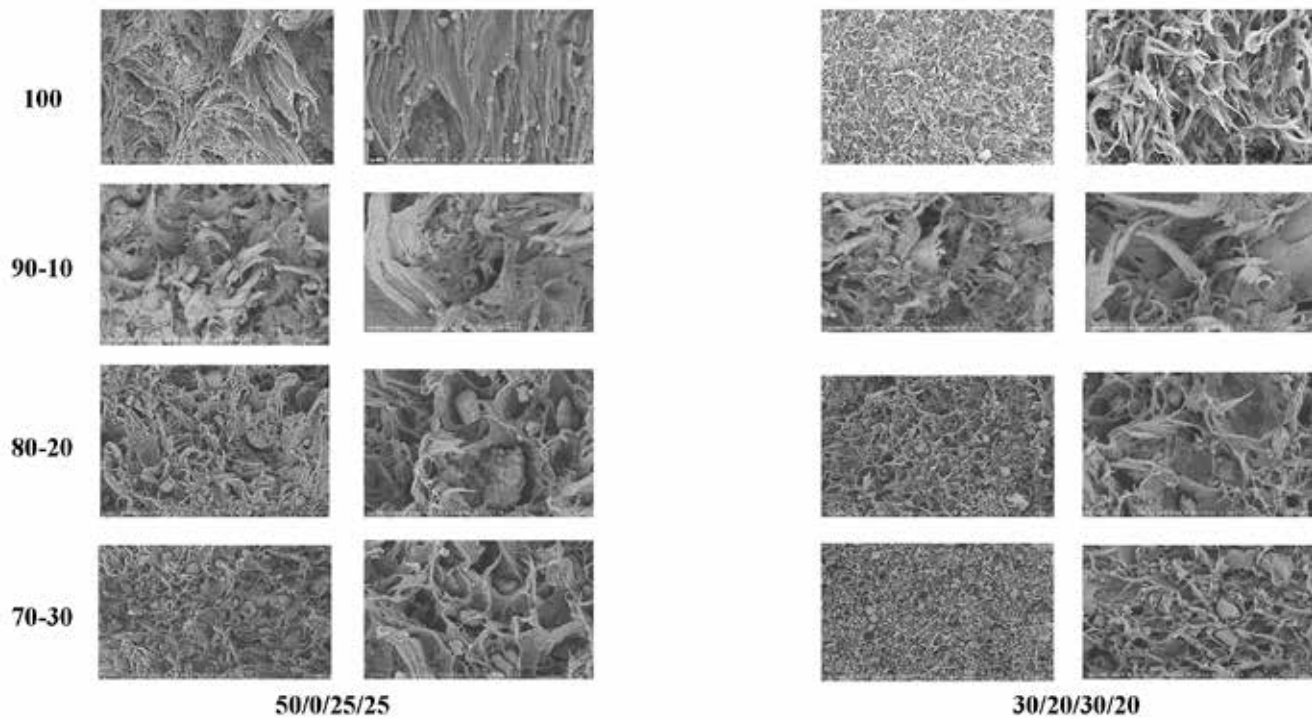
Heat release rate of neat linear low-density polyethylene (LLDPE) along with nanocomposites

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, use of non-halogenated fire retardants is fast gaining importance

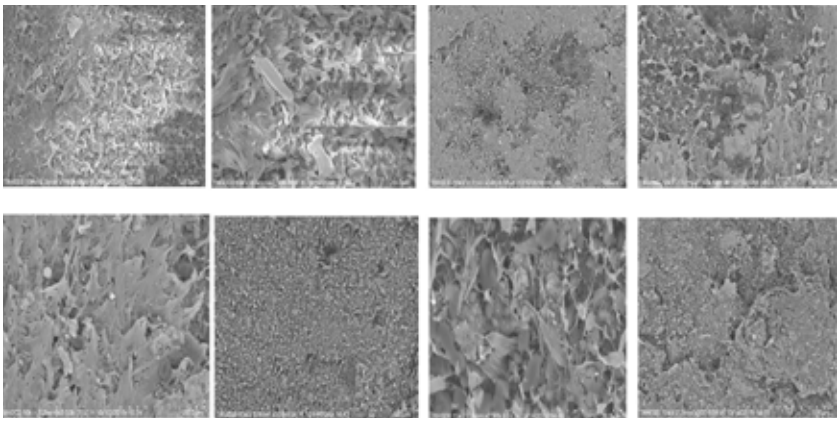


Cone calorimetry analysis for HDPE nanocomposites



Fractography: LLDPE nanocomposites @different magnifications (LLDPE/HDPE/EVA/EPDM)

as ammonium polyphosphate (APP) along with pentaerythritol 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, that is, propane terephthalamide 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.



The tensile fracture morphology using SEM for HDPE nanocomposites

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 based on evidence generated on the health effects of high air pollution exposures in a variety of cities, communities, and occupations. 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, health care 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. 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 the resilience of 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 2019/20, 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

With an aim to develop and implement integrated solutions for sustainable water management, the Water Resources Division provides services in core areas, such as applied research, training, and implementation. The group is continuously expanding its horizon of work to address the emerging challenges of the sector. The main competency of the division is in the following thematic areas: quantitative and qualitative assessment of water resources; water audit and water foot-printing; 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; high altitude glacio-hydrological studies and policy analysis.

The Division in 2019/20 was actively involved in undertaking field studies and suggesting strategic actions for enhancing water-use efficiency in various sectors, such as agriculture and industries, through

various projects and contributed towards the goals of the National Water Mission. The team contributed in improving the agricultural water-use efficiency by developing a pressure-independent flow controller under the OPTIFLO project which gives a near-constant flow rate and reduces the associated water losses through which additional water savings in an existing micro-irrigation system can be accrued. In another pilot project, Direct Benefit Transfer for Electricity Agriculture, potential opportunities of enhancing the irrigation water-use efficiency through innovative technologies and participatory irrigation management through stakeholder prioritized interventions with an upscaling potential for a wider impact were identified.

For improving the industrial water-use efficiency, the team is working on establishing potential benchmarks for industrial water use to assist policy for enhancing

industrial water-use efficiency in the four sectors—thermal power plants, textile, steel, and pulp and paper industry. The team is also working on a project, Pavitra Ganga, in which opportunities are being explored for wastewater treatment, reuse and resource recovery for urban and peri-urban sites in India with a consortium of leading institutes from India and Europe.

The group has been instrumental in assisting corporate sector at grassroots level by undertaking implementation-based activities. Pond rejuvenation for groundwater recharge has been undertaken at eight locations in the states of Punjab and Rajasthan to promote water conservation, a goal of the National Water Mission. Further, the group also undertook construction of thousands of individual household toilets in the state of West Bengal to support Swachh Bharat Mission of the Government of India.

The Division has been regularly carrying out outreach and capacity-building programmes for various stakeholders on different themes of water with main focus on enhancing water-use efficiency, water conservation, and river basin management. Under the Modular Training Programme on the River Basin Management Cycle, training programme has been developed and implemented for policymakers, senior officials, technical staff, training institutes to introduce the RBM Cycle as per the EU-WFD as adapted to the Indian context to serve as a steering and management instrument.

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, health, and education.

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 the hand and assisting government bodies to frame enabling policies on the other the 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.

Centres for Impact
Evaluation and Energy Access

The Centres for Impact Evaluation and Energy Access (CIEEA) in Delhi and Bengaluru work closely with communities, government departments, and academia, among others, on overarching themes of energy, gender, social inclusion, and livelihoods. The mechanisms of facilitating these include research and analysis, impact evaluation, need assessment, market studies, socio-economic surveys, watershed development, and efficient utilization of natural resources.

One of the major thrust areas of CIEEA-Delhi is to carry out research in the overarching issues of social and gender inclusion in order to facilitate 'just' energy systems for a sustainable future. To achieve this, the group's efforts are directed towards creating tools and techniques to mainstream gender into policy, projects, and implementation frameworks for the governments, private sector, and international organizations. The area's strength is also reflected with its use of qualitative methodological approach comprising participatory appraisal tools, ethnographic case studies, perception analysis, and stakeholder and gender analyses.

For instance, in partnership with the University of Oslo it undertook a study to assess the gender dimension of electricity systems in East Africa and South Asia and their social effects. Its efforts are also directed towards identifying, assessing, and documenting case studies of women-led or women-centric energy service delivery models to enable the energy sector to develop a gender-inclusive policy framework. It has helped develop guidelines for the project developers to incorporate gender effectively into their climate change project cycles designed with Climate Technology Centre and Network's technical assistance. Another project examined the ways in which women and men participate in activities related to renewable energy. A study supported by UN Women to examine the role of women as entrepreneurs and leaders in the field of renewable energy was undertaken in Rajasthan and Uttar Pradesh to capture the effects of resultant opportunities in terms of gender-based distribution of work, employment, and income. Likewise, the area has contributed to accelerate the involvement of women

in the use of biomass-based energy systems which help rural communities and small enterprises secure access to clean energy services. The study, which was undertaken in Karnataka, was supported by the Swiss Agency for Development and Co-operation.

Further, the area provided evidence-based suggestions to align national energy policies with the overall national objective of gender equality. Other than research, it also conducts trainings and workshops for gender integration across wide focus areas, such as water, climate change, natural resources management, and sustainable development. For a flagship international project – Himalayan Adaptation, Water and Resilience (Hi-AWARE), supported by IDRC – CIEEA-Delhi contributed actively to assess the socio-economic, governance, and gender drivers that lead to vulnerability of the poor in mountains and plains of the Himalayan region. Similarly, as part of a Norwegian-funded project – Vulnerabilities and Community-based Adaptation in India – enabling conditions for effective community-based adaptation to the impacts of extreme events at the community level in Maharashtra were assessed. Broadening the scope of work on gender-inclusive approach, the area has worked for an Indo-German Project to develop strategies to mitigate the gender-differentiated human–wildlife conflict in a few states of India.

Currently, CIEEA-Delhi is engaged in assessing challenges and opportunities for social and gender-inclusion and community participation in various renewable energy initiatives, such as offshore wind energy, solar thermal, and solar photovoltaic for developing robust protocols and guidelines to develop 'just' energy systems.

CIEEA-Bengaluru has been working with the Karnataka Watershed Development Department to carry out intensive monitoring, evaluation, learning, and documentation of the World Bank-assisted Karnataka Watershed Development Programme (Sujala-3). Widening its reach in scientific monitoring and evaluation of government flagships, it undertook the evaluation of Compensatory Afforestation Fund Management and Planning Authority (CAMPA), National Afforestation Programme, and National Bamboo Mission Schemes in Karnataka. The area also carried out an in-depth evaluation of North Eastern Region Textile Promotion Scheme of the Government of India in the silk sector and apparel garmenting units in the north eastern states.

Centre for Rural Action

The Centre for Rural Action area brings together its knowledge base of techno-socio-institutional aspects of energy access to design and deliver locally appropriate solutions that address the needs of communities as well as micro-industries. In the fast-changing context of energy access scenario in India due to various government programmes such as SAUBHAGYA and UJJWALA, the focus of the area shifted from addressing basic minimum energy needs to enabling reliability of energy services. In this regard, the area continues to innovate, facilitate 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. Its efforts are directed towards addressing 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 users. This has been driven through the development and implementation of innovative, responsive, and replicable techno-delivery models; the creation of new partnerships and collaborations at the grassroots levels; adoption of a bottom–up approach; and engaging community members to create inclusive energy provisioning supply chains. LaBL – TERI's flagship initiative for clean energy access – is anchored in the area. The initiative 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.

The second key aspect is its endeavour to weave 'energy' as a contributor towards other associated facets of development, such as health, education, livelihoods, empowerment, and climate change mitigation. In this context, some of the key projects undertaken by the area include development of clean and reliable solar-based power infrastructures to improve the operational reliability of power looms in Varanasi, famed for *Benarasi* sarees. The initiative led to enhancement of livelihood opportunities for the weaver community besides raising their quality of life by enabling fixed working hours through reliable electricity supply. Another key project, that is, solarization of boats, is one of the major initiatives undertaken to reduce air pollution around India's holy rivers, including the Ganges. This unique model revolves around swappable lithium-ion batteries and centralized solar charging stations to charge the batteries. The initiative not only enhances the livelihood opportunities for the boatmen community, it also creates additional business opportunities for entrepreneurs. In the field of education, the area works to provide infrastructure for reliable energy in remote schools to ensure quality education for the children. With an objective to enhance livelihood and create green jobs, the area provides training in solar energy-related skills in different states under the 'Green Skill Development Programme' of the Ministry of Environment Forest and Climate Change (MoEFCC). Further, the area is determined to expand its scope through innovative and integrated solutions.

SUSTAINABLE AGRICULTURE

A number of global trends are influencing food security, poverty, and the overall sustainability of food and agricultural systems. The world's population is expected to grow to almost 10 billion by 2050, boosting agricultural demand – in a scenario of modest economic growth – by some 50% compared to 2013. Income growth in low- and middle-income countries would hasten a dietary transition towards higher consumption of meat, fruits, and vegetables, relative to that of cereals, requiring commensurate shifts in output and adding pressure on natural resources.

The decline in the share of agriculture in total production and employment is taking place at different speeds and poses different challenges across regions. Satisfying increased demand for agricultural products with existing farming practices is likely to lead to a more intense competition for natural resources, increased greenhouse gas emissions, and further deforestation and land degradation.

High-input, resource-intensive farming systems, which have caused massive deforestation, water scarcities, soil depletion, and high levels of greenhouse gas emissions, cannot deliver sustainable food and agricultural production. Thus, the innovative systems that protect and enhance the natural resource base, while increasing productivity and reducing losses (post harvest, disease/pest, storage, transportation, etc.) are needed. A transformative process towards 'holistic' approaches, such as agroecology, agro-forestry, climate-smart agriculture, and conservation agriculture, which also build upon indigenous and traditional knowledge is also needed. Technological improvements, along with drastic cuts in economy-wide and agricultural fossil fuel use, would help address climate change and intensification of natural hazards, which affect all ecosystems and every aspect of human life. Greater international collaboration is needed to prevent emerging transboundary agriculture and food system threats, such as pests and diseases.

Agriculture accounts for 46% of land use in India with more than 54% of the workforce being dependent on the sector for their livelihood and sustenance. The Indian government has three main objectives related to agriculture: food security, food self-sufficiency, and income support for farmers; thus, government missions such as doubling farmer's income by 2022, National Mission for Sustainable Agriculture (NMSA), and Women in Agriculture are giving a major thrust to the agriculture sector in the country. With the Make in India initiative, agri-industries are also on rise. Indian agriculture has the potential to impact global agriculture.

The Sustainable Agriculture Programme of TERI aims to identify and develop new ways for profitable farming while conserving natural resources. The Programme has a solid and optimally robust foundation to deliver on its ambitions for defined streams. The area has optimally diverse expertise to address contemporary problems in most of the main themes of agriculture, environment, and bioenergy. It has most opportunistic and diverse superior gene pools (world's biggest mycorrhizal germplasm and functionally superior bacterial cultures, superior quality planting material from micropropagation, molecular-assisted breeding and GM) and world class infrastructure with globally acceptable accreditations and, that too, under a single roof. The area's capabilities and skills for local and global networking with industry and academia are very strong to accomplish the programme goals. It has had successful, sustained, and credible technology transfers, end to end services offered, 300+ publications, 11 patents, national and international awards, product validations by most credible stakeholders, POPs and FCO inclusion of products and processes, and farmers field demonstrations across different agroclimatic regions of India, Europe, and North America.

The area is the global leading technology developer/partner and centre of excellence for future and next generation innovations/innovators in sustainable agriculture with a mandate of focused research in frontier areas of precision and smart agriculture, bio-inputs, plant science, synthetic biology, and nanotechnology. It aims to innovate smart materials and formulations from untapped natural/waste resources and green technologies for food and nutritional security, eco-compatible climate-resilient farming, nutrient, water, and energy-use efficiency, carbon minimal energy, contribution to bio-economy, develop future food ingredients and nutraceuticals with economic feasibilities, convert wasteland/environmentally degraded land into productive land with added product, and enhancing livelihood opportunities. It also strives to contribute to the bio-based economy in the agriculture sector, with a view to expanding local, regional, national, and export markets.

Agriculture, Farming, and Bio-inputs

Centre of Excellence for Advanced Research in Agricultural Nanotechnology

The Centre is the first of its kind research platform in India in the field of agricultural nanotechnology which carries out end-to-end research to innovate green nano-agri-products, including nanofertilizer, nanopesticide, and nanocarriers. The globally acceptable standard guidelines are being followed to make these novel products which are not only highly efficacious as compared to the bulk agrochemicals but also safe to the environment and human health. During 2019/20, the Centre of Excellence (CoE) programme nearly completed the establishment of the following two facilities: (1) National Facility for Nanotoxicity Assessments *in vitro* and (2) a 1000-L facility for the production of nanoproducts. Two nanoproducts, namely, nano phosphorous and nano zinc-iron, were synthesized by using safe/green synthesis methods and characterized by using advanced instrumentation including DLS, AAS, ICPMS, XRD, FTIR, and TEM & SEM imaging. Along with successful multi-field trials, these products were scaled-up for a-1000 L production capacity. To ensure that these nanoproducts have no side effects on humans and the environment, multiple tests on multiple model systems for humans, microbes, and plants were carried out by following internationally accepted protocols. The most important assessments for human health included human cell line HEK 293 and human blood cells. Different kinds of effects, such as damage to cell surface, damage to DNA, and damage to vital compartments of a cell were investigated using standard NCL protocols. The value for the parameter that adjudges toxicity to human cells (LD 50 value) was not attained even at a very strong dose as high as 1000 PPM. Also, in a preclinical test, where the effect of nanoproducts on the human blood cells' properties was investigated, nano phosphorus and nano zinc-iron were found compatible to human blood. These standard tests emphasized complete safety of nano phosphorus and nano zinc-iron to human health on exposure. Similarly, investigations for ecotoxic effects on model species of bacteria, nematode, microalgae, and plants by using OECD guidelines proved that these products are safe for agricultural applications. Additionally, prototypes for four new nano-fertilizers (molybdenum, magnesium, sulphur, and boron), and two insecticides (copper and methoxyfenozide based) are now ready for efficacy and safety assessments.

DBT–TDNBC–DEAKIN–Research Network Across Continents for Learning and Innovation

TERI–Deakin Nanobiotechnology Centre (TDNBC), Gurugram, India and Deakin University, Australia, in association with the Department of Biotechnology, Government of India formulated 'DBT–TDNBC–DEAKIN–Research Network Across continents for learning and innovation (DTD–RNA)'. The network was launched at TERI Gram, Gurugram, Haryana, on September 3, 2019 (for more information, please visit: https://www.teriin.org/projects/dtd-rna/).

Launch of DTD–RNA Network

The newly developed network is in a process of creating joint labs as country hubs and network of research institutions across all continents with the view to integrate strengths from TDNBC India and Deakin University, Australia to develop International Centre for Translational Research for research training and education in biological synthesis of nanomaterials. Different institutes and countries were invited to join in the network for jointly undertaking cutting-edge research projects to train young global students,

postdoctoral fellows for collaborative research, high-end technologies for basic to advanced level of research (joint research publications), to impart education and training (joint research mentorship), workshops, and networking (joint workshop/training). Institutes representing countries, that is, Portugal, Sri Lanka, Indonesia, Malaysia, Japan, Korea, and Ethiopia confirmed to join this network and are in different stages of signing MoUs.

CRISPR Library for Canola

Current advances in CRISPR-Cas9 genome editing technology and the basic understanding of gene integration into the plant genome provide a unique opportunity for rapid genetic improvement of canola. The area has conducted a comprehensive genome-wide analysis of a canola genome and selected 10,000 genes for targeted modification using a high-throughput CRISPR technology. Also, the area has specifically focused genes attributed to major traits contributing to the productivity of canola, namely, early flowering, male sterility, cold and drought stress tolerance, seed and oil quality/quantity improvement, mildew resistance, pod shattering resistance for mechanical harvesting, clubroot resistance, etc. The functional validation of genes in the post-genomics era is the key challenge. This project targeted useful genes by developing a 20,000 gRNA library for functional validation by creating a high-throughput molecular genetic platform for the community and is of high importance for the dependence on edible oil import.

