ANNUAL REPORT 2018/19

teri | The Energy and Resources Institute
Creating Innovative Solutions for a Sustainable Future

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

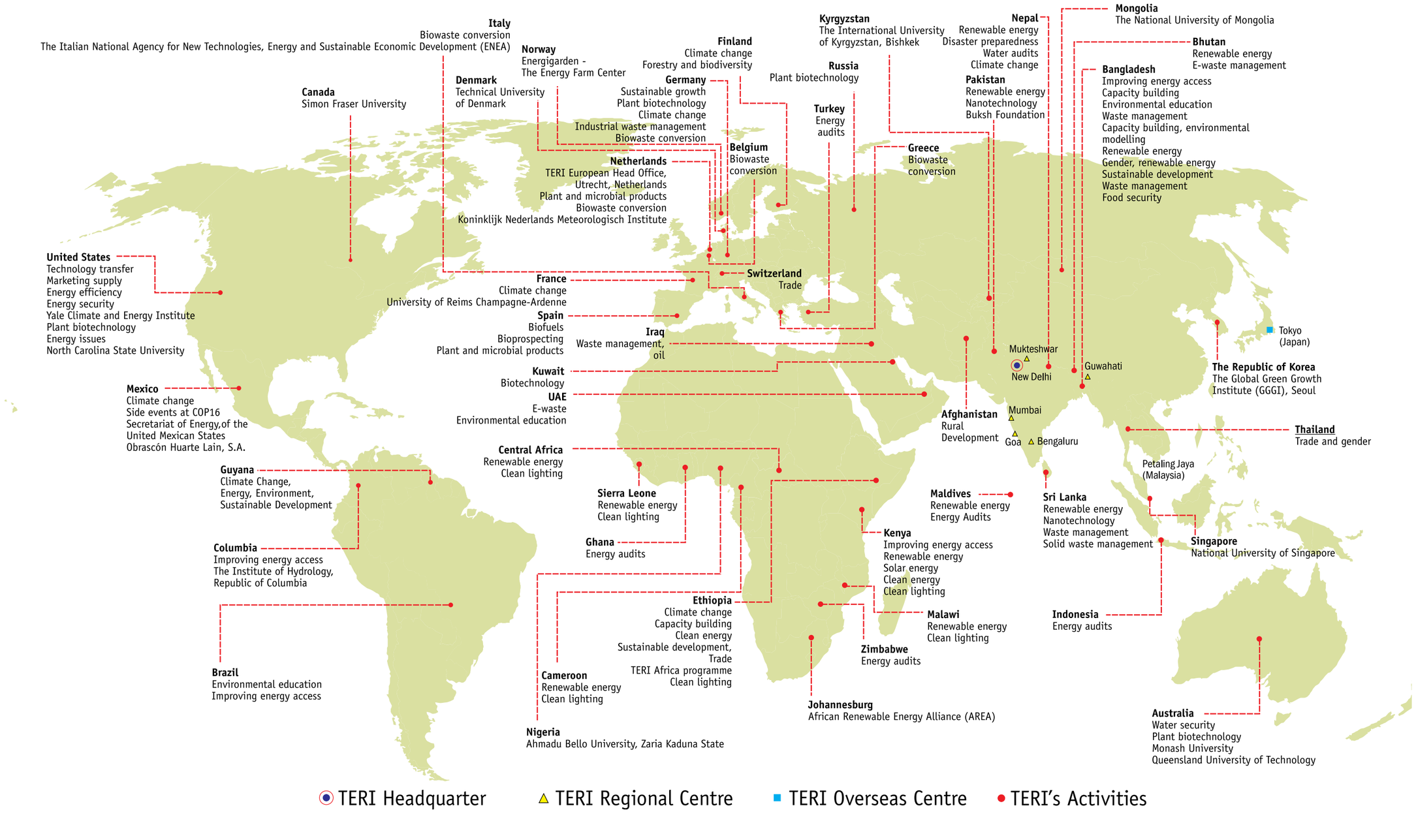
Enhance networking for sustainable interventions

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



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Annual Report 2018/19

DIRECTOR GENERAL'S MESSAGE

The year 2018/19 heralded a paradigm shift in TERI's growth as a multidisciplinary and polyphonic firm through a synthesis of its Division-based areas and Programme-driven work culture. The harmonious integration of its 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 information technology also efficiently supported TERI's research efforts.

Electricity is the backbone of our country's socio-economic advancement, and over the years, the growth in the electricity sector has been monitored and sustained through changes and variations in both the demand and supply sides. Promotion of clean-energy solutions and working on cross-cutting themes of the electricity sector with allied focus on fuels, such as coal and natural gas, used in the sector for power generation are the key areas that TERI's Electricity and Fuels Division has been striving relentlessly for with policymakers, stakeholders to envision a zero-carbon energy sector in India.

In 2018/19, TERI was appointed by West Bengal State Electricity Distribution Company Limited (WBSEDCL), the state's nodal agency to assist in working towards infrastructural development and electric vehicle (EV) tariff modelling. Our Division's research activities involved detailed modelling of distribution feeders and distributed RE-based generators, simulation studies, such as load flow, short-circuit and harmonics, and protection coordination impact studies to recommend possible system upgrades to accommodate increasing RE and EV penetration. After being awarded many projects by WBSEDCL (under MacArthur Grant) and Calcutta Electric Supply Corporation (CESC), we also spearheaded many tasks under the US–India Collaborative for Smart