Abscisic Acid Mimetics for Superior Agronomic Traits

Abscisic acid (ABA)-metabolism regulation through agrochemicals is a viable strategy for managing major agronomic and postharvest traits. The area has identified important ligand-binding features for the future development of specific ABA signalling modulators in *Oryza sativa* and developed *in silico* models for designing and virtual screening to

Phenogram showing the chromosomal distribution of CRISPR targets in the Brassica napus L. *genome was identified mainly using the knowledge from model Arabidopsis literature and transcriptome studies in* B. napus L. *and its close relatives. Important major traits are colour coded*

identify potent ABA receptor ligands. They have also comprehensively illustrated designing, development, and versatile usage of ABA-mimicking compounds displaying ABA agonists and antagonist activities.

Reversal of Antimicrobial Resistance

Antimicrobial resistance (AMR) is a serious concern in pathogenic bacteria. As a new approach to addressing AMR, the area reported the green synthesis of vanillin-capped gold nanoparticles using the popular flavouring molecule vanillin ($C_8H_8O_3$) as a reducing and capping agent. The antibiotic potentiation activity was studied in combination with seven widely used antibiotics against extremely drug-resistant *Pseudomonas aeruginosa*. The results reveal that vanillin capped gold nanoparticles impart susceptibility to the last line antibiotics meropenem, trimethoprim, and a few widely used antibiotics in extremely drug-resistant *P. aeruginosa* clinical isolates that display resistance to these antibiotics for addressing AMR problem affecting health and environment.

Non-coding RNAs Associated with Abiotic Stress and their Role in Plant–Bacterial Interactions Using *Azospirillum Brasilense* and Sorghum as a Model

The area's research on bacterial non-coding RNAs has identified two novel ncRNAs, that is, sSp_p4 (AbSp_464) and sSp_p6 (AbSp_465), which play an important role in a plant's growth promoting traits such as IAA biosynthesis, biofilm production, biological nitrogen fixation, PHB production, and chemotaxis, displayed by *Azospirillum brasilense* Sp245. The research also corroborated that these ncRNAs improved the bacterial stress endurance potential. Results of the research confirmed methyl-accepting chemotaxis gene and poly(R)-hydroxyalkanoic acid synthase as the targets for ncRNA p4. Also, an interaction network of the ncRNA, p6, vnfG, and sigma factor,-54 was unravelled.

Bioengineering of Rice (*Oryza sativa*) for Enhanced Photosynthesis and Higher Yields

Rice is the staple food for nearly half of the people on earth, and its yields need to be doubled over the next 30 years to keep pace with the projected population growth. Improving photosynthesis through a range of genetic engineering strategies was identified as a promising target for rice improvement with regard to increased photosynthetic yield. One such approach is based on integrating components of highly efficient carbon dioxide-concentrating mechanism (CCM) present in cyanobacteria (blue-green algae) into rice, a C3 crop plant. The CCM machinery operates with high efficiency in cyanobacteria to overcome the catalytic deficiencies of Rubisco catalysis. Hence, the area initiated a project to engineer the genetic components of the cyanobacterial CCM into rice to enable the assembling of carboxysomes in chloroplasts to enhance the efficiency of photosynthetic CO_2 fixation in this crop plant. During 2019/20, the TERI team developed several types of transgenic rice plants carrying various combinations of cyanobaterial CCM and Rubisco genes. Currently, work is in progress to characterize transgenic rice plants for enhanced photosynthesis and yield responses.

QTLs for Heat Tolerance in Tomato

Heat stress is a major limiting factor in tomato production. In tropical and subtropical regions, where temperatures easily reach above 40°C, reproduction, yield, and quality of tomato are adversely affected. Identification of QTLs associated with heat stress in tomato would enable breeding of productive varieties which can be grown under high temperature conditions. TERI has undertaken a study aimed at mapping and identification of molecular markers linked to quantitative trait loci which are responsible for heat tolerance in tomato. Breeding was performed between JBT-02 (heat tolerant) and Pusa Rohini (heat sensitive). Positive F_1 line was selfed to get F_2 population and segregating population further advanced to a total of 125 individuals of F_4 population. Important phenotypic data which influence, under heat stress, such as flowering, pollen viability, fruit set, number of fruits per bunch, and average fruit weight were recorded for QTL

mapping. Currently, all individuals of F_4 population have been sequenced based on GBS, and QTLs mapping is under progress.

Germplasm Collection and Genetic Diversity Assessment of Kadaknath

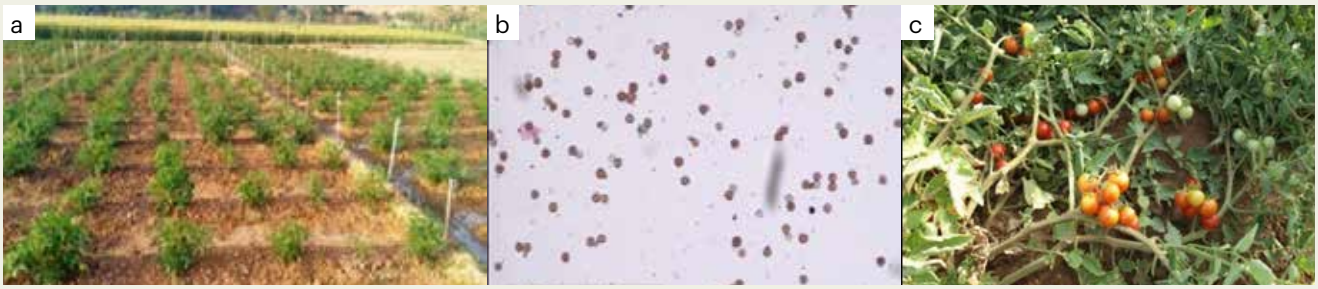
Kadaknath is an indigenous poultry breed of Jhabua and only black meat chicken (BMC) of India. Its black flesh is considered not only a delicacy of distinctive taste but also known for nutritional and medicinal values. Its shrinking base population and lowering of genetic diversity, which may lead to its loss of germplasm, has become a major problem. Considering the issue, it is important to capture maximum genetic diversity in Kadaknath to conserve and make this breed sustainable in stressed environments, especially under the current regime of climate change.

In this context, TERI conducted a study wherein a total of 205 birds were collected from Jhabua and Alirajpur districts of Madhya Pradesh, which were maintained at the College of Veterinary, Mhow. Important phenotypic data including body weight, sex of birds, type of variety, etc., were collected at different growth stages. Genotyping by sequencing (GBS) was performed to assess genetic diversity. Based on the genetic diversity study, most diverse germplasm from each cluster were identified as core germplasm for future selection and conservation.

Nanobiochar as a Low Cost and Efficient Delivery Vehicle for Agrochemicals

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 delivery of agri inputs. Biochar, being one of the established materials used in soil amendment since ages, could be a promising alternative compared to other materials because of its biocompatibility, high functionality, and inexpensive synthesis methods. Nanotization of biochar could further enhance its functionality and tailorability for the successful delivery of agrochemicals in plants. The area's work aims to establish 'nanotized' biochar as a novel delivery vehicle for the delivery of agrochemicals resulting in its agronomic biofortification. In the study, biochar nanoparticles were synthesized to an average size of 40 nm and as a demonstration immobilized zinc (micronutrient) on the surface of nanobiochar. Owing to its high porosity and favourable surface charge,

Phylogenetic tree of Kadaknath using neighbour-joining method



***(a)** Plantation of tomato F4 lines at TERI Gram; **(b)** pollen viability test; and **(c)** F4 line at fruit-bearing stage*

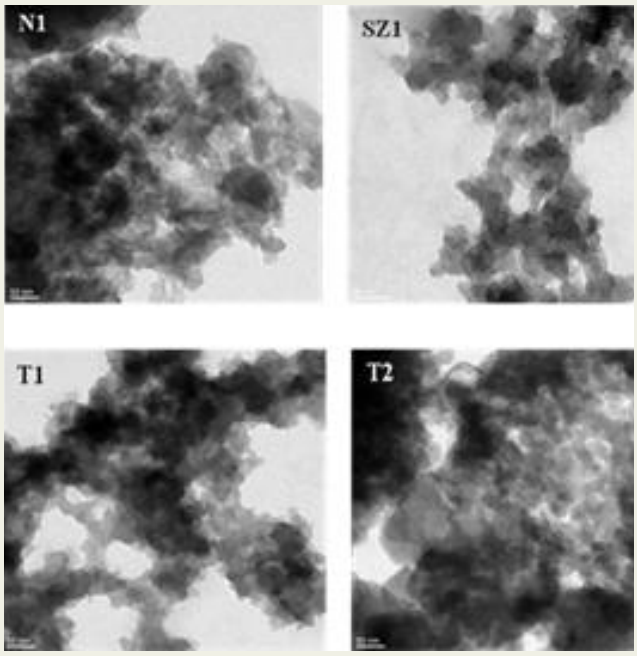
high dosage of approximately 110.16 mg/g of Zn was loaded on a nano-biochar surface. The preliminary results showed excellent uptake of these Zn-loaded nanoparticles of biochar in a seed and its translocation in root, shoot, and leaves of maize plantlet. Detailed investigation of the release of Zn inside a plant's vascular system and the fate of nanobiochar particulates and Zn on a plant's growth is under investigation.

Bioactive Metabolites from Microbes as Potential Value-added Compounds

Metabolites from natural sources play a noteworthy role either as the foundation of or as a stimulation for lead molecules for food, agrochemical, and pharmaceutical industries. 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, antifungal, etc. Among the various alternatives of a natural origin, the group is focusing majorly on endophytic fungi, microalgae, and lichens as a potential resource for the bioactive molecules. The research programme addresses all the aspects of discovery, isolation, and identification of metabolites with potential as nutritional/functional food agents and phytomedicines. The overarching aim of this project is to isolate active metabolites from bioresources showing potent antioxidant and anticancer activities. Another target is to increase the potency and physical properties of the identified active compounds through the use of nanotechnology. The obtained metabolites are used for the biological synthesis of nanoparticles and also polymeric biodegradable nanoformulations are prepared for further applications.

Development of Tailor-made Nanozeolite Carrier for Slow Release and Targeted Delivery of Nitrogen for Sustainable Crop Production

Nanozeolite variants – N1, SZ1, T1, and T2 – were synthesized and characterized for optical properties, zeta potential, hydrodynamic size, structural/ morphological properties, and elemental properties. The nanozeolite variants were tested for the adsorptive nature using congo red as a model dye. Based on the overall data analysis (characterization and adsorption), the variants SZ-1 and T-2 were found more promising for the development of control release fertilizer of NPK nutrients.



TEM images of synthesized nanozeolite variants

Development of Nano-immobilized Enzyme System for High-value Omega-3 Production

Nanomaterial variants – Gr1, Z1, Z2, and M1 – were synthesized using different approaches. The variants were characterized for the structural, morphological, and elemental properties. The synthesized nanomaterial variants were used for the development of nano-enabled lipase system for omega-3 fatty acid concentration.

Biostimulant Bioprospecting for Selected Microalgal Isolates

The effects of microalgal extracts on the growth of a corn plant were examined. In this study, an algae extract demonstrated the characteristics similar to those of major plant growth stimulants. Algae-based extracts remain unexploited worldwide. This study highlights a few of the potential approaches to be used in research and development related to this field. There was a significant difference in the root length in treated sample compared to negative and positive controls.

In-vitro Produced Mycorrhiza

TERI's mycorrhiza has already proved to be a valid option for a sustainable high-quality crop production in low-input and marginal areas. It promises to improve the nutritional status and health of the rural Indian population. TERI has already set up the world's biggest facility for producing mycorrhizae through an *in vitro* technology. In 2019/20, TERI supplied its mycorrhiza product to various stakeholders for application in different crops and agro-climatic regions.

High-quality Superior Tissue Culture Plants

The Micropropagation Technology Park, a state-of-the art facility established at Gwal Pahari almost three decades back with the generous support from the Department of Biotechnology, Government of India, has complete infrastructural facilities to produce tissue-cultured plants, ranging from modern laboratories and greenhouses to nurseries with an annual production capacity of 3 million. During 2019/20, 2.2 million tissue-cultured plants of banana Grand Naine variety were supplied to famers in Uttar Pradesh, Bihar, Gujarat, and Maharashtra. Work was also done to optimize the *in-vitro* multiplication of elite trees of Chironji (*Buchanania lanzan*).

Enhancing Livelihoods of Marginal Farmers Using Bio-innovations

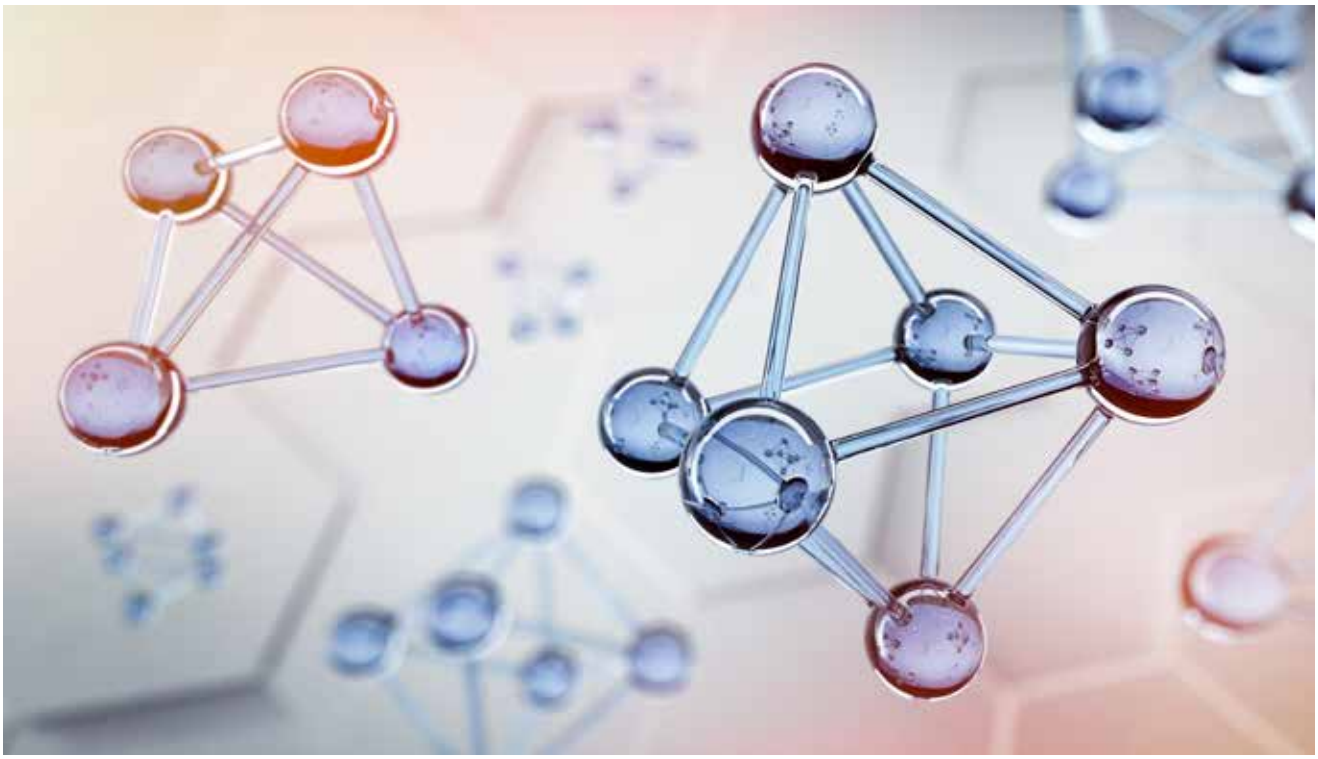
TERI has been working at TRISHA (TERI's Research Initiative at Supi for Himalayan Advancement) at village Supi in Nainital district of Uttarakhand since its establishment in 2003. Our efforts encompass a strategy for enhancing land productivity by using sustainable biotechnological approaches and harmonizing modern technologies and traditional knowledge. In 2019/20, TRISHA promoted various high-altitude medicinal plants in the district of Nainital including Bageshwar, Pithoragarh, Tehri, Rudraprayag, and Uttarkashi on cluster basis for women farmers. The prioritized species were *Picrorhiza kurroa, Aconitum heterophyllum, Hedychium spicatum, Taraxacum officinale, and Saussurea costus*. One distillation unit at TERI Paharpani campus for the sustainable use of aromatic crops with the help of IHBT-CSIR, Palampur, Himachal Pradesh.

Training programme for women farmers

Centre for Processes and Structures to Support Translational Research and Innovations in Nano-biotechnology

The project has launched a unique online platform (http://www.dbtnanobiotech.com) that brings together academicians, researchers, industries, and other stakeholders to address important and critical scientific and technical challenges through translational research in the area of nano-biotechnology. A total of 183 projects funded by DBT nano-biotechnology task force from 2006 to 2017 were uploaded on the website. The sanctioned projects were arranged in three categories, namely, (i) year wise; (ii) PI wise; and (iii) category wise. The project categories include (i) diagnostics and imaging; (ii) nano-medicine and therapeutics; (iii) delivery vehicle; (iv) nano-enabled systems and devices; and (v) agriculture, environment, nano-toxicology, and others. The project details include project title, information on the date sanctioned, total budget, objectives of the project, knowledge outcomes, resulting publications, patents, technology transferred, and manpower supported along with the full information about the PI including their contact details and web links. In addition, a live excel plot providing information on the 'current' status of the project was also placed on the website.

Besides ongoing projects, facilities, and infrastructure duly supported by DBT were comprehensively searched and uploaded on the website. Comprehensive links of nanotechnology institutes, funding agencies, R&D industries, incubation centres, investors, and lists of books and journals relevant to nanobiotechnology were also uploaded. The website has a complete list of all PIs, domain experts, domain application contributors, and technical expert committee members. This would enable both the researchers and the stakeholders to connect with each other and receive and provide mentoring and collaborative support to facilitate translational research.



Biodiversity

Centre for Mycorrhizal Culture Collection

The Centre for Mycorrhizal Culture Collection (CMCC) is a mycorrhizal bioresources centre which aims at conservation of mycorrhizal biodiversity by means of collection, isolation, propagation, characterization, and maintenance of cultures under *in-situ* conditions. The next-generation germplasm bank now houses over 1500 trap cultures obtained from various sources, and from these trap cultures more than 4248 monosporals cultures representing a total of 816 different monosporal lines being maintained were raised. Apart from these, there are around 250 different isolates of ectomycorrhizal fungi which were obtained from different hosts situated around the world. Both the ectomycorrhizal fungi and AMF are being characterized on the basis of their unique FAME signatures, rDNA sequences, and morphological features. Apart from this, the mycorrhizal isolates were characterized for their functionality and uniqueness in improving plant growth and ameliorating biotic and abiotic stress under greenhouse conditions. In 2016/17, an online electronic database that provides an overview of the available AMF and ectomycorrhiza collection with all the relevant characterized results was made available to the researchers and general public around the world through a webpage – http://mycorrhizae.org.in/cmcc/.

Environment

Green Belt Development on Abandoned Gypsum Waste Pond at Coromandel International Limited, Vizag, India

Coromandel International Limited (CIL) has an area of 100 acre containing phosphogypsum dump. The waste at the abandoned retention pond is acidic in nature and rich in phosphate, fluoride, and chlorides. Due to its typical acidic nature and water-retention capacity, phosphogypsum waste cannot support vegetation. Thus, the abandoned ponds are devoid of any plants. In this context, reclamation of these abandoned gypsum ponds becomes strategically important for CIL. During 2019/20, TERI's researchers identified certain strains of naturally occurring mycorrhizal fungi which provide nutritional support and high level of stress tolerance to plants. The fungi form a reciprocating relationship with the living roots by providing nutrition to plants from the substrate and receive carbon in turn from them. Using mycorrhizal inoculations, 2 acre of the phosphogypsum dump-laden wasteland was converted into a green belt covered with lush green vegetation.

Green belt development at phosphogypsum ponds

Development of Green Belt on Jarofix Dump at Chanderiya Lead–Zinc Smelter

In pursuit of global sustainable development, it has always been TERI's regular and continuous efforts to bring forth sustainable green technologies for all industries/sectors. Winds of change are needed to manage the limited resources for meeting the challenges of increase in population. There are pressuring demands of industries to manage and reclaim wastelands/effluents which are otherwise havoc to the environment and public health. TERI has found ways to reclaim jarofix dump by using the mycorrhizal technology. Development of a green belt at a jarofix dump site of Chanderiya Lead-Zinc Smelter, Hindustan Zinc Limited, Chittorgarh, Rajasthan is a success story of the mycorrhizal reclamation technology. Native and tolerant tree species were planted with grasses on a specially designed jarofix dump inoculating it with mycorrhiza to overcome the stressful substrate and fugitive dust. The mycorrhizal fungi form a reciprocating relationship with living roots by providing nutrition to plants from a substrate and receive carbon in turn from them. The mycelial network of the mycorrhizal fungi accumulate heavy metal from jarofix waste and retain them in their living cells. Within a short period of time, 3 ha area containing heavy metal laden jarofix waste dump was converted into a green vegetation land.

Green belt development at jarofix dump site of Chanderiya Lead-Zinc Smelter

Energy

Chromogenic, Redox-active, Microbial Metabolite-based Solar Cells

The unavailability of grid electricity in remote, rural, and hilly areas in India causing vulnerability to women, children, and less productivity of adults deprived of information is the thrust behind this study. Women performing daily household chores in dark, children exposing themselves to kerosene lamp to study, danger of snake and other venomous bug attacks, protecting agriculture produce from insects and wild animals are some of the concerns that require urgent solutions. Though dye-sensitized solar cells (DSSC) are of low efficiency compared to other solar cells, they offer a unique advantage for small electrical needs of agriculture and farm. As the current dye-sensitized solar cells use expensive dye molecules, the study seeks to address this by extracting dyes from microbial resources that have the ability to be mass produced at low cost. The anticipated product from the study would greatly help in catering to small and inevitable electricity needs of agriculture and farm.

Outreach

Networking Event on Nano-interventions in Fertilizers: Current Status and Future Perspective

A networking event, specialized on 'Nanointerventions in Fertilizers: Current Status and Future Perspectives' was organized on August 2, 2019 at Gwal Pahari campus of TERI-Deakin Nanobiotechnology Centre. The event aimed to bring together academicians, researchers, industries, and other stakeholders on a single platform to address important and critical challenges in the area of nanofertilizers. Different sectors participated in the event that included government, industries, start-ups, investors, philanthropists, and academicians.

Indo-US Bilateral Symposium

A bilateral symposium on the 'Next-generation Biologically Synthesized Nanofertilizers for Seed Coating and Foliar Application' was organized from September 5 to 7, 2019 at TERI-Gwal Pahari. The symposium observed talks and discussions on the critical and yet unexplored field of environmental fate of engineered and applied nanofertilizers. During the event, the regulatory and policy aspects of nanofertilizers were also covered. It acted as a platform that brought together world-renowned speakers, 80 participants including budding young researchers, scientists from R&D institutes, academia, technology providers, and industries from India and the USA for the purpose of scientific discussion on current practices and future scope of nanotechnologies to promote innovation and knowledge transfer for agriculture.

Nanobiotechnology for Agriculture: Translational Research for Future Food and Agriculture Technologies

The international conference on 'Nanobiotechnology for Agriculture: Translational Research for Future Food and Agriculture Technologies' by TERI-Deakin Nanobiotechnology Centre, TERI in partnership with the Department of Biotechnology, Government of India was held on November 21 and 22, 2019 alongside the Prestigious GLOBAL Bio Summit. The conference developed a deeper understanding of advances in nanobiotechnology in food and agriculture. It encouraged interaction within the research community for wider application of the advances and benefitting the society by innovating to achieve sustainability of agricultural practices in India. The conference had an innovative

programme, amalgamating scientific sessions and discussions for scientists to aid them in undertaking translational research in nanobiotechnology. The talks held during the event focussed on the thematic scientific sessions on 'Nanotechnology-based strategies being implemented to enhance crop production, crop protection and food preservation', while the discussions were dedicated to 'Translational Research'. The programme was specifically aligned to allow early and mid-career principal investigators and associates to interface with one another, empower them with the knowledge to adapt their research for maximum impact, and help their transition into a new career in the translational research platform. Further, the conference enabled research collaborators with the goal of basic research to achieve consistent improvement and expansion of their product-based research towards commercialization.

Training Programme on 'Quality Evaluation of Mycorrhizal Biofertilizers'

A one-day hands-on training programme was organized on January 10, 2020 for the scientific staff from the National Centre of Organic Farming (NCOF) to create awareness about the quality evaluation of mycorrhizal biofertilizers. There were 18 participants from diverse backgrounds who came to attend the training programme from different parts of the country. The programme aimed to strengthen the quality regulation of mycorrhizae-based biofertilizer products by way of capacity building of the scientific staff of the regulatory bodies. The training programme included an interactive session and discussions on various quality parameters of products as per guidelines pertaining to the Fertilizer Control Order (FCO) 1985, Government of India and the challenges faced by the regulatory staff and the manufacturing industries.

Discussion Forum on 'Landscaping of Industrial Perspectives on Biofertilizer Policy and Regulations on Biologicals in Agriculture'

A discussion forum was organized on 'Landscaping of Industrial Perspectives on Biofertilizer Policy and Regulations on Biologicals in Agriculture' on February 14, 2020 at India Habitat Centre, Lodhi Road, New Delhi. Industry representatives from fertilizer, agriculture, and bio-fertilizer industries attended this discussion forum. For more information, please visit https://www.teriin.org/projects/dtd-rna/events.php.

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.

Accelerating urbanization and its associated phenomenon of increased resource consumption in India have unleashed unprecedented opportunities to embed resource efficiency and waste management in buildings, transport, and cities sectors. For instance, *'India Energy Outlook: World Energy Outlook Special Report 2015'* estimates that three-quarters of the anticipated 2040 building stock in India are yet to be constructed; with this arises a need for developing newer cities and transport systems to be established for foremost occupancy and operation of this building stock.

Integrating the principles of Smart Cities Transport and Buildings will proliferate action towards resilient and sustainable infrastructure development within the cities. This will have three-fold benefits. First, it minimizes the long-term costs of these projects. Second, it will enhance resilience of built environment, transport systems, and their mitigation potential. Third, it aligns the socio-economic initiatives such as the Smart Cities Mission, AMRUT, HRIDAY and PMAY with the Nationally Determined Contributions (NDCs) and the Sustainable Development Agenda 2030.

In order to nudge the country towards low-carbon development pathways, it is imperative to assist nodal ministries/departments and local governance bodies to provide integrated solutions for sustainable development. The SHP aims to create a network of CoE that engages with government entities as knowledge partners for evidence-based policy research and analysis, development of green rating systems for buildings–transport–cities sectors, effective implementation and monitoring and training, and capacity building. TERI also served as a Member of the Advisory Committee of the National Mission on Sustainable Habitat.

Some of the major initiatives that have been taken by the SHP are listed as follows:

1. Established Mahindra–TERI CoE to develop energy-efficient innovative solutions, tailored to the Indian buildings sector and climates.

2. Established the TERI–UTC (United Technologies Corporation) CoE on building energy diagnostics and evaluation for improving energy efficiency in existing buildings.
3. Developed a building material directory tool for the use of efficient building materials in India.
4. Developed the Green Rating for Integrated Habitat Assessment (GRIHA) rating system, which has been acknowledged as the tool to evaluate emission reduction through buildings in India's NDCs submitted to the United Nations Framework Convention on Climate Change (UNFCCC).
5. GRIHA in partnership with Public Works Department (PWD), Maharashtra, pushed the agenda to shift towards resource-efficient buildings, both for the new and the existing buildings in Maharashtra.
6. Establishment of ECBC cell at Madhya Pradesh and Karnataka to facilitate the implementation of ECBC cell in the state.
7. Carried out study on sustainable heating solutions for Indian Himalayan Region for WWF.

GRIHA Council

We at GRIHA Council stand for credibility, integrity, and inclusiveness, while upholding Indian ethos for future-ready and sustainable habitat. The GRIHA rating has been acknowledged as a tool to evaluate reduction in emission intensity through habitat, as part of mitigation strategy for combating climate change in India's Nationally Determined Contributions (NDCs) submitted to the UNFCCC. At present, there are more than 2000 projects registered under the GRIHA rating with a green footprint (built-up area) of 650,000,000 sq.ft.

Inauguration of GRIHA exhibition at Chaar Minar, India Habitat Centre by (from left to right) – Dr Ajay Mathur, President, GRIHA Council and Director General, TERI; Prof. Ian Jacobs, Vice-Chancellor, UNSW, Sydney; and Shri Nitin Jairam Gadkari, Hon'ble Minister for Road Transport and Highways, Government of India

Launch of the GRIHA V2019 rating abridged manual by (from left to right) Prof. Ian Jacobs, Vice-Chancellor, UNSW, Sydney; H E Mr Freddy Svane, Danish Ambassador to India; Dr Ajay Mathur, President, GRIHA Council and Director General, TERI; Shri Nitin Jairam Gadkari, Hon'ble Minister for Road Transport and Highways, Government of India; H E Ms Harindher Sidhu, Australian Ambassador to India, and Mr Sanjay Seth, CEO, GRIHA Council

The last year saw the rating of 300 new and existing buildings for the Public Works Department, Government of Maharashtra under the landmark agreement signed with the government in 2018/19. Three additional MoUs were signed with First Construction Council, Indian Institute of Architects (IIA), Northern Chapter, and National Real Estate Development Corporation (NAREDCO) at the 11th GRIHA Summit.

Signing of MoU between GRIHA Council and National Real Estate Development Corporation (NAREDCO) by (from left to right) Mr Sanjay Seth, CEO, GRIHA Council and Brig. R R Singh, Director General, NAREDCO

Launch of policy brief on 'Future shift: Integrating Sustainability Initiatives in Functional Buildings at the 10th Regional GRIHA Summit by (from left to right) Shri S S Salunkhe, Chief Engineer, Public Works Region, Pune; Ms Shabnam Bassi, Secretary, GRIHA Council; Mr Sanjay Seth, CEO, GRIHA Council, Shri Nitin Jairam Gadkari, Hon'ble Minister for Road Transport and Highways, Government of India; Shri A A Sagane, Secretary (Works), Mantralaya; Shri U P Debadwar, Chief Engineer, P W Region, Nagpur, and Ms Namrata Mahal, Senior Program Manager, GRIHA Council

The 11th GRIHA Summit was once again co-created in association with UNSW, Sydney, which was held from December 17 to 18, 2019 at India Habitat Centre, New Delhi with the theme – 'Approach to Integrated Sustainability'. The event was supported by many premier international and national organizations such as the 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). The Summit platform was leveraged to showcase collaborative research and development works between TERI, GRIHA, and UNSW in the built environment cutting across various thematic areas.

The 10th Regional GRIHA Summit was organized on June 15, 2019 in association with Public Works Department, Government of Maharashtra at Nagpur with the theme – Transformation Strategies for the Built Environment'. The event was supported by other premier national organizations such as Smart City Council, ASHRAE (Mumbai Chapter), and All India Association of Industries (AIAI).

Signing of MoU between GRIHA Council and the Indian Institute of Architects, Northern Chapter by (from left to right) Mr Sanjay Seth, CEO, GRIHA Council and Mr Ashish Gupta, Hony Jt Secretary IIA, Northern Chapter

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 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 which 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, Delhi, provides innovative, integrated, and cost-effective solutions to mainstream the principles of sustainability in the buildings sector. The division promotes resource efficiency and optimization in design, construction, operation, maintenance, and demolition of facilities. Its objective is to create Centres of Excellence, which aim at stimulating low-carbon development pathways leading to increased resilience and mitigation potential. 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).

The Energy and Resources Institute carried out a study on 'Sustainable Space Heating Solutions in the Himalayan Region' that studied the impact of the adoption of new clean energy technologies on emissions in the IHR and suggested that sustainable space heating systems can bring down CO_2 emissions by 30% in the Indian Himalayan Region (IHR) by 2030.

TERI obtained a patent for its innovative wastewater treatment technology called as TERI Advanced Oxidation Technology (TADOX). The technology provides end-to-end treatment of municipal and industrial wastewater streams having high colour, chemical oxygen demand, biochemical oxygen demand, total organic carbon dissolved organics, non-biodegradable, and persistent organic pollutants.

NABL Accreditation

MTCoE 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'.

Sustainable Buildings, SRC

Sustainable Buildings, Bengaluru at TERI's Southern Regional Centre has been working with real estate developers, private sector organizations, public sector organizations, corporate entities, and institutions to provide green building design consultancy services for energy-efficient buildings. The Centre additionally works 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 and research scholars, students, and academicians.

In 2019/20, 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 and Technology. Under this project, construction of two test beds and a prototype of dynamic shading was done. With funding from the Department of Biotechnology, the area continued research on design and engineering of cold storage containers using biowaste as an energy source. A chiller unit, manufactured in Germany, was brought to TERI's campus at Gurugram, Haryana which is awaiting approval following the testing phase.

Three consultancy projects were completed with the Power Grid Corporation of India project in the second phase earning 3-star rating, NACIN Campus and ASTRA Campus project in Bengaluru earning 5-star each as per GRIHA rating. The Centre also organized four training programmes which witnessed participation of nearly 100 students and 60 professionals from the Indian building industry and paved the way for future collaborations with the industry on research and development. Institutional engagement to disseminate research work has been carried out in partnerships with educational institutes, such as NIT Trichy, SJB SAP, BGS SAP, and BMS College of Architecture.

Completed Projects

Power Grid Project – Residential Quarter in Second Phase

The residential campus developed by Power Grid Corporation of India Limited has five types of residential quarters, transit accommodation, and community halls. The project was provisionally rated as 3-star as per the GRIHA rating system. The project encompasses an outstanding green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting, water re-use from STP and rainwater, and solid waste management.

Panoramic view of the Power Grid Project – Residential Quarter in Second Phase

Award of the rating given to PGCIL during the GRIHA Summit in December 2019

Astra Microwave Products Limited, Bengaluru

The technical campus developed by Astra Microwave Products Limited has three types of buildings, including an administrative building, a canteen-cum-guest house, and laboratory spaces. The project was provisionally rated as 5-star as per the GRHA rating system. The project encompasses an outstanding green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting, water re-use from STP and rainwater, and solid waste management.

Astra Microwave Products Limited, Bengaluru

The National Academy of Customs, Indirect Taxes and Narcotics Campus, Bengaluru

The campus developed by The National Academy of Customs, Indirect Taxes and Narcotics Campus (NACIN) has three types of buildings, including an administrative building, an auditorium, and a hostel. The project was provisionally rated as 5-star as per the GRIHA rating system. The project encompasses an outstanding green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting, water re-use from STP and rainwater, and solid waste management.

On-going Projects

Green Building Design Consultancy for Indian Green Building Council Compliance for the Proposed Buildings by Government of India

The Indian Navy is developing a campus in India as per the IGBC guidelines for which TERI is acting as the green building design consultant for IGBC certification.

NACIN Campus, Bengaluru

Corporate Conclave at WSDS 2020: Mobility Talks, held on January 30, 2020

In this project, TERI has provided recommendations for efficient architectural design, management of waste and 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 and developing benchmarks and framework for performance assessment of new age shading devices, through field studies, lab testing, and test bed monitoring. The second part of the project aims

to investigate 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 plans for their commercialization, it is proposed that TERI will construct a demonstration model of an energy-efficient habitat integrating the above solutions.

DBT: Biogas-driven Cold Storages for Sub-zero Applications in India

The objective of the project is to design and engineer a cold storage container using biowaste as an energy source to reduce high losses that occur in food supply chains due to missing cold storage and cooling facilities in developing countries. Such countries are also affected by lack of biowaste treatment and uncontrolled dumping, causing huge impact on the hygiene of public spaces which leads to challenges for human health. As biowaste and cooling demand often occur concomitantly in the food industry (e.g., cleaning of fish in the fish industry, meat processing in slaughterhouses), cold storage by using biowaste-based cold production would be a smart way to address the problem.

Chiller unit at TERI campus

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

A new facility has been proposed by KTPO with an objective to design it as a green building as per the GRIHA rating system. TERI, as a green consultant, is supporting the project in achieving the standard for the rating.

Transport and Urban Governance Centre for Urban Planning and Governance

With the growing urban population of India, perpetually dealing with a range of complex challenges, the Centre focuses on strategic planning, policy research, and capacity building to foster improved and informed decision-making for sustainable urban development. To this end, TERI is 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, organized sessions at the Urban Thinker's Campus by UN-Habitat with National Institute of Urban Affairs, and conducted Australia–India Knowledge Exchange Workshops on smart energy management initiatives, as well as Indo-Afghan TechCamps on Sustainable Urbanization. TERI is supporting the Royal Danish Embassy in developing Urban Living Labs for Smart and Sustainable Cities for implementation of pilot projects in Panaji, Goa through a knowledge partnership and technical assistance.

TERI is a member of the Advisory Committee of the Global Compact of Mayors (GCoM), and is part of the India Coordination Group of the International Urban Cooperation and the Global Resilience Research Network (GRRN) with urban climate resilience as one of its key focus areas. TERI has conducted climate risk assessments for the ULBs of Telangana, and supported Andhra Pradesh Capital Region Development Authority (APRCDA) to prepare a holistic climate change action plan for the new capital city of Amaravati.

Training workshops conducted by TERI and UN-Habitat for Indian and Afghanistan urban practitioners as part of the IndoAfghan TechCamp project supported by the US Consulate General, Mumbai, the US Embassy Kabul, Afghanistan, and the Bureau of Educational and Cultural Affairs

Release of a policy brief on 'Mainstreaming Urban Resilience: Lessons from Indian Cities' at World Urban Forum 10, in Abu Dhabi, from February 8 to 13, 2020. Prepared with NIUA, the policy brief highlights key takeaways from discussions held at the Urban Thinkers Campus in September 2020

Centre for Sustainable Mobility

Transportation is the backbone of any economy and also a key contributor to GHG emissions. During a 'normal' period, that is, pre-COVID-19, transportation was the second largest contributor to the global emissions, after the power sector. It accounted for about 24% of the total global CO_2 emissions in 2018. With the world getting struck by a deadly virus – COVID-19 – in December 2019, transportation has been one of the worst affected sectors, as economies, including India, have been under severe lockdown.

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

The Centre has a vast experience of conducting studies on electric mobility, scoping analysis and presenting it in an easy-to-comprehend manner, and handle web-based tools. CSM has a very wide range of capabilities in the fields of modelling and scenario building, low-carbon passenger as well as freight transport solutions, including research works in the field of electriv vehicles and alternate/green technologies, non-motorized transport, development of tools (web-based or offline), and training and dissemination activities.

During 2019/20, TERI continued to conduct detailed studies focused on analysing the future prospects of electric mobility in India. The Centre came out with a report 'Faster adoption of electric vehicles in India: Perspective of consumers and industry' with a special focus on the two-wheeler sector. It also initiated a research study on the 'Roadmap for electrification of urban freight sector in India'. The aim of the study is to understand, map, and recommend strategies for faster adoption of electric commercial vehicles across Indian cities.

Corporate Conclave at WSDS 2020: Mobility Talks, held on January 30, 2020

Thematic track at WSDS 2020: Inclusive and Integrated Mobility Systems for Cities, held on January 29, 2020

DOMESTIC AND GLOBAL OPERATIONS

Advanced Biofuels Programme

The global concern for energy and climate security issues made it imperative for scientists to explore the production of clean fuel from renewable sources in a sustainable manner. Advanced biofuels do not rely on fossil resources and thus present a renewable alternative to conventional petroleum-based fuels. Advanced biofuels can be produced from next-generation non-edible feed, such as lignocellulosic biomass, agricultural residues, aquatic weeds, algae, and organic waste. In order to make the production process economically viable at a commercial scale, it is essential to integrate this process with the production of high-value bio-commodities in a bio-refinery approach. To achieve sustainability and to address climate change issues, TERI's Advanced Biofuels Division is exploring the possibilities of the development of clean technologies for biofuel and bio-commodity production from second-and third-generation feed, such as algae, aquatic plants, and used cooking oil (UCO), under DBT-TERI Centre of Excellence project on 'Integrated production of advanced biofuels and biocommodities'. To assess the long-term viability of the processes, comprehensive techno-economic analysis, environmental assessment, and socio-economic assessment are also being undertaken.

Based on the research thrust, the division's research themes are categorized into the following two areas: 'Microbial biofuels and biochemicals' and 'Pyrolytic biofuels, biochar, and green chemicals'.

Microbial Biofuels and Bio-chemicals Area

The research activities of the 'Microbial Biofuels and Biochemicals' area concentrate on the development of bio-based renewable technologies for the production of advanced biofuels; biohydrogen, bioethanol, biomethane, biobutanol including third-generation algal biofuel and biochemicals; second-generation 2,3-Butanediol, nutraceuticals, high-value organic acids, in an integrated manner by using microbe(s) and algae as cell factory.

Algal Production for Biofuels and Biocommodities

Algal Cultivation to Develop Feed for Advanced Biofuels and Bio-commodities Production at a Large Scale (100,000 L)

Microalgae are one of the promising options for renewable fuel production. Microalgae have the potential to mitigate carbon emissions and to reduce crude oil imports. To realize the economic viability, production of biofuels from microalgae should be combined with biocommodities in an integrated manner. With intensive research explorations, a marine algal production system of an area of 220 m^2 (100,000 L) has been established near Mumbai coast last year with the objective of producing algae as next-generation feed for advanced biofuel (biodiesel, pyrolytic oil, and biohydrogen production). This microalgal cultivation system is based on a sunlight-distributed improved productivity system that is integrated with downstream processing units. The unit consist of a settling tank and a lipid extraction unit along with an on-site set up for an R&D laboratory. With an objective of recovering lipid with high recovery efficiency at a low cost, intensive research explorations are being carried out including a process developed for lipid extraction directly from wet algae (without sun drying that requires large areas of land). The lipid extraction unit installed at the Mumbai project site has the capacity to process 5–7 kg/h of wet algae. The deoiled algae after lipid extraction gets tested for possible application as feed for the production of value-added commodities, such as animal feed, aqua feed, biodegradable food packaging plastics, platform chemicals, nutraceuticals, biohydrogen, and pyrolytic bio-oil.

Marine algal production system in Mumbai (220 m^2/100,000 L)

Biohydrogen Production from Second- and Third-Generation Biomass

Aquatic plants and algal biomass are being tested as next-generation feed for biohydrogen production through the use of select C_5 and C_6 sugar-utilizing microbes.

Water hyacinth is an aquatic invasive species that multiplies very fast in wetlands. It is estimated that water hyacinth covers more than four million hectare of freshwater surface in India, leading to the generation of 450 tonne of water hyacinth biomass (wet weight) per hectare per year. Rapid colonization of negatively 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 the weed from waterbodies regularly, which in turn increases the financial pressure on the municipal bodies. Water hyacinth's biomass contains more than 50% carbohydrates (on dry weight basis) and thus gained attention for being a possible feed to produce biofuel. The dried biomass can be used as feed after its pre-treatment and enzyme hydrolysis. Acid pre-treated can be used biomass for hydrogen production by using *Enterobacter cloacae* strain DT-1 as a host. The process for biohydrogen production from acid pre-treated water hyacinth biomass (rich in pentose sugar) was up-scaled in 30 litre and subsequently in 150 litre bioreactor.

Scale up of biohydrogen production from acid pre-treated water hyacinth hydrolysate in 30 litre bioreactor

Scale up of biohydrogen production from acid pre-treated water hyacinth hydrolysate in 150 litre bioreactor

Azolla species is one of the fastest growing aquatic ferns which can grow in contaminated water and has the potential of generating substantial biomass. *Azolla* sp. has a high biomass productivity potential (12 tonne/ha/year). Major fraction of this biomass includes 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 the production of clean fuels and bio-commodities (aqua feed, animal feed, biofertilizer, etc.).

Large-scale cultivation of Azolla in outdoor ponds in TERI Gram

The large-scale cultivation of *Azolla* has been carried out in outdoor ponds in TERI Gram and the sun-dried *Azolla* biomass was processed for acid pre-treated and enzyme hydrolysis for conversion to monomeric fermentable sugar. The fermentable sugar was used as feed for biohydrogen production. Then, biohydrogen production from acid pre-treated *Azolla* biomass sugar (pentose stream) was up-scaled in 10 litre scale by using *E. cloacae* strain DT-1.

Further, the possibility of using deoiled algae for hydrogen production was tested.

Bioethanol Production from First- and Second-generation Feedstock

Bioethanol has received 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 using first- and second-generation feedstock, a range of feedstock are being explored for use as feed for bioethanol production. Intensive research explorations paved the way for the development process for 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 was developed for bioethanol production from water hyacinth and corn cob biomass through the use of *Pichia stipitis* and *C. tropicalis* TERI DC as microbial cell factory. With a proof of concept established, the process will be studied at the pilot scale.

Scale up of bioethanol production by an industrial grade sugar/sugar cane black strap molasses novel yeast isolate; Candida tropicalis *strain TERI DC*

Enhanced Methane Recovery from Livestock Waste

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

High-value Biochemical Production

Fermentative Production of 2,3-Butane Diol from Glycerol, the Co-product from Biodiesel Transesterification Process

The 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 a range of chemicals (1,3-butadiene, butanes, methyl ethyl ketone [MEK], gamma butyrolactone, diacetyl, esters, etc.). These downstream products have applications in chemical industries, fuel additive, textiles, polymers, synthetic rubbers and plastics, etc. With a goal of zero-waste discharge, this area is also researched with a possibility to develop a microbial process for the production of 2,3-Butane Diol from glycerol, the co-product from the algal biodiesel transesterification process. The bioprocess for 2,3-Butane Diol production from glycerol and low-cost commercial-grade sugar was developed using two selected microbes; *Enterobacter roggenkampii* strain TERI CT and *Klebsiella pneumoniae* strain RA1 (newly isolated non-pathogenic strains isolated by a Research Team at TERI), respectively. A laboratory-scale process for downstream purification of 2,3-BD from low-cost commercial-grade sugar and glycerol-based fermentation broth was developed.

Scale-up of upstream fermentation process and downstream 2,3-BD purification process is under progress.

TERI's downstream processing laboratory

Pyrolytic Biofuel, Biochar, and Green Chemicals

Development of Technology for Production of Biodiesel from Mixed Oil (Algal Lipid and Used Cooking Oil)

Most of the established biodiesel plants are based on a particular type of feedstock oil. However, it will be beneficial to develop a process model for different types of feedstock mix so as to attain feedstock sustainability.

Under DBT-TERI Centre of Excellence of Biofuel and Bio-commodity, two indigenous processes were developed for two-stage transesterification of UCO and a pilot-scale unit of 10 kg/h capacity was established. These processes completely eliminate the use of water for biodiesel purification and thus are sustainable. The prime objective was to develop models based on primary research data generated at a scale which is suitable for production and quality prediction of biodiesel from any type of mixed oil. The steps of the processes were established for conversion to BIS-VI compliant biodiesel with respect to properties, such as purity, cetane value, oxidization stability, cold flow properties, and calorific value.

TERI's Process 1 conversion efficiency (98–99%) is greater than the literature-reported benchmark for UCO conversion (65–97%), whereas, TERI's Process 2 conversion efficiency is 95–97%. The electricity consumption per unit of biodiesel produced is <0.5 kWh.

TERI's 10 kg/h biodiesel pilot test unit

TERI's two-stage catalytic cracking and pyrolysis vapour upgrading unit

Development of Technology for Pyrolytic Biofuels

TERI has developed an indigenous pyrolysis technology for making refinery-grade bio-oil and biochar from different agro-industrial biomass residues. The patented pilot-scale pyrolysis test unit of 20 kg/h capacity is a uniquely designed fully automated programmable logic control-based gas-fired auger pyrolysis reactor system. The Pilot Reactor has been tested extensively with non-edible oil seed residues, for example, Jatropha and Karanja, and other biomasses such as sugar cane bagasse, paddy straw, cotton stalks, ground nut shell, mustard stalk, wheat and maize stalk, cashew nut shells, and lignin residues from ligno-cellulosic ethanol plant.

A catalytic pyrolysis process was established for downstream catalytic upgradation of pyrolytic vapour produced in the non-catalytic pyrolyser over indigenously-made novel catalysts for improving bio-oil characteristics in terms of oxygen content (<5%) and H:C ratio. This upgraded oil is intended to be co-processed in a refinery or its possible direct applications as an alternate transport fuel could be found.

The integrated two-stage catalytic cracking and pyrolysis vapour upgrading unit reactor has been commissioned for testing pyrolysis vapour over stage-I and stage-II catalysts. Chemical and physical characterization of the oils indicates high degree of upgradation w.r.t. oxygen content and heating value.

Dry algal (*Scenedesmus, Spirulina, and Chlorella*) biomass was processed in the 10 kg/h continuous pilot reactor and the bio-oil was upgraded to transport grade biofuels through catalytic route by separating the valuable chemicals. In-house green catalysts were synthesized for *ex-situ* drying of wet algal paste as an alternative to electrical drying.

Industrial Wastes to Green Char and Value-added Chemicals

With the objective of using industrial waste for value added product formulation, pyrolysis technology was developed for the production of commercial-grade biochar, chemicals (phenols, catechol, etc.) from industrial wastes – solvent-extracted catechin and cutch waste.

The waste from the Indian Wood Products Company Limited was explored to produce value-added chemicals at pilot scale. Phenol/catechol and activated carbon are the two major pyrolysis products formed that have high economic values. An innovative method of drying of wet liquor was developed by using lowcost catalysts (Cat-I and Cat-II) as a drying agent. Under catalytic drying, the overall yield of biochar was found to be 35–48 wt % for different waste streams where phenolic compound are produced between 74 and 85 wt % of bio-oil. This biochar is suitable for heating applications and also would be explored as soil amender. The highly microporous-activated carbon produced through downstream activation of biochar using environmentally benign green chemicals has high Brunauer–Emmett–Teller surface area 900–1200 m^2/g, thus having future potential for gas purification as well as water purification applications. Currently, TERI is working on Phase-III pyrolysis technology's demonstration in Indian Wood Products.

Phenol and catechol derived by pyrolysis of Indian Wood Products plant

Value-added Biocommodity Production from Algae

Fish is an excellent source of protein and is rich in beneficial polyunsaturated fatty acids and vitamins. With increasing health awareness and fish being a staple food in many regions worldwide, overfishing has resulted in insufficient recovery and dwindling fish stocks has become a global problem. One of the main components in rearing fish is their meal; initiative has been taken to improve the quality of fish meal at an affordable price. Appropriate feeding results in better quantity and quality of fish flesh and oil. Algal co-products have shown potential for fishmeal formulation. Substitution of fishmeal with algae biomass aids in increasing growth rate, omega-3 fatty acid content, and taste improvement of the fish. Hence, algae biomass is explored for aqua feed formulation and large test set-ups were established for trail runs of this aqua feed formulation with various combinations of ingredients in experimental feed diets for fish, such as Tilapia, Pearl Spot, Common Carp, Rohu, and Catla. The compositional analyses of

Pyrolytic biochar from Indian Wood Products plant waste (prior to activation)

formulated feeds showed positive growth and high potential for the development of a commercial aqua feed.

Algae biomass was explored for the production of high-value carotenoid and polyunsaturated fatty acids. A laboratory-scale process was developed for the production of lutein and omega-3 fatty acid from *Nannochloropsis oculata* and *Dunaliella tertiolecta*.

Experimental fish tank set-ups for aqua feed development housed in the aquaculture centre at the TERI Coastal Education Hub

TRISHA, Mukteshwar

TERI's Research Initiative at Supi for Himalayan Advancement (TRISHA), situated at a height of 7500 feet in Supi village of Nainital district, Uttarakhand, is a distinct endeavour of TERI towards sustainable agriculture. Since agriculture is the main occupation, research and extension have been largely undertaken to improve quality and quantity of agricultural produce. It involves:

- Diagnosing deficiencies and applying biotechnological tools for improvement of nutritional, physical, and biological health of agricultural lands
- Providing innovative solutions to increase yield by providing planting material of an array of high-value temperate crop varieties, culinary herbs, aromatic crops and horticulture crops along with complete package of practices
- Optimally enhancing resource-use efficiency
- Increasing marginal farmers' capacities through training, capacity building, and demonstration
- Development of market linkages guaranteeing economic returns to the farmers by establishing value chain development

There are various facilities at Supi, including a soil testing laboratory for farmer fields, vermicomposting unit, polyhouses and glasshouses, oil distillation unit, herbal garden, resource centre of organic products, air quality monitoring unit, knowledge-cum-training centre, the Kumaon Vani facility (a community radio service for the local populace), quality-planting material nursery, and rainwater harvesting systems. There is also a passive solar greenhouse which can facilitate vegetable production all-round the year under unfavourable climatic conditions. TERI has touched the lives of around 4000 farmers in 35 villages in Ramgarh, Dhari, Okhalkanda blocks of Nainital, and other districts of Uttarakhand to provide end-to-end solutions for increasing their farm income. Hence, TERI has produced a platform for enhancing livelihood security by eliminating intermediaries and effectively creating a win-win situation for farmers, community-based organizations, various clusters, and other stakeholders.

TERI Southern Regional Centre, Bengaluru and Goa

TERI Bengaluru–Goa covers the southern states and territories through its network of various groups—Industrial Energy Group (IEG); Centre for Research in Sustainable Building (CESB); Centre for Impact Evaluation and Energy Access, Bengaluru (CIEEAB); Resource-efficient Technology (RET); Environmental Education and Awareness (EEA) in Southern Regional Centre, Bengaluru; and Coastal Ecology and Marine Research Centre (CEMRC) based in the Goa Centre.

The IEG provides services to large energy-consuming industries in better conservation and optimal utilization through energy audit and implementation assistance. During the year under review, the Group coordinated (a) verification audits of newly designated consumers under the PAT schemes II and III; (b) mandatory energy audits; and (c) phase III of HAL's CSR initiatives with the partnership of BESCOM. The completion of the project on design, installation, and commissioning of power gasifier of 600 kWp for Amazonia Rice Investment Guyana, a rice mill of Nand Persaud Company from the Berbice region, was a significant achievement.

The CIEEAB works with communities, particularly in rural areas, on aspects, such as renewable energy, watershed development, forestry, women empowerment, livelihoods, and efficient utilization of natural resources. Other activities are: dissemination of relevant technologies, monitoring, evaluation, and providing consultancy.

The CESB is currently working with corporates, developers, and public sector units to provide consultancy services for designing energy-efficient buildings. The Centre has also been working on research projects and policy frameworks with Government of India, as well as private institutions on energy efficiency, thermal and visual comfort for habitat, and energy efficiency in cold storages. The CESB also holds training and knowledge dissemination programmes for professionals and students in the building industry.

The RET, Bengaluru, is working on research and development (R&D) activities in the areas of development of biodegradable and environmental-friendly plastics for short- and long-term applications. The group is well equipped with sophisticated testing equipment for polymer processing and testing services as per standard test procedures.

The EEA area at TERI is playing an effective role in facilitating the youth and children in understanding environmental problems and to act towards addressing them by creating awareness and bringing in behavioural changes. The activities of the area will prepare students to enhance their sense of responsibilities towards the environment. The group is actively involved in training and delivering sessions to schools and colleges on several issues of environmental concern.

The CEMRC, Goa, which is attached to Southern Regional Centre, Bengaluru, is a multi-disciplinary 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

TERI North-Eastern Regional Centre has been working for innovative research in the fields of agriculture and biotechnology, and is also implementing projects related to the rural extension of research activities. The Centre continues to focus on production of quality planting-material and implementing rural extension services. The Centre is currently undertaking several projects related to different facets of environment. Recently, the Centre in the north-eastern region has installed 200 biotoilets in schools across 8 north-eastern states. These biotoilets are eco-friendly and require less water. The Centre has also undertaken training programmes on solid waste management for urban local bodies and is also carrying out evaluation of interpersonal communication and behavioural change communication under Swachh Bharat Mission, Gramin. TERI North-Eastern Regional Centre is in the final phase of carrying out monitoring, evaluation, and documentation of Integrated Watershed Management Programmes (IWMPs) in five districts of Assam. In biotechnological research, the Centre is engaged in enzymatic retting and processing of banana fibres, which will result in simple processing and their utilization as a renewable fibre source for industrial uses. In another project, the Centre is working with plant-based bio-protecting edible coating for post-harvest storage of a few indigenous fruits of Assam to enhance the durability and fruit quality during storage. Orchid being a major bioresource of the region, the Centre is co-partnering in a project for collection, characterization and ex-situ conservation of rare and endangered orchids of Northeast India. The new initiative of Centre is setting up of a state-of-the-art food technology laboratory for testing of quality of food items, especially in the north-east region and will be operational very soon.

Global Operations

TERI Japan

During 2018/19, TERI Japan continued to promote relationships with Japanese institutions, universities, governmental agencies, and non-governmental organizations (NGOs) interested in emerging global concerns in the areas of energy, environment, and sustainable development. In recent years, the bilateral relations between Japan and India have grown much closer in all areas and this has opened up many new opportunities in the bilateral economic and political engagement.

TERI continues to have a close working relationship with the Institute of Global Environmental Strategies (IGES) and the office of TERI Japan continues to be located in the Tokyo office of IGES. As a reciprocal arrangement, the IGES has the office of its own representative in India, located at TERI, New Delhi. The TERI–IGES collaboration has been going on for the last 20 years, during which the researchers of the two institutions have been collaborating with each other in undertaking joint projects in areas of mutual interest with the objective to promote India–Japan technological cooperation in the areas of energy, environment, and sustainable development.

Like every year, Professor Kazuhiko Takeuchi, President of IGES, participated in the annual World Sustainable Development Summit (WSDS), organized by TERI in New Delhi in February 2019.

In July 2019, Dr Ajay Mathur, Director General, TERI, visited Japan and participated in the International Forum for Sustainable Asia and the Pacific (ISAP 2019), organized annually by the IGES in Tokyo. Mr Girish Sethi, Senior Director, TERI, Industrial Energy Efficiency Division, also participated in the ISAP 2019. Taking advantage of their presence in Japan, bilateral meetings were held between IGES and TERI to review and plan programmes and activities to be undertaken jointly.

Dr Mathur is expected to visit Japan in October 2019 to participate in the Innovations for Cool Earth Forum (ICEF). Such visits by the Director General provide excellent opportunities for interactions with various institutions in Japan with a view to explore possibilities of mutual collaboration in areas of common interest.

SUPPORT 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 COAU 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. The COAU 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. Amongst these are regular thematic workshops and seminars for mid-level research professionals as well as sensitization workshops, and facilitation of participation of journalists at key events. The Programme Cell of the organization that works within the COAU is the backbone for every such event. It is responsible for the smooth execution of TERI's numerous events and workshops.

TERI's annual flagship event, the World Sustainable Development Summit (WSDS), organized within the COAU, has been designed as a platform that facilitates meaningful dialogues that promote North–South cooperation and initiate discussions on strategies that would bridge the gap between the developed and the developing nations of the world. The WSDS promotes global equity, equitable distribution of natural resources, and pragmatic solutions to existing issues of climatic importance. An epitome of Track 2 diplomacy, the Summit platform provides an enabling atmosphere that encourages people-to-people dialogue; fosters understanding; cooperation and collective action to achieve the universal goals of sustainable development.

The Environment Education and Awareness Area forms another wing of the Unit that works towards providing interesting education pedagogies that instil among the youth, consciousness of existing social structures within our society, cultural norms, economic realities, and global trends.

For our stakeholders who share TERI's vision of a common sustainable future, the Unit recurrently produces a vast body of communication material that focuses on scientific knowledge on energy and environmental issues, with a layered attention on the many human challenges that exist in tackling developmental concerns for dissemination, both internationally and within the country.

The Unit's work falls within the ambit of four major areas, allowing for a streamlined and efficient division of work. These areas are discussed next.

World Sustainable Development Summit

Through its journey of 20 years, the WSDS platform has extended to every participant–individual and institution–an opportunity to further strengthen their position as a proactive advocate of the fight against climate change. The Summit has also shared plans, policies and priorities on sustainable development and climate action with a high-level and diverse audience. Thus, in the process it has enabled the exchange of rich information, technology and best practices, and shaped partnerships across sectors, sections, and geographies.

WSDS 2020 focused on the need to assess the global contributions made towards the realization of the goals of sustainability and analysed further steps that ought to be undertaken by the world communities to meet the targets of the 17 SDGs. Under the broad theme of 'Towards 2030 Goals: Making the Decade Count', this Summit edition helped established the terms of the discourse for making the most of the remaining decade. This was achieved by weaving together the many strands of climate action through myriad, high-level discussions. The Summit series, to date, has hosted 49 heads of state and government, ministers from over 77 countries, 13 Nobel laureates, over 2500 corporate delegates, and participants from across continents, in addition to many subnational leaders from across the world.

Environment Education and Awareness Area

The Environment Education and Awareness Area engages with youth across the country on diverse environmental issues to enlighten, enable, and empower them to take positive actions at individual, family, and community levels. To commemorate the successful completion of two decades of GREEN Olympiad, GO4Youth, a new feature, was launched for college students. A youth declaration on Climate Action was presented at WSDS 2020 as a grand finale to a series of events conducted across the country with support from European Union to India and GIZ. The Green School Project, a Tata Steel-TERI initiative was showcased at COP 25 in Spain. TERI-NCSTC Eco Next Investigation for Youth supported by National Council for Science Technology and Communication, Department of Science and Technology, Government of India, trained college students to find science-based solutions to prevailing environmental problems. An important output of the project is development of an e-training manual. An intensive training and infrastructure support to select schools and communities through the WASH (Water Sanitation and Hygiene) education programme supported by Sony India Software Private Limited, Bengaluru was completed. A comprehensive water balance and efficiency solution involving rainwater harvesting and training was implemented for employees of Titan, Bengaluru.

Environment education interventions were integrated into several interdivisional projects - GRIHA for existing

day schools; awareness campaign on energy under Jamshedpur Utility Services Company Limited (JUSCO); LOTUS-HR (Local Treatment of Urban Sewage and Streams for Healthy Reuse); energy survey under MacArthur project; Preparation of IEC plan for the municipalities of Varanasi and Panaji under GIZ supported Development and Management of Nationally Appropriate Mitigation Action for Waste in India.
A thematic track, titled Youth Conclave on SDGs was held under the aegis of ICSE (International Conference on Sustainability Education) held on 9–10 September 2019 at India Habitat Centre, New Delhi.

Programme Cell

To complement its research agenda, TERI organizes a large number of conferences, training programmes, and seminars on diverse issues and topics. This also includes training and capacity building, exchange of experiences concerning best practices, and information dissemination. The Programme Cell at TERI functions under the Communication Outreach and Advocacy Unit to provide logistic support for all events within and outside TERI to enable the maintenance of quality and cost-effectiveness. It is a dedicated team of professionals geared up to provide timely and quality support along with audio/visual set-up for events, exhibitions, and social programmes. The Programme Cell provides for services, such as drawing up preliminary budgets, online registrations, travel desk at the venue, hotel reservations, organized tours, special activities for spouses, side events, recreational activities, and other pre- and post-conference activities, including transcription and documentation of proceedings. It also prepares the accounts statement as part of its post-conference protocol. The team successfully executed more than 100 events in 2019/20,

including 11th GRIHA Summit and TERI's flagship event—WSDS 2020.

Creative Content

The Creative Content Division 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 in electricity and industry transition in India, green stimulus proposal for reviving the economy in the wake of COVID-19, launch of India's Climate Atlas, and urban flood early warning system received wide attention from both traditional and new media.

This year, TERI's website maintained a steady flow of content, including research papers and articles, and a growing emphasis on videos, infographics, and podcasts. On social media, TERI's engagement continued to grow across platforms – notably by 118% on Youtube, 67% on LinkedIn, and 32% on Twitter.

TERI's community radio Kumaon Vani, located in

Kumaon Vani volunteer interviewing community member on environment conservation and livelihood under SECURE Himalaya project

Mukteshwar, Nainital, produced and broadcast a number of programmes to raise public awareness on COVID-19, among other issues related to environment and conservation. The Creative Content Division also initiated a Media Fellowship programme on climate change reporting in the Himalayan region. Supported by the Earth Journalism Network, the programme trained a total of 13 local journalists from India and Nepal in climate science, policy, and multimedia production. These efforts brought out a wide-ranging collection of video and audio stories on impacts and solutions related to climate change in the Himalayas.

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 the Ministry of New and Renewable Energy, Government of India, BSES Rajdhani Power Limited, 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.

Growth, Diversification, and Commercialization Unit

The primary focus of Growth, Diversification, and Commercialization Unit (GDCU) is as follows:

- To build on TERI's existing strong relationships with bilateral, multilateral, and government agencies;
- To explore and develop linkages with new stakeholders, mainly corporates and foundations, thereby expanding the reach of TERI's research capabilities and output;
- Using TERI's strengths to create new cross-functional platforms with multi-year agendas that will appeal to a multi- stakeholder community;
- To promote and support the commercialization of TERI technologies, products, and services and support the scaling up of emerging technologies;
- To collaborate with Indian companies and other multinational corporations (MNCs) and work on sustainability challenges facing various industries.

Broadly, the mandate of GDCU is operationalized by the Technology Dissemination group, the TERI Council for Business Sustainability (TERI CBS), the International Implementation team, and the Ecotourism unit. These teams work closely with the research programmes and researchers at TERI to develop and provide an array of services in the fields of energy, environment, and sustainable development.

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 co-creates business solutions with members 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, Management Development Programmes, 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

TERI CBS engages with the core issue of what businesses must do to shape and lead in sustainability. Activities of the Council are governed by an Executive Committee from amongst member companies.

Technology Dissemination

The primary objective of the Technology Dissemination Group in TERI is to facilitate wide-scale dissemination and commercialization of TERI inventions/solutions. The focus of the research groups in TERI has always been on developing workable and viable solutions that are sustainable. Over time, this has resulted in a range of technologies that are suitable for wide-scale dissemination.

The activities of the Technology Dissemination team essentially aim at promoting and supporting the commercialization of TERI technologies, products, and services and support scale up of emerging technologies. Broadly, these activities include the following:

1. Securing and managing TERI Intellectual Property (Patents, Trademarks, Copyrights, etc.).
2. Developing strategic alliances and partnerships with industry for technology licensing, technology development, etc.
3. Facilitate the framing and signing of contracts for effective dissemination: Licensing agreements, collaborative research, etc.
4. Developed 'Standard Form Contracts' for TERI: NDAs (non-disclosure agreements), MTAs (material transfer agreements), product – dealer/distributor agreements, sub-contract agreements.
5. Promoting TERI solutions and technical capabilities: Developing and disseminating promotional material (publications, e-brochures, videos, etc.); showcasing TERI solutions at events and exhibitions.

The Intellectual Property (IP) portfolio of TERI has been strengthened due to the focus on filing and securing of patents, trademarks and copyrights. Currently, TERI has 45 patent applications filed before the Indian Patent Office, which are at different stages of prosecution in the patent cycle prior to grant. TERI has 14 trademarks registered in its name, and has also secured copyright for one of its flagship programmes 'Lighting a Billion Lives'. TERI has concluded more than 18 licence agreements with industry for TERI technologies which has resulted in ecological and economic gain for industry and society.

Some of the more recent collaborations that have been concluded are:

a. Technology Development and Technology Transfer Agreement with 'The Indian Wood Products Company Limited', Bareilly related to TERI's novel Pyrolysis Bioreactor Technology.
b. Collaboration Agreement with 'Maxop Research and Testing Institute Private Limited' to establish a state-of-the-art 'TERI-Maxop Solar Research and Test Facility'.
c. Technology Development/Dissemination agreement with M/s Perfact Researchers Private Limited to promote TERI's wastewater treatment technology.

In order to promote TERI R&D capabilities and solutions, the TD Group has actively participated in events and exhibitions to showcase TERI solutions. One such event was the exhibition organized by (MoEFCC) as part of the 'World Environment Day' celebrations. TERI actively participated at this exhibition that took place on 3–5 June, 2018 at Vigyan Bhawan and showcased its innovative technologies, products, services and programmes at this event.

The TD Group also tied up M/s Messe Munchen (global exhibition organizers) to collaborate and conduct events on relevant topics with respect to energy and environment. TERI was able to disseminate its research work at Intersolar India 2018 that was organized by M/s Messe Munchen.

International Project Implementation

The International Project Implementation (IPI) area was set up in 2017 and its primary objective is to enhance collaboration with international governments to facilitate NDC implementation. The first collaboration began with Fiji, a vulnerable pacific island country. The first project is complete and focused on key activities from the UNDP–GEF funded Ridge-to-Reef project and the results were duly lauded by the Fiji government. Now another project has been initiated with Government of Fiji to revise their State of Environment Report. In addition, IPI intends to expand its work in other geographies that can leverage on its skill-set.

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.

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 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; and bringing out peer-reviewed publications and knowledge products on contemporary issues.

During this year, 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, involving collection, compilation, and dissemination of information on energy efficiency improvement technologies and carbon dioxide reduction technologies being used and practiced in Indian industry sub-sectors, namely, 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 its dissemination for policymaking, 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. Till now, 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.

TERI KRC also organized its flagship international conference – the 6th edition of International Conference on Digital Landscape (ICDL) on 'Digital Transformation for an Agile Environment' from November 6 to 8, 2019. Apart from emphasizing on digital library development, preservation and access, and knowledge management, ICDL 2019 identified Industry 4.0 as one of the key areas where digital transformation is undergoing a paradigm shift. The flagship event saw widespread participation by 650 experts, policymakers, academicians, corporates, and research scholars from 12 countries.

Corporate Social Responsibility

Corporate Social Responsibility (CSR) has evolved over time and has been gaining importance for businesses in the context of sustainability and sustainable development. Earlier, CSR and business were interpreted separately by the corporates and the linkage between the two had been missing. business houses used to see CSR as one of many activities of social work. Gradually, over time, businesses realized that CSR and business cannot be conducted in isolation.

The CSR Department of TERI formulates 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
- Achieving Sustainability in CSR projects

TERI has a proven history of working on a wide range of projects within the domain of CSR, sustainability and sustainable development. TERI has state-of-the-art facilities, laboratories with latest sophisticated instruments, software and experienced manpower, and has implemented CSR projects across India. It also conducts training and awareness programmes, workshops, stakeholders' consultation, and participatory approaches to project implementation in CSR and sustainability.

TERI has received the following awards related to its CSR programmes:

1. Best CSR organization on rural development project for Coal India CSR project in Purulia in West Bengal.
2. Mahatma Award for best CSR project on Environment and Sustainability for Coal India project.
3. Best CSR project for CSR and Environment Sustainability for CONCOR CSR project implemented in Himachal Pradesh.
4. Many prominent awards on themes of Education, Water, Clean Energy CSR projects.

Project Management Unit

Projects are the mainstay of TERI. At any given time, hundreds of 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.

SUPPORT
UNITS

Information Technology and Services Division

The year 2019/20 faced lot of challenges due to the COVID-19 pandemic which also enabled an environment of fast-tracking the digital transformation. The Information Technology (IT) team worked extended hours to meet the needs and demands of colleagues during the lockdown period.

Enabling Work from Home

The IT team enabled the following key IT services to facilitate most of the colleagues to work from home across the regional centres:

- Online meetings (Microsoft Teams): This platform provides excellent experience of online meetings or collaborations and integrates people, contents, and tools. It facilitates web, audio, and video conferencing using desktop/laptop or mobile devices. The online meetings bring back the human element of face-to-face work experience. Integration with Outlook Calendar is an added advantage not only to invite colleagues from the address book but also external guests to join scheduled meetings just by clicking a link.
- Cloud storage space (OneDrive): OneDrive is one of the important tools that enabled people to access their data/files from anywhere/homes and on any device. The automatic synching or backup of files ensures that you will never lose your files even in case your computer crashes or be lost. It has a seamless integration with Microsoft Windows operating system and it appears as one of the folders in file explorer. It works well with Microsoft Office apps, that is, Word, Excel, PowerPoint, etc. With this, one can collaboratively work on the files stored in OneDrive in real time and securely share them with others.
- Secure access to applications through SSL VPN: The Secure Socket Layer Virtual Private Network (SSL VPN) enabled remote users to access applications, internal network utilities, and directories. The SSL VPN client was installed on home systems to securely access Project Management System, Employee Self Service, ERP Systems, other applications, and office desktop remotely.

This phase is the beginning of taking the digital transformation to the next level within the institute. The readiness of the TERI colleagues to easily adopt the digital change has been a huge advantage.

The IT and Services Division continues to contribute in IT-related research activities and its key projects are specified in the subsequent sections.

Demand Forecasting Tool [http://electricitydemandforecast.in/]

This tool enables the utility officials to assess the historical demand patterns and foresee the future behavioural characteristics of the utility. The scenario-based approach allows accounting the changes in the load pattern due to increased adoption of energy-efficient appliances and technologies, alternate green power sources, and e-mobility. The tool facilitates the research community in distribution planning, informed policymaking, demand-side management, and resource planning.

Features

System-level analysis: This module enables the utility to analyse the historic utility-level demand pattern and its variations, which informs about the behaviour of consumers as well as indicate the long-term trends.

Feeder-level analysis: This module helps the utility officials to assess the impact of electricity demand of various consumer categories in the utility-level demand profile based on the historical data of the particular year.

Demand forecast: This module of the analytical tool forecasts the future electricity demand profile of a utility based on the historical data of the preceding years. The tool enables user to envisage the hourly, monthly, and annual load profile as well as peak day and lean day load curves for succeeding 3 years.

Scenario analysis: This module examines the types of DSM measures and introduction of new and renewable technologies that can alter energy demand. This can provide way and means to manage the loads and to convert unsustainable energy practices into more efficient and sustainable energy use.

Stakeholders

TERI, Shakti Sustainable Energy Foundation, and Electricity Distribution Companies and Utilities

Green Olympiad (GO4YOUTH) Online Examination [http://52.76.109.165/goexam/login/index.php]

The IT team developed an online platform for GO4Youth, which is a pan-India examination to test the environmental knowledge, aptitude, and attitude of students. 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 were 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 the student can access sample questions, and get a simulated environment before actual examination.

Online examination: Through an online secure platform, students can attempt the examination that comprises 50 multiple-choice questions to be completed in an hour.

Exam result: The result of the examination can be viewed online by the students. The students can access the correct/incorrect answers also.

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 to promote 'GO4Youth' within their network.

Stakeholders

Students, schools, and colleges

Building Materials Directory of India [http://52.76.109.165/bmdi/public/index.php/]

The Energy Efficient Building Materials Directory (BMDI) provides manufacturers/suppliers/retailers of the Indian construction industry an opportunity to enhance their visibility by registering their products with comprehensive information and getting listed on the online building materials directory. It also gives them a chance to showcase their building materials which satisfy the parameters for energy efficiency and are highlighted in the directory.

Features

1. Company and product registration process: The manufacturer provides details about the company and the products manufactured by them. The system ensures that each manufacturer in the directory is unique by validating his/her mobile number and email address (through a secure OTP process).
2. End-to-end registration evaluation process: The website admin evaluates the submitted entries by providing comments and accepting/rejecting the registration.
3. Category-wise product management
4. Dashboard for manufacturers/suppliers to view their products, manage them, and request changes to admin.
5. A robust product search mechanism for the user to help them in making the informed decision on selection of energy-efficient products for construction.
6. The user can compare different products in the directory with the help of a comparison matrix.

Stakeholder

The Bureau of Energy Efficiency, Ministry of Power, Government of India, sponsored this project.

IKI PORTAL

The IKI India Interface aims to increase collaboration, conversation, and cooperation among the IKI project partners in India. The platform caters to the IKI projects and IKI partners in India providing them a one-stop platform to interact and engage with each other and disseminate their work more widely through the large platform.

The web portal features projects undertaken by IKI India categorized under overarching themes, such as Mitigation and Adaptation to Climate Change, Forests and Natural Carbon Sinks, Protection of Biodiversity, India's NDC, and other cross-cutting topics. A provision has been made for managing the website content, such as projects, events, activities, etc., through an admin panel. In addition to the IKI Portal, a 'We Share' platform was also developed to enable greater synergy among all the project stakeholders.

Features

1. Website admin and project coordinator roles: Both have different set of rights for managing the portal.
2. Enables project coordinators to manage region-wise (global, regional, and bilateral) content of their projects and events along with activities themes.
3. Facilitates collaboration with peers to discuss and share knowledge pertaining to their subject matter expertise using moderated discussion forums.
4. Polling feature to brainstorm and initiate discussions on relevant subject areas with project coordinators.

Access to Knowledge (A2K) on Energy-Efficient Technologies [http://52.76.109.165/a2k/index.php]

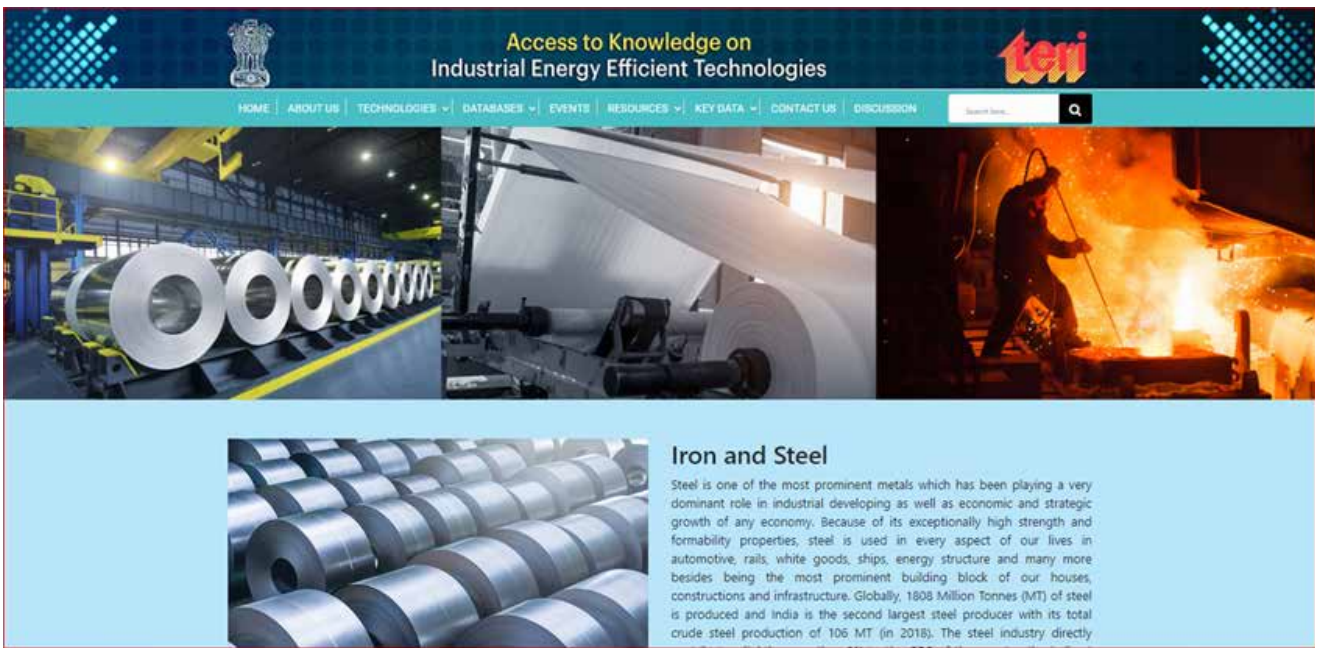
TERI, under Department of Scientific and Industrial Research (DSIR)'s Access to Knowledge for Technology Development and Dissemination (A2K+) scheme, developed the A2K Portal to enable access to technology information with emphasis on energy efficiency in the Indian industry sub-sectors – Iron and Steel and Pulp and Paper. As a key source for information exchange and knowledge sharing, this platform aims to consolidate available information on emerging technologies with the goal of disseminating information for policy formulation by the government. It enables industry and plant professionals to identify and know of the best available technologies and practices that improve productivity while reducing energy consumption and CO2 emissions in these industry sectors.

Features

1. Acts as a data repository for two industries – Iron and Steel and Pulp and Paper.
2. Provides databases for literature abstracts and case studies for the technologies.
3. Provides key data on technologies.
4. Acts as a discussion forum for knowledge sharing and collaboration among stakeholders.
5. Allows robust search to retrieve information from different databases available in the website.
6. Provides resources, such as books, journals, and news, ab the technologies for further reference and knowledge.

Stakeholder

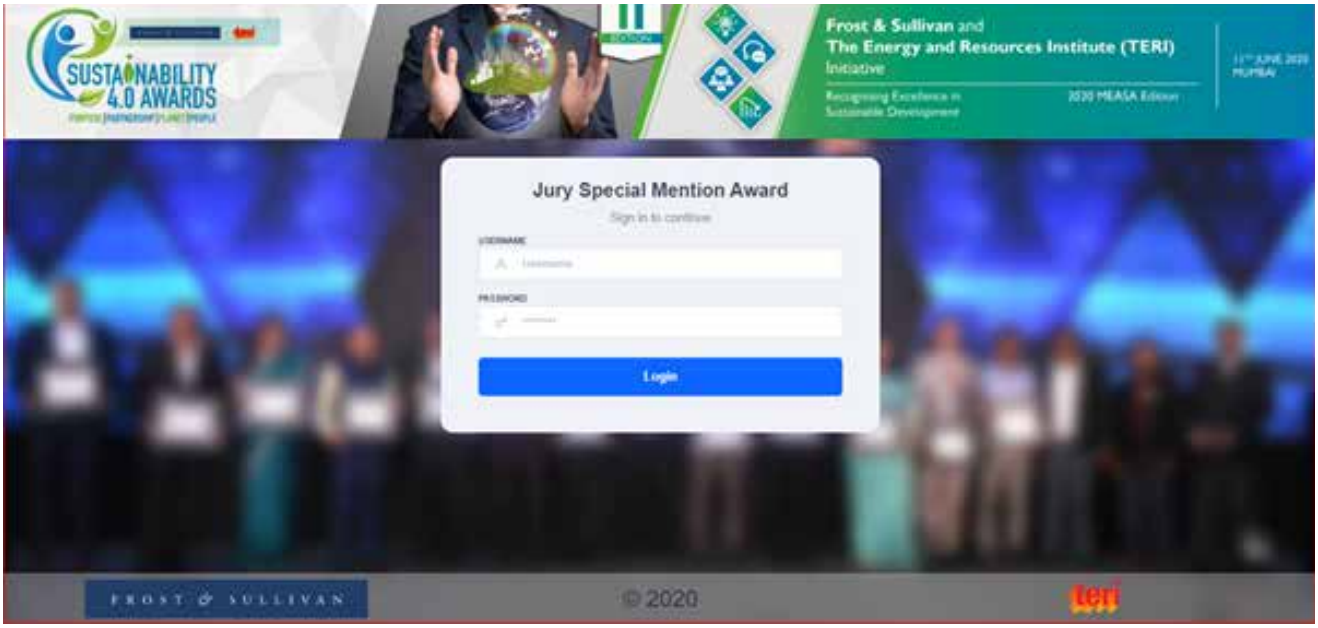
Department of Scientific and Industrial Research (DSIR)



Jury Special Mention Award Tool

This Frost & Sullivan and TERI initiative aspires to assist organizations to unearth the risks, leverage the opportunities, enable them to benchmark their performance, and of course, be rewarded for their accomplishments in the field of sustainable development. The awards platform instituted in 2009 has evolved in its scope and boundary ever since its inception. There has been a series of transformation in the scope of assessment, sector coverage, and the programme title as well.

This tool enabled corporates to submit their applications through a versatile form and enabled screening of the application documents by the committee. The jury reviews the companies qualified for awards and finalizes the award map. Erstwhile, winners and qualifiers were felicitated at the Sustainability 4.0 awards banquet.



TERI Envis Mobile App

The Environmental Information System Network (ENVIS) was established as a programme under the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, in December 1982. TERI has been working as one of the nodes of ENVIS, from TERI library since 1984. It was known as the Centre on Renewable Energy and Environment since July 1984; however, since 2017, TERI started acting as the ENVIS resource partner on renewable energy and climate change.

In line with the popular outreach of TERI ENVIS website, to cater to the mobile-savvy audience, a feature-rich mobile app was launched for both Android and iOS platforms.

Features

- The mobile app is a parallel channel of communication and engagement with stakeholders.
- It has several sections to highlight and disseminate information on renewable energy and climate change.
- It has **recent updates** about the activities undertaken by TERI ENVIS centre.
- **Ask Query** is available on the app.
- It has a **Registration/Login** tab.
- There are details of the events conducted by TERI ENVIS.
- Publications submitted by research community are available on the app.
- There are infographics, statistics, etc.
- There is a dynamic **community engagement section** that allows the end-user community to discuss, collaborate, and share their experiences and views on sustainable development.

ICDL Website and Mobile App

TERI, in collaboration with multiple governments and corporate and private organizations, organized the Sixth Edition of International Conference on Digital Landscape (ICDL), under the theme 'Digital Transformation for an Agile Environment'. The ICDL is held every 3 years covering contemporary topics which have global relevance with localized focus, and gathering digital luminaries across the globe, visionary policymakers, major corporates, and meticulous learners at a single collaborative platform for shared knowledge and benefits.

Features

A website and a mobile app for both Android and iOS platforms were developed for ICDL 2019 edition with the following features:

1. Virtual conferences, wherein expert panels of think tanks engaged with stakeholders to explore how immersive digital technologies on agile environment could be useful for digital transformation.
2. A series of webinars were organized on contemporary areas related to emerging trends on digital landscape to augment knowledge.
3. Storytelling gives a compelling reason to stay connected with customers. An interactive storytelling section, wherein stakeholders from all around the world submitted their stories and discussed their experiences using a moderated discussion forum.
4. Workshops, thematic events, and conference sessions.
5. Paid and guest registrations.
6. Agenda management.
7. Multimedia – photo and video.
8. Event live streaming.
9. In-event polling and result publish.
10. Events and activities pertaining to the event, such as news, bulletins, brochure, etc.

Facilitating Survey Activities Using IT Tools

The ITS division provides end-to-end survey services, including requirement gathering and conceptualization, design and development of survey forms, data management, and data analysis. Some of the projects implemented through this initiative include Groundwater Assessment in the City of Lucknow, Pilot Implementation of DBTE in Punjab, CAMPA Afforestation, etc.

The following different platforms are used for the survey projects, as per need:

1. Web-based online surveys
   - Registrations
   - Polls/quizzes
   - Feedback
2. Mobile-based online/offline field surveys
   - Offline surveys
   - Multiple questions
3. Customized IT applications for complex surveys
   - Custom branding
   - Authentication based

Features

The key features of the survey activities are as follows:

- Offline survey tool, including access in remote areas
- Structured data are stored in a centralized repository
- Multilingual forms development
- More than 35 question types, including multimedia
- Conditional/branching questions and validation checks
- Custom branding and authentication
- Manage survey forms and survey teams
- Survey data verification, including send back
- Data management and survey access control
- Data analysis in various formats
- Integrations with data visualization tools (such as Power BI/Tableau)

TERI Website–Hindi Subsite

Through its Hindi subsite, TERI aims to reach out to the largely untapped regional audience with a view to expanding its outreach to readers of Hindi content. The section provides an avenue for readers to engage with TERI on a range of themes, such as agriculture, climate, energy, environment, health, nutrition, etc., in their local language.

The Hindi subsite contains the following components:

- Blogs and articles – content written by TERI's researchers to connect to the relevant Hindi audience.
- Infographics – information representation through the use of visual data, charts, and statistics.
- Films and videos for engaging audience and creating a positive impact.
- Press Releases serve as a tool for information dissemination with respect to big projects, events, conferences, policy document release, etc.
- Photo series, highlighting TERI's major initiatives and projects in the form of guided tour of rich images with captions.
- Kumaon Vani community radio station – Aapun Radio Aapun Baat – was set up in March 2010 to bring together communities across the Kumaon region. The aim is to promote sustainable development among the farming community in their local language.
- TERI in the News and more.

1. Knowledge Management System

Creation and sharing of knowledge is important for TERI to establish and sustain competitive advantage. Through TERI's Knowledge Management System (KMS) employees can share knowledge items in one's possession (namely, reports, fact sheets, data in excel, case studies, lesson learnt, survey questionnaire, etc.) and collectively learn.

Features

- KMS provides options to upload, search, and download the desired resources for projects, proposals, project reports, project documents, articles, MoUs, and presentations.
- Accessibility and confidentiality: Most of the resources are made accessible to TERI's research professionals, while some have controlled access on account of confidentiality. In case one needs to access such resources, one may contact their project investigators or KM Admin.
- My Contribution/My Division's Contribution: KMS provides a dashboard to show the contributions made by the logged in member as well as his/her division.
- Announcements and Events: The section comprises announcements and a list of upcoming events.

Stakeholders

All TERI professionals

2. Intranet-Beta

Intranet is the central repository for TERIers to access the important organizational resources at a single location. With the beta version, the Intranet has been made accessible to the employees even outside of TERI's network, which comes handy while working remotely in COVID times.

Features and Sections

- Organizational structure (GC, CoD, ACs, etc.)
- Rules, policies, guidelines, QHSE
- Organizational updates banner section
- Staff details (new staff, staff on travel, staff on leave, birthday list, etc.)
- DG Tippani
- Documents repository (MoMs, MoUs, MIS reports, annual reports)
- Links to important external websites
- TERI events and newsletters
- Featured and research articles
- Photo and video gallery
- HR announcements (internal job posting, TERI jobs, HR training schedule, HR updates, etc.)
- Open calls
- Nutrition tips/facts
- Quick contacts
- IT apps and services
- Employees on map

Stakeholders

All TERI employees

3. Customer Relationship Management

Customer relationship management (CRM) has been in place for managing customer relations and in continuing the efforts to enhance the services the following new implementations have been made:

- **Lightning implementation in TERI, TERI Press, and GRIHA Council**

  Lightning (Salesforce Lightning) is a component-based framework for app development from Salesforce.com, designed to simplify processes for the users in TERI. Basically, the design and interface for users have been changed.

- **CRM data analysis and reporting**

  This includes division-wise monthly contacts update, newly created data analysis by CRM team, and reporting to TERI secretaries and directors.

- **TERI CRM – dashboard development**

  This includes daily monitoring of division-wise contacts and newly created contacts through dashboard. All users/employees of TERI can access the CRM through intranet.

- **CRM mobile app–development and implementation**

  Salesforce mobile app implementation was done for some divisional directors through which they can access contact details anytime and anywhere.

- **Stay in Touch**

  This is the application created for updating contact details. The contact details are automatically updated in CRM.

Stakeholders

TERI employees, TERI Press, and GRIHA Council

4. Green Rating for Integrated Habitat Assessment

(https://tools.grihaindia.org/)

The GRIHA Rating variants undergo periodical technical revisions and from time to time new rating systems are developed to meet the evolving demands. The following are the major developments carried out in GRIHA in 2019/20.

- **GRIHA Affordable Housing Panel Rating Development**

  GRIHA Affordable Housing (AH) rating is a performance-oriented system where points are awarded for meeting the intent (appraisals) of the criteria. It is a 100-point system consisting of 30 criteria categorized under various sections, such as Site Planning, Energy and Occupant Comfort, Water Saving, Waste Management, Sustainable Building Materials, Social Aspects, and Bonus Points. Different levels of certification (one star to five stars) are awarded based on the number of points earned.

- **Pre-certification Rating Development for GRIHA AH and Simple Versatile Affordable GRIHA**

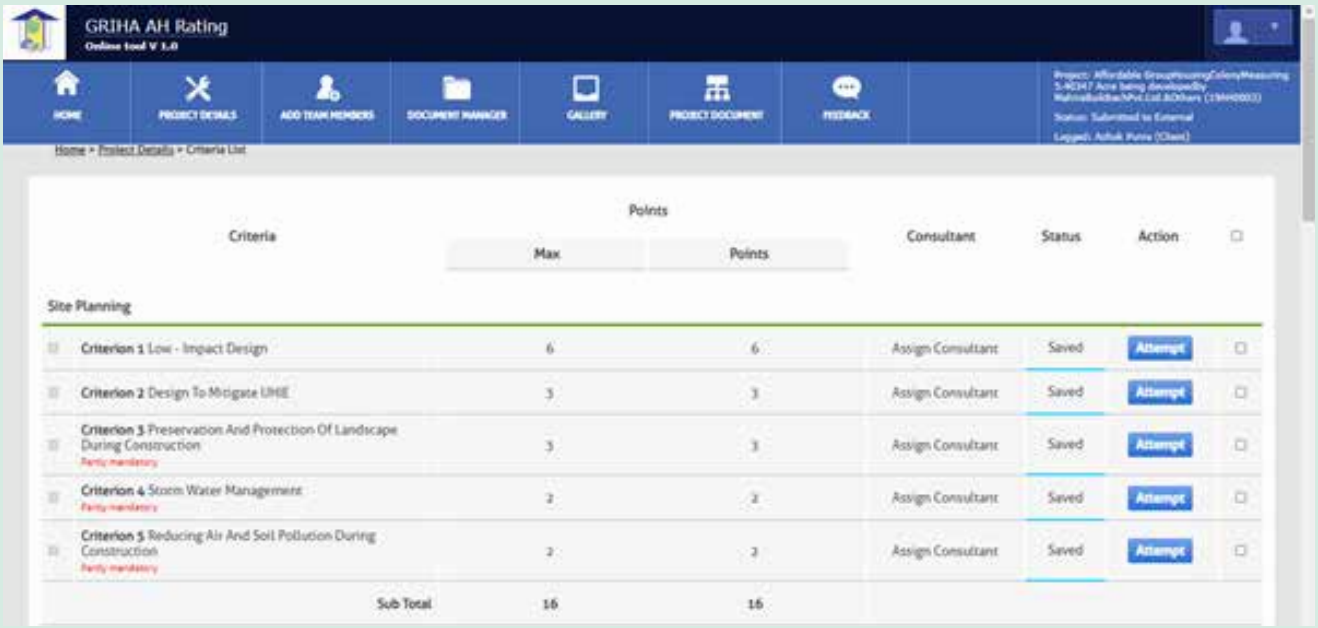
  Pre-certification ratings were developed for both the GRIHA Affordable Housing and Simple Versatile Affordable GRIHA (SVAGRIHA) Ratings.

- **Site Visit Panel Development**

  The panel was developed to help the GRIHA representatives to manage the site visit work in an effective manner and to organize and simplify the process of making and submitting due diligence reports. The panel contains all the relevant clauses that must be observed during the due diligence visits. GRIHA representatives have to select the status of each clause relevant to the project. It is an offline panel with an in-built intelligence. During the life of the project, three due diligence visits are conducted at various stages of construction to verify the on-site compliances.

Stakeholders

GRIHA team members and users opting for GRIHA ratings



The IT Division migrated from Lotus Notes email system to Microsoft Office 365 in the last financial year, which is provided free to non-profit organizations. The Division introduced and implemented the use of cloud-based storage, 'OneDrive', which is part of the Office 365 Suite, wherein users are allowed to store 1 TB of their data; the users in TERI are advised to store their data in this and they are trained for its efficient use also.

The upgraded supercomputing facility was also made available to colleagues working remotely or from home through secure connectivity. This helped the researchers to work on the supercomputer and deliver the project output on time. The performance and the outputs of the models run on the system were satisfactory and appraised.

The division coordinated and conducted many major online events for the first time in TERI, such as Virtual Divisional Retreats, HR Orientation programmes, Town Halls and Project review meetings using different tools, such as Cisco WebEx Meeting Centre, Cisco WebEx Event Centre, and Zoom platforms, successfully.

A number of laptops with Intel core I7 processor, 8 GB of RAM and 1 TB hard drives were refreshed and provided to colleagues who mostly travel and work remotely. For better use of these laptops on the office network, docking stations were also provided which allow them to connect to the LAN network easily. The docking station allows to connect the laptop with bigger TFT screen, external keyboard, mouse, etc.

The Division also implemented two new tools to manage IT issues of the colleagues and to manage all the IT assets of the organization, such as hardware, IT devices, and software. The tools are hosted on cloud, which allow TERI colleagues to log their complaints anytime from anywhere. The resolution time, SLA of the helpdesk service provider are monitored and maintained.

The network at Gwal Pahari campus was revamped and replaced with high-end network devices, which allowed controlling the network traffic within the LAN system. A new Unified Threat Management (UTM Firewall) device was added to enable high availability of gateway firewall to avoid internet downtime.

This year, the primary focus of the team is to promote the use of advanced IT technologies, such as artificial intelligence, machine learning, internet of things, etc., in research activities/projects.

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 enables employees to connect and collaborate while working from home. Flexible work from home policies were introduced to ensure employee 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 focus 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 an environment that is transparent and enhances employee engagement.

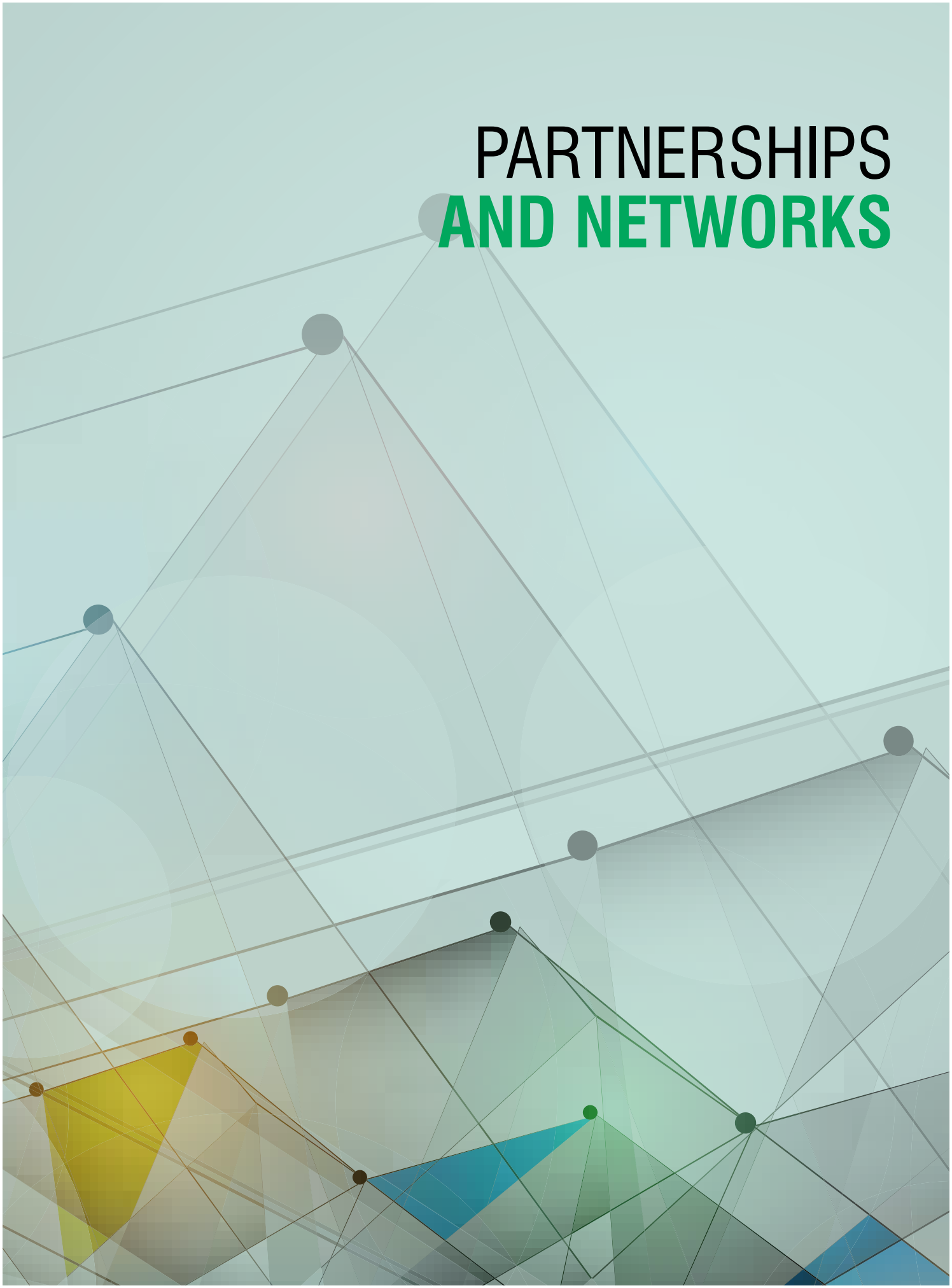
Administrative Services Division

The Administrative Services Division provides the necessary administrative and maintenance support 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 9001:2008 standards, its Health and Safety Management System as per BS OHSAS 18001:2007, and its Environment Management System as per ISO 14001:2004. 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 2019/20, are listed in this section.

Partner	Profile	Focus Area	Type of Association
Agarkar Research Institute, Pune	Government organization	Microbial biotechnology	Partnership network
Andhra Pradesh Capital Region Development Authority (APCRDA	Government organization	Sustainability partner to Andhra Pradesh Capital Region Development Authority (APCRDA) for the new capital city of Amaravati, Andhra Pradesh	Sustainability partner/funding support
Assam Agricultural University, Jorhat	Government organization	Microbial biotechnology	Collaborating project partners
Assam Science Technology & Environment Council (ASTEC)	Autonomous Council of the Department of Science Technology & Environment, Government of Assam	Post-harvest and possible collaboration for project	Funding support and collaborative project partner
Assam State Council for Science and Technology, Assam	Government organization	Microbial research	Funding support
Bharat Petroleum Corporation Limited (BPCL)	Public sector undertaking company	Bioremediation of oily sludge, contaminated soil	Funding support
Biotechnology Industry Research Assistance Council (BIRAC)	Government organization	Research support	Funding support
Bureau of Energy Efficiency and GIZ	Government and German Development Agency	Development of National Directory of Energy-Efficient Building Materials	Funding support
Bureau of Energy Efficiency, Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL), Karnataka Renewable Energy Development Limited (KREDL)	Government	Implementation of Energy Conservation Building Code in the states	Funding support
Bureau of Energy Efficiency and GIZ	Government and German Development Agency	Organizing Knowledge Exchange Programme-cum-field visit on built environment framework through implementation pathway of Australia	Knowledge partner/ funding support

Partner	Profile	Focus Area	Type of Association
Cairns Energy Limited, Gurgaon	Public sector company	Microbial Biotechnology	Funding support/ Partnership net work
Cairn Oil & Gas, Vedanta Limited	Public sector company	Microbial biotechnology	Partnership networking
Central Power Research Institute,	Government organization	Research and developmental studies EMI shielding nanocomposites for power sector	Collaborative research
Central Silk Board, Bengaluru	Government organization	Sericin /polysaccharide encapsulated fertilized for crop management and growth	Collaborative research
Chhatrapati Sahuji Maharaj Unversity, Kanpur	Government organization	Medicinal plants	Collaborating project partners
Council of Scientific & Industrial Research (CSIR)	Government organization	Dental nanocomposite resins based on hybrid dimethacrylates: mechanical, wear and shrinkage characteristics	Collaborative research
DBT-CIAB Center for Integrated and Applied Biosciences, Mohali	Government organization	Microbial biotechnology	Funding support
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	Government organization	Microbial biotechnology	Funding support
Delhi Metro Rail Corporation	Metro operator/Special purpose vehicle (SPV)	Sustainable Mobility	Funder
Department of Biosciences and Bioengineering, Indian Institute of Technology Guwahati, Assam	Government organization	Microbial biotechnology	Collaborative project partners
Department of Biotechnology	Government of India agency	Collaboration for research activities	Funding support
Department of Biotechnology	Government of India	Sericulture and medicinal plants	Funding support
Department of Biotechnology	Government organization	Local treatment of urban sewage streams for healthy reuse	Research collaboration

Partner	Profile	Focus Area	Type of Association
Department of Biotechnology	Government organization	DBT-CoE – Sustainability assessment of biofuel production systems	Sustainability assessment of integrated biofuel production systems – sustainability assessment of biofuel production systems
Department of Chemical Engineering, for Process System Computations, Curtin University, Perth, Western Australia	Government of Australia	Microbial biotechnology	Collaborative project partners
Department of Horticulture, Bihar	Government organization	Biotechnology	Supply of plants
Department of Microbiology, Central University of Rajasthan	Government organization	Microbial biotechnology	Collaborative project partners
Department of Science and Technology	Government of India agency	Collaboration for research activities on enhancing energy performance and thermal comfort in Indian buildings	Funding support
Finnish Meteorological Institute, Helsinki, Finland	Government of Finland	Microbial biotechnology	Collaborative project partners
Flood and River Management Agency of Assam (FREMAA)	Government of Assam	Livelihood enhancement	Funding support
Gail India Limited	Public sector company	Microbial biotechnology	Funding support
Helmholtz-Centre for Environmental Research, Leipzig, Germany	Government of Germany	Microbial biotechnology	Collaborative project partners
Hindustan Petroleum Corporation Limited (HPCL)	Public enterprise company	Bioremediation of oily sludge, contaminated soil	Funding support
INBIGS, ONGC Jorhat	Public sector company	Microbial biotechnology	Funding support
Indian Institute of Chemical Technology (IICT), Hyderabad	CSIR Institute, Government of India	Microbial biotechnology	Collaborative project partners
Indian Institute of Technology (IIT), Delhi	Government of India	Microbial biotechnology	Collaborative project partner
Indian Institute of Technology (IIT), Guwahati	Government organization	Microbial biotechnology	Collaborating project partners
Indian Institute of Technology (IIT), Madras	Government organization	Microbial biotechnology	Partnership network

Partner	Profile	Focus Area	Type of Association
Institute of Advanced Studies for Science and Technology, a Unit of DST, India	DST Unit, Government of India	Microbial biotechnology	Collaborative project partner
Institute of Bioresources and Sustainable Development, Imphal	Government organization	Biodiversity and bioprospecting	Collaborative project partners
Institute of Reservoir Studies, ONGC, Ahmedabad	Public sector company	Microbial biotechnology	Collaborative project partners Partnership network
Karnataka Trade Promotion Organization	Government of Karnataka agency, established to promote domestic and international trade	Client for development of new exhibition centre for Karnataka Trade Promotion Organization	Project client
MECON Limited	Public sector undertaking under the Ministry of Steel, Government of India	Project client on project related to campus development for Indian Navy	Project client
Ministry of Environment, Forest and Climate Change	Government of India	Livelihood enhancement	Funding support
Ministry of Food Processing Industries	Government organization	Infrastructure support	Funding support
Ministry of Housing and Urban Affairs, Government of India	Government	Empanelled consulting firm for Smart City Mission Empanelled training agency for AMRUT, Government of India	Advisory
Mizoram University	Government organization	Biodiversity and bioprospecting	Collaborative project partners
Nagaland University	Government organization	Biodiversity and bioprospecting	Collaborative project partners
National Academy of Customs Indirect Taxes and Narcotics	Government Training Institute – apex institute of the Government of India	Project coordinator for campus development at Bengaluru	Project client
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	Government organization	Microbial biotechnology	Funding support
NBCC (India) Limited	Government of India Navratna Enterprise	Project coordinator for campus development at Bengaluru	Project client

Partner	Profile	Focus Area	Type of Association
National Capital Region Planning Board (NCRPB)	Government organization	Expert member of the study group on Environment for National Capital Region Planning Board (NCRPB)	Expert member
National Institute of Technology, Rourkela	Government organization	Microbial biotechnology	Collaborating project partners
Nation Institute of Urban Affairs, New Delhi	Government organization	Capacity building	Funding support
Naval Research Board	Government organization	Co-microencapsulated intumescent fire retardant system	Collaborative research
NITI Aayog	Government organization	Assessing environmental and economic impact of coal washing, transportation, power plant, and any other area (affecting directly or indirectly)	Engagement with NITI Aayog and other stakeholders, such as NTPC and BHEL
North Easter Hill University, Shillong	Government organization	Biodiversity and bioprospecting	Collaborative project partners
North Eastern Council	Government of India	Capacity-building programme	Funding support
Norwegian Ministry of Foreign Affairs	Government organization	Enhancing energy efficiency in the residential sector	Information and market-based instruments influencing energy demand in the residential sector
NTPC (APCPL), Jhajjar	Public sector company	Microbial biotechnology	Partnership networking
NTPC (NETRA), Greater Noida	Public sector company	Microbial biotechnology	Partnership networking
N V Patel College of Pure and Applied Sciences, Vallabh Vidyanagar – 388120, Gujarat	Government organization	Microbial biotechnology	Collaborating project partners
Oil India Limited 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
Oil and Natural Gas Corporation (ONGC) Limited	Public sector enterprise company	Bioremediation, consultancy for soil fertility improvement	Funding support

Partner	Profile	Focus Area	Type of Association
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
Public Health Engineering Department, Assam	Government organization	Sanitation	Funding support
PWD Department	Government organization	Providing green rating for existing government building stock in the state	Project client
Rajiv Gandhi University, Itanagar	Government organization	Biodiversity and bioprospecting	Collaborative project partners
Regional Centre of Institute of Bioresources and Sustainable Development (RCIBSD), Sikkim	Government organization	Biodiversity and bioprospecting	Collaborative project partners
Sharjah Electricity and Water Authority	Government	Resources (energy and water)	Research collaboration
State Institute of Panchayat and Rural Development, Guwahati	Government organization	Consultancy for detailed project report	Funding support
State Level Nodal Agency (SLNA), WDC-PMKSY, Assam	Government of Assam	Monitoring, evaluation, and documentation	Funding support
Tata Steel Limited, Jamshedpur	Public sector company	Microbial biotechnology	Funding support
Temper University of Technology, Helsinki, Finland	Government of Finland	Microbial biotechnology	Collaborative project partners
Tripura University	Government organization	Biodiversity and bioprospecting	Collaborative project partners

Domestic & Multinational Corporations

Partner	Profile	Focus Area	Type of Association
Amsar Goa Private Limited	Private organization	Marine technology	Project partner
Asia Pacific Ministerial Conference on Housing and Urban Development (APMCHUD)	International network	Member of Working Group in Asia Pacific Ministerial Conference on Housing and Urban Development (APMCHUD) for disaster resilience and climate change	Member of working group
Asian Cities Climate Change Resilience Network	International network	National Partner to the Asian Cities Climate Change Resilience Network (ACCCRN)	Knowledge partner
Astra Microwave Products Limited	Private organization into R&D of microwave and RF products	Project coordinator for campus development in Bengaluru	Project client
AETS France	Consultancy	EU Public Diplomacy in India	Policy and outreach for strengthening India–EU relations
Confederation of Indian Industry	Industry association	Sustainable consumption and production	Research collaboration
Counsellor, Environment, Energy & Climate Change, EU Delegation to India	International network	Resource efficiency and circular economy, marine litter	Profile partner
Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ) GmbH	International organization	NAMA - GIZ IKI Interface Project	Indo-German bilateral project on development and management of NAMAs in India
Environmental Solutions Consultancy	Consultancy	Resources (energy and water)	Research collaboration
European Union	Multilateral association	Resource efficiency	Partnerships are established between European and Indian businesses and stakeholders on resource efficiency in sectors of interest
Federation of Indian Chambers of Commerce & Industry	Industry association	Sustainable consumption and production	Outreach and advocacy

Partner	Profile	Focus Area	Type of Association
GlS Polymers	Polymer industry	Fire-retardant cable sheaths	Collaborative research
GIZ	German development agency	Organized ANGAN conference	Knowledge partner/ funding support
Global Resilience Research Network (GRRN), pioneered by Global Resilience Institute (GRI), at Northeastern University, Boston, MA, USA	International network	Member of Global Resilience Research Network (GRRN), pioneered by Global Resilience Institute (GRI)	Network member
Green Economy Coalition	Network/multilateral organization	Sustainable consumption and production	Outreach and advocacy
Green Growth Knowledge Platform	International network	Knowledge management and outreach	Knowledge sharing and outreach
Hindustan Petroleum Corporation Limited, Vizag	Industry	Biotechnology	Collaborative research
Hindustan Zinc Limited, Chittorgarh, Rajasthan	Industry	Biotechnology	Collaborative research
Integrated Environmental Solutions-Virtual Environment	Software development company	Supported in providing free licence for participants during training workshops	Knowledge partner
International Urban Cooperation (IUC) and Global Compact of Mayors , South Asia, funded by European Union	Multilateral organization	Member of Advisory Committee for International Urban Cooperation (IUC)/Global Compact of Mayors, South Asia	Advisory committee
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 in Bengaluru	Project client
Mahindra Lifespaces	Industry partner	Mahindra-TERI Centre of Excellence for Sustainable Habitat	Funding support
Nirmal Seeds Private Limited, Maharashtra	Industry	Boitechnology	Collaborative research
ONGC–Teri Biotech Limited (OTBL)	Private limited company	Bioremediation of oily sludge, contaminated soil, MEOR	Funding support
Partnership for Action on Green Economy	Network/multilateral organization	Sustainable consumption and production	Policy research

Partner	Profile	Focus Area	Type of Association
Reliance Industries Limited	Private sector corporation	Bioremediation of oily sludge, contaminated soil	Funding support
Royal Danish Embassy	Embassy	Partner for Urban Living Lab for Smart and Sustainable Cities in India	Knowledge partner
Royal Haskoning DHV	Independent, international engineering, and project management	Engineering and project management consultancy for new projects of the Government of India	Consortium partner for research
SB Industrial Engineering Private Limited	Private limited company	Bioremediation of oily sludge, contaminated soil	Funding support
The World Bank	Multilateral organization	Potential role of natural gas in MSMEs	Study to assess potential and impact of switch to natural gas from heavier polluting fuels in India's National Capital Region MSME sector
UBER	Transport service provider	Sustainable Mobility	Funder
World Resources Institute	International organization	Food and Land Use Coalition – Engagement in India	Research collaboration

NGOs & Foundations

Partner	Profile	Focus Area	Type of Association
Adelphi Research, Germany	Not-for-profit research institute	Policy analysis and strategy consulting, marine litter	Collaborative research and partner in field implementation Project partner
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 and partner in field implementation
Central Salt Marine Chemicals Research Institute (CSMCRI)			Project partner
Centre for Orchid Gene Conservation of Eastern Himalayan Region, Manipur	Research centre, NGO	Biodiversity and bioprospecting	Collaborative project partners
Chamber of Commerce and Industry of Uzbekistan	Not-for-profit organization	Consultancy	Collaborative research
CIFF – Children's Investment Fund Foundation	Foundation	Just transition	Research collaboration to develop the low-carbon industrial transition strategy
Dhaka Chamber of Commerce & Industry (DCCI), Bangladesh	Not-for-profit trade organization	Promote private sector enterprises and businesses with advocacy, awareness and policy inputs to government	Collaborative research and partner in field implementation in Bangladesh
Development Alternatives	Non-governmental organization	Sustainable consumption and production	Outreach and advocacy
Human India	Non-governmental organization	Biotechnology	Collaborative research
Konrad-Adenauer-Stiftung (KAS)	Foundation	Security concerns in the global maritime	Conducted a background study and event on addressing non-traditional security concerns in the global maritime order and contextualizing India
National Association of Small and Medium Business of the Republic of Tajikistan	Not-for-profit organization	Consultancy	Collaborative research

Partner	Profile	Focus Area	Type of Association
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 and partner in field implementation in Sri Lanka
Shakti Sustainable Energy Foundation	Funding agency	Sustainable mobility	Funder
Society for Environmental and Economic Development Nepal (SEED Nepal)	Non-government organization (not-for-profit)	Providing solutions for enhancing productivity, preventing industrial pollution, providing better working environment, and improving the quality of life	Collaborative research and partner in field implementation in Nepal
STENUM Asia Sustainable Development Society (STENUM Asia), India	Not-for-profit society	Consulting in resource efficiency for industries	Collaborative research and partner in field implementation
The Regional Environmental Centre for Central Asia (CAREC)	Not-for-profit organization	Research	Collaborative research

Research and Academic Institutions

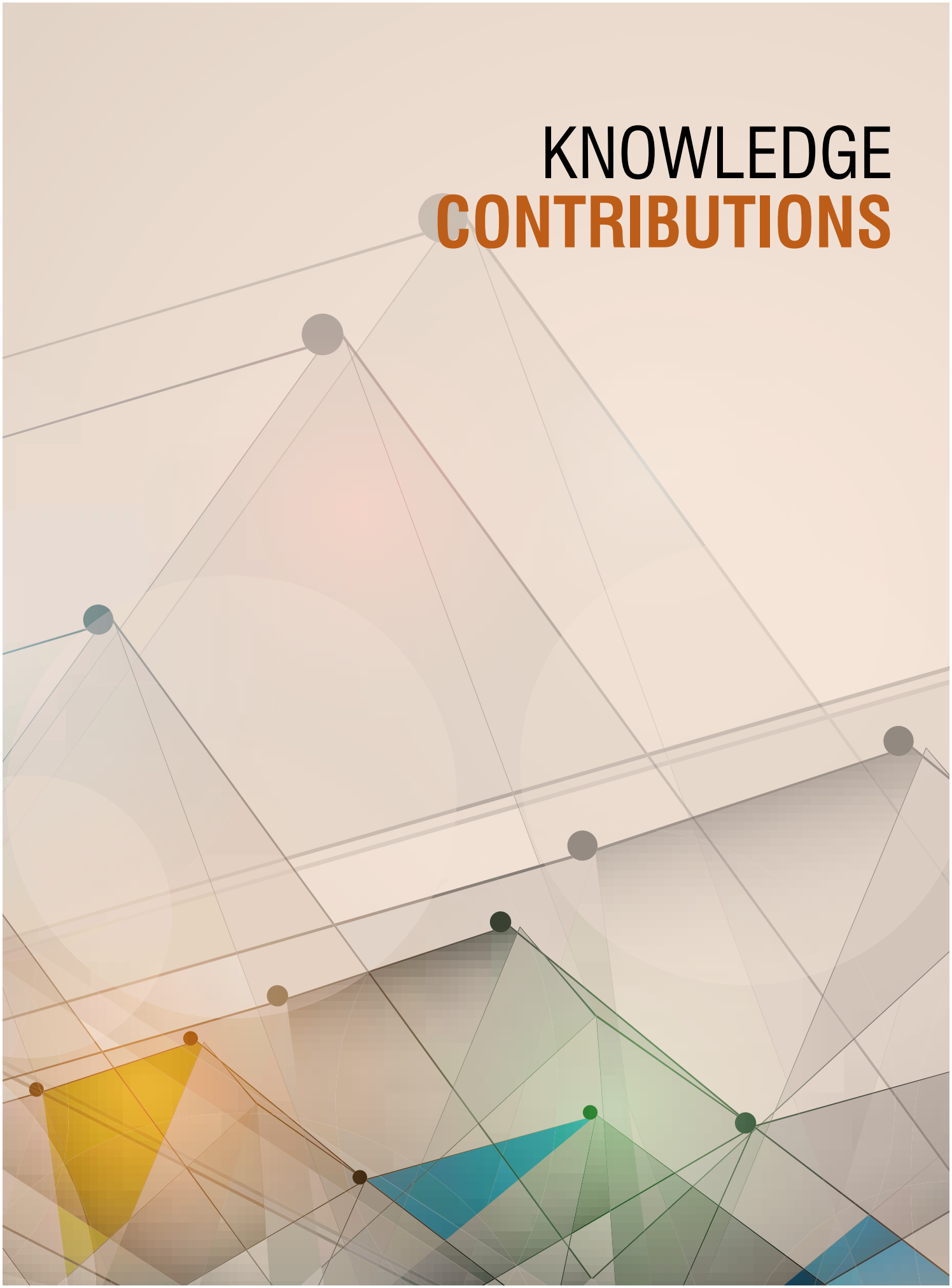
Partner	Profile	Focus Area	Type of Association
Amsar Goa Private Limited		Project partner	
All India Institute of Medical Sciences, New Delhi	Academic Institute-National	Biotechnology	Collaborative research
Assam University, Silchar	University	Bioremediation	Collaborative project partners
Central Salt Marine Chemicals Research Institute (CSMCRI)	Research institute		Project partner
Centre for Energy, The University of Western Australia, Perth, Australia	University	Microbial biotechnology	Collaborative project partners
Chemical Oceanography Division, CSIR-National Institute of Oceanography, Goa	Research institute	Marine litter	Project partner
CIIMAR - Interdisciplinary Centre of Marine and Environmental Research of the University of Porto, Matosinhos | Portugal	Research institute	Marine biology	Project partner
College of Veterinary, Mhow, M P	Academic institute, National	Biotechnology	Collaborative research
CSIR – IITR Lucknow	Institute	Bioremediation	Collaborative project partners
CSIR – NEERI Nagpur	Institute	Bioremediation	Collaborative project partners
CSIR-NIO Goa	Institute	Bioremediation	Collaborative project partners
CSIRO Energy Transformed Flagship, North Ryde, New South Wales Australian	Research institute	Microbial biotechnology	Collaborative project partners
CUO, Odisha	University, National	Biotechnology	Collaborative research
Deakin University	University, International	Biotechnology	Collaborative research, support for higher degrees by research
DBT-ICT Centre for Bioenergy Research, Mumbai, India	Research institute	Microbial biotechnology	Collaborative project partners

Partner	Profile	Focus Area	Type of Association
DBT-ICGEB Center for Advanced Bio-energy Research, Center for Genetic Engineering and Biotechnology, New Delhi	Research institution	Microbial biotechnology	Funding support
DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, Mumbai	Research institute	Microbial biotechnology	Collaborative project partners
DBT-IOC Centre, Faridabad	Research institute	Microbial biotechnology	Collaborative project partners
DBT-IOC Centre for Advanced Research on Bioenergy, R&D Centre, Indian Oil Corporation, Faridabad	Research centre	Microbial biotechnology	Collaborative project partners
Department of Environmental Engineering, Korea Maritime and Ocean University, Busan, South Korea	Research institute	Microbial Biotechnology biotechnology	Collaborative project partners
Department of Nano Science & Technology (NST) in Tamil Nadu Agricultural University (TNAU), Coimbatore, India	Academic institute, National	Nanotechnology	Collaborative research
Dr Alxendre S. Kellichenkoo, Director of Polytechnic Research Institute, Belarus National Technical University	Research institute	Microbial biotechnology biotechnology	Collaborative project partners
Helsinki Environmental research, Helsinki, Finland	Institute	Microbial biotechnology	Collaborative project partners
Indian Agricultural Research Institute, PUSA, New Delhi	Research institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
IARI, New Delhi	University, National	Biotechnology	Collaborative research
IASST Guwahati	Institute	Bioremediation	Collaborative project partners
ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru	Academic institute, National	Biotechnology	Collaborative research
INESC P&D Brazil & INESC TEC Portugal	Technology institutions	Marine technology	Project partner

Partner	Profile	Focus Area	Type of Association
INESC TEC - Instituto de Engenharia de Sistemas e Computadores-Tecnologia e Ciência, Campus da FEUP, R. Dr Roberto Frias, 4200- 465 Porto	Technology institutions	Marine technology	Project partner
Indian Institute of Chemical Technology, Hyderabad, India	CSIR Institute, Government of India	Microbial biotechnology	Microbial biotechnology
IISER Bhopal	Institute	Bioremediation	Collaborative project partners
Indian Institute of Technology, New Delhi	Academic institute	Wastewater treatment	Collaborative research
Indian Institute of Technology Bombay	Academic institute	Climate change, water resources management	Project partner
Indian Institute of Technology, Mandi, Himachal Pradesh	Research institute	Microbial biotechnology	Collaborative partner
Indian Institute of Technology Guwahati	Research institute	Microbial biotechnology	Collaborative project partners
INL, Portugal	Research institute, international	Biotechnology	Collaborative research
Institute of Nano Science and Technology (INST), Mohali	Academic institute, national	Nanotechnology	Collaborative research
Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bengaluru	Academic institute, national	Biotechnology	Collaborative research
Laboratório Nacional de Engenharia Civil, Lisbon, Portugal	Institute	Groundwater	Project partner
Metropolia Institute of Technology, Helsinki, Finland	Institute	Microbial biotechnology	Collaborative project partners
Motilal Nehru National Institute of Technology (MNNIT), Allahabad	Institute	Microbial biotechnology	Collaborative project partners
National Environmental Engineering Research Institute (NEERI), Nagpur	Research institute	Environmental pollution, wastewater	Collaborative research
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	Research institute	Microbial biotechnology	Collaborative partner
National Institute of Hydrology, Belgaum, Karnataka	Institute	Climate change, water resources management	Project partner

Partner	Profile	Focus Area	Type of Association
National Physical Laboratory, New Delhi	Research institute	Biotechnology	Collaborative research
Norwegian Technical University – Norges teknisk-naturvitenskaplige universitet (NTNU)	Academia		Knowledge partner
Oil India Laboratory, Chemical Department, Duliajan, Assam	Research institute	Microbial biotechnology	Collaborative partner
Portuguese Institute for the Sea and Atmosphere (IPMA) Division of Aquaculture and Upgrading (DivAV)	Research institute	Marine technology	Project partner
Sardar Patel University, Bakrol, Anand, Gujarat	Research institute	Microbial biotechnology	Collaborative research
State Forest Research Institute, Jabalpur, Madhya Pradesh	Research institute	Biotechnology	Collaborative research
The Maldives National University	University	Research	Collaborative research
University of Aveiro, Portugal	University	Developing porous ceramics from waste	Collaborative research
University of Delhi South Campus	University, central	Biotechnology	Collaborative research
University of Leicester, UK	University, international	Biotechnology	Collaborative research,
University of Lisbon, Portugal	University	Climate change, adaptation modeling	Project partner
University of New South Wales, Sydney	Academia		Knowledge partner/ funding support
University of Pannonia, Veszprem, Hungary	Research institute	Microbial biotechnology biotechnology	Collaborative project partners
University of Salerno, Italy	University	Wastewater treatment	Collaborative research
Wageningen University & Research, Netherlands	University	Wastewater treatment	Collaborative research

KNOWLEDGE CONTRIBUTIONS



Representation in National and International Expert Group Committees

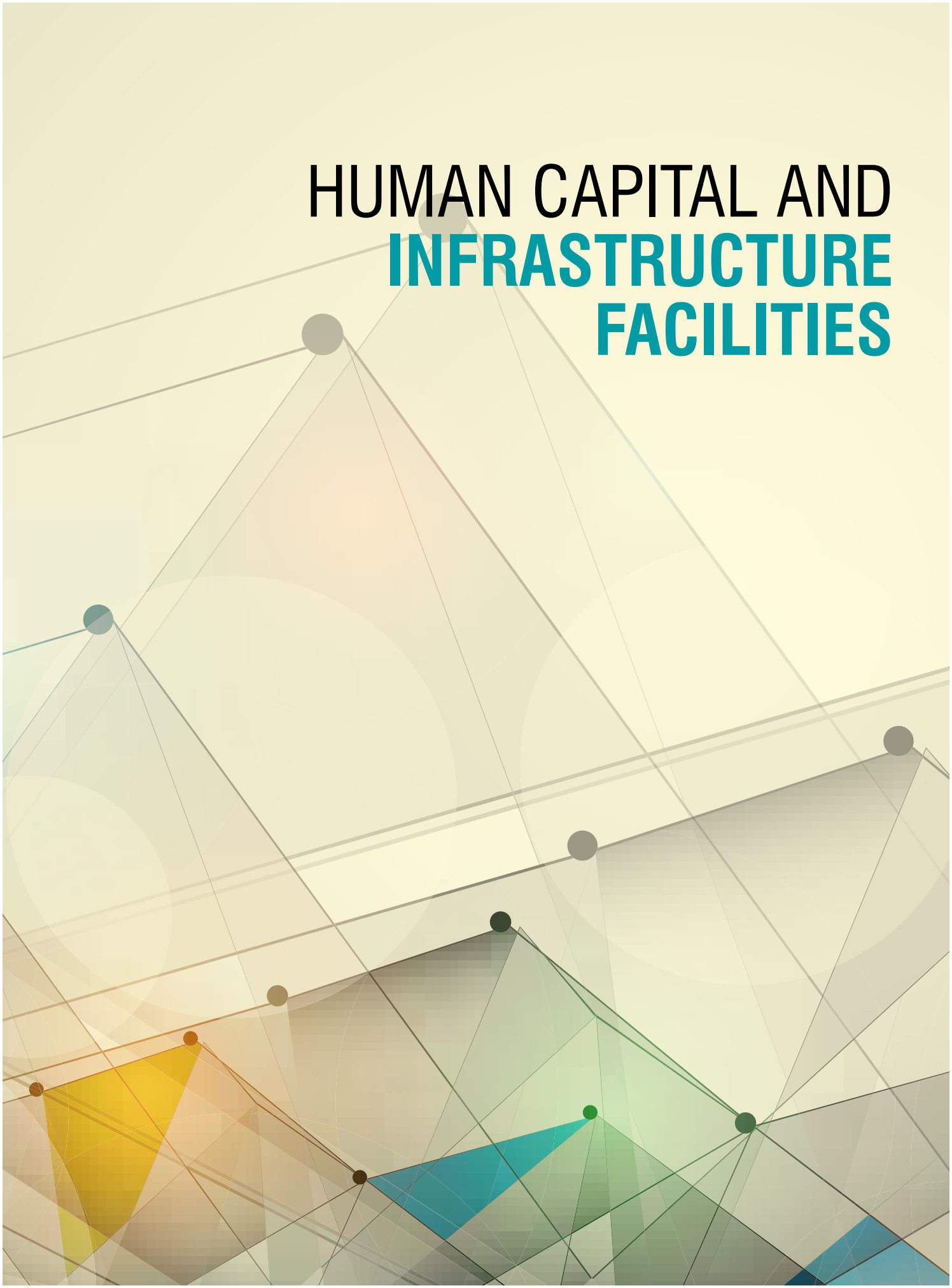
- Balakrishnan M. 2017-till date Expert member for DST Engineering & Technology Development under Women Scientists Scheme-B (WOS-B)
- Balakrishnan M and Batra V S. Member of Chemical Division Council of Bureau of Indian Standards (BIS)
- Bhattacharjya S. Team leader to support Ministry of Environment, Forest and Climate Change towards preparation of India's draft resource efficiency policy of India
- Bhattacharjya S. Expert member of MEITY project on "Study for development of process technology to recover valuable materials from end-of-life silicon solar modules" implemented by C-MET Hyderabad
- Bhattacharjya S. Member of the Bureau of India Standard committee on environment management
- Dhingra S. Member, Project Appraisal Committee constituted by the Ministry of New and Renewable Energy for Evaluating and Recommending Proposals for Biomass-based Power, Bagasse-based Cogeneration 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
- Dubey M. Life Member of Indian Society of Nanomedicine, New Delhi, India
- Garud S. Member, 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 on ElectroTechnical Division 42 on Wind Energy, Bureau of Indian Standards
- Lal B Technical Expert Committee on Environmental Biotechnology of the Department of Biotechnology to Review the Proposal and Progress of an Ongoing Project
- Lenka SK. Life Member of Society for Plant Biochemistry and Biotechnology, New Delhi, India
- Kedia S. Expert, Green Budgeting, Government of Bihar
- Kedia S. Member, Taskforce on Greening Rural Development, Ministry of Rural Development
- Kedia S. Board Member, World Sustainable Development Forum
- Kedia S. Lead Author (Finance, Economics, and Private Sector), Second Assessment Report on Climate Change and Cities
- Kedia S. Co-chair, Research Committee on Inclusiveness, Green Growth Knowledge Platform
- Kedia S. Member, Indo-German Expert Group on Inclusive and Green Economy
- Khan A. Life Time Member of Indian Society of Systems for Science and Engineering (ISSE)
- 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 since 1986
- 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, Solid Mineral Fuels and Solid Bio Fuels Sectional Committee, Bureau of Indian Standards (Petroleum, Coal and Related Products Department)

- Roy P. Life Time Member of Indian Society of Systems for Science and Engineering (ISSE)
- Sailaja R R N. Member (for life) of the Indian Society for Technical Education, India.
- Sailaja R R N. Life Member of Society of Polymer Science India (SPSI)
- Sailaja R R N. Life Member for the Asian Polymer Association (APA)
- Sailaja R R N. Member of American Chemical Society(ACS) up to 2016
- Sailaja R R N. Life Time Member of Indian Society of Systems for Science and Engineering (ISSE)

Representation in National and International Journals

- Adholeya A. Chairman, Task Force on Biological Agents, DBT (Department of Biotechnology), Ministry of Science & Technology
- Adholeya A. Chair Policy Committee, International Mycorrhiza Society, Canada Adholeya A. Member, International Fertilizer Association, France
- Adholeya A. Member, Scientific and Technical Appraisal and Advisory Groups (STAGs), Department of Biotechnology, Government of India, New Delhi
- Adholeya A. Member, Advisory Board Louis Dreyfus Foundation, France
- Adholeya A. Member, Soil Quality and Fertilizers Sectional Committee, Bureau of Indian Standards, New Delhi
- Adholeya A. Member, Experts Committee on the Application of Nanotechnology in Agriculture and Medicine, DBT (Department of Biotechnology), Ministry of Science & Technology, New Delhi
- Adholeya A. Member, Advisory Board, The Fertilizer Association of India, New Delhi

HUMAN CAPITAL AND INFRASTRUCTURE FACILITIES

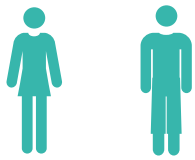


Human Capital

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.

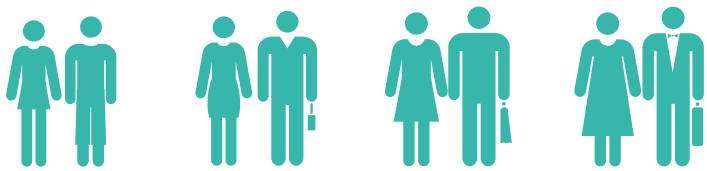
GENDER



31% Female

69% Male

AGE DISTRIBUTION



22% AGE 22-30 YEARS

33% AGE 31-40 YEARS

23% AGE 41-50 YEARS

22% AGE 51 AND ABOVE

QUALIFICATION

28% GRADUATE

48% POSTGRADUATE

12% PhD

OTHERS 13%

SPECIALIZATION

11% SOCIAL SCIENCE & AWARENESS

17% BIOTECH & AGRICULTURE

4% ECONOMICS

7% 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.

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.

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.

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.

Solar Power Pack

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

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.

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.

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.

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.

APPENDICES

Contribution to Journals and Proceedings

ENERGY

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Poster Presentations

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- Bhuyan D. 2019. The silky way of post-harvest preservation, Poster, NanoforAgri, Aerocity, New Delhi, December 21–22
- Gehlout S, Pandey A, Das R, Bhat M, Afonso L, Schultz A, Dinda A, Singh P P. 2019. *In vitro* toxicity analysis of agriculturally useful and biologically synthesized iron oxide nanoparticles. E-Poster, Indo-US Symposium Indo-US bilateral symposium: Next generation biologically synthesized nanofertilizers for seed coating and foliar application, TERI-Gwal Pahari, September 5–7
- Mishra R C, Barrow C J, Goel M. 2019. Anti-oxidative Bioactive Compounds from Terrestrial Endophytic Fungus *Aspergillus terreus* – AREF023 as Potential Food Additive at 3rd International conference on NanoForAgri – 2019, New Delhi, India, November 21–22
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- Singh N. 2019. Poster on advance cultivation technologies of apple for Uttarakhand presented on Apple Day organized by CITH-ICAR, Mukteshwar, Uttarakhand, December 23
- Tiwary I, Callahan D, Conlan X, Johnson S, Mishra A K, Adholeya A. 2019. Extraction of red colored pigment from natural resources. Poster, NanoforAgri, Aerocity, New Delhi, December 21–22

Patents

- Lenka S, Arya S S. A novel vanillin coupled EPI (efflux pump inhibitor) mediated process protocol-based product (IN 2018 1104 1967, full application)
- Lenka S, Arya SS, Das R K. A novel vanillin linked noble metal nanocomposite (nanoformulation) for enhancing antibiotic (IN 2018 1104 1968, full application)

Conferences

- Adholeya A. 2019. Speaker in Green Technologies, Circular Economy and Restoration of Cultural Heritage (GTCERCH-2019). Raja Balwant Singh College, Agra
- Adholeya A. 2019. Chair, Session 10: Sustainable management 1 (agriculture, rangeland and forestry management), Mycorrhizas in the Global Change context, ICOM10, Merida, Mexico
- Adholeya A. 2019. Speaker – National Conference on Recent Trends in Chemical Sciences & RSC Workshop on Periodic Table: Boon for Mankind, University of Delhi, Delhi
- Adholeya A. 2019. Speaker – Leveraging Water Security for Sustainable Agricultural Water Management: Role of ICID. ICID Foundation, New Delhi
- Adholeya A. 2019. Speaker – Deakin Agritech Conference, Australia
- Adholeya A. 2019. Speaker – Biotikos 2019, TERI University, New Delhi
- Adholeya A. 2019. National Conference on 'Biotechnology & Environment for Sustainable Development (BioESD2019)' in Jaipur from March 29 to March 30, 2019
- Adholeya A. 2019. Speaker – International Symposium on 'Biotechnology for Food-Nutritional Security & Organic Agriculture' in Jorhat, Assam
- Adholeya A. 2019. Workshop on Biotechnology Start-up Ecosystem in India, BCIL at New Delhi in March, 2019
- Adholeya A. 2020. Esteemed speaker for the technical session titled 'Key enablers for the growth of seed business' to speak on 'Nano Biologicals-Emerging Innovation in Biological Seed Treatments' scheduled on February 17, 2020
- Giriyan A and Garg S. 2020. Isolation of biofilm-forming bacteria to remediate heavy metal arsenic pollution. Presented at the International Conference on Biotechnology and Applied Microbiology (ICBAM-2020) at the Institute of Applied Medicine and Research, Ghaziabad, Uttar Pradesh, February 7–8, 2020
- Panandiker A P, Venkatesh B, Gude S, Mahender K, and Chachadi A G. 2020. Analyzing implications of land-use change coupled with climate change on river flow using a hydrological model: Case study of River Sal in Goa, India. Presented at 3rd International Web Conference on Climate Change Impacts on Environment and Biodiversity, Bangalore University, India
- Panandiker A P, Honnungar V, Venkatesh B, and Machineni N. 2019. Projections of future dependable flow in the light of changing climate: A case study of Uguem River in Goa, India, Presented at IUKWC workshop 'Science & Innovation for Catchment Management', University of Warwick, UK

Memoranda of Understanding

- Memoranda of Understanding with INESC TEC - Institute for Systems and Computer Engineering, Technology and Science,
- Memoranda of Understanding between National Real Estate Development Corporation (NAREDCO) and GRIHA Council at the 11th GRIHA Summit
- Memoranda of Understanding with GRIHA Council at the 11th GRIHA Summit for First Construction Council
- Memoranda of Understanding between Indian Institute of Architects (IIA), Northern Chapter and GRIHA Council at the 11th GRIHA Summit
- Memoranda of Understanding between PWD Department, Government of Maharashtra and GRIHA Council for providing green rating for existing government building stock in the state
- Cooperation for Excellence in Marine Exploration and Navigation Technologies (CEMENT) initiative was also signed, which constitutes the basis for a strategic alliance amongst many institutions located in Goa namely, National Institute of Oceanography, National Centre for Polar and Ocean Research, IIT Goa and Goa Shipyard Limited.

Training Programmes

- Sixteen, three-day training under GRIHA V2015 training programmes pan India
- Nine, one-day training programmes on GRIHA rating pan India
- Seven student training programmes pan India
- Two webinars on GRIHA rating
- Ten Paryavaran Rakshak programmes

FINANCIAL SUMMARY

FINANCIAL SUMMARY 2019/20

INFLOWS (₹ in Lakh)

81.18%
₹14652.05
INCOME FROM PROJECTS

1.56%
₹282.55
INCOME FROM INVESTMENTS

0.72%
₹130.2
SALE OF PUBLICATIONS

16.54%
₹2984.48
INCOME FROM OTHERS

TOTAL **100%** (₹18049.28)

OUTFLOWS (₹ in Lakh)

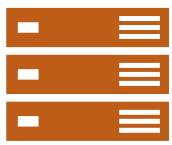
47.03%
₹8066.99
SALARIES

4.28%
₹734.35
EQUIPMENT

0.18%
₹30.08
BUILDINGS

40.22%
₹6898.81
RESEARCH MATERIAL, TRAVEL

5.86%
₹1004.43
RENTAL,UTILITIES, INFRASTRUCTURE AND MAINTENANCE



2.43%
₹416.15
ADMINISTRATIVE EXPENSES

TOTAL **100%** (₹17150.81)

About TERI

A dynamic and flexible organization with a global vision and a local focus, TERI was established in 1974, with initial focus on documentation and information dissemination. Research activities, initiated towards the end of 1982, were rooted in TERI's firm conviction that efficient utilization of energy and sustainable use of natural resources would propel the process of development.

All activities in TERI, the largest developing-country institution working towards sustainability, move from formulating local and national-level strategies to shaping global solutions to critical issues.

Buoyed by more than 43 years of excellence in research and innovation, TERI is now poised for future growth, driven by a global vision and outreach, with a philosophy that assigns primacy to enterprise in government, industry, and individual actions.

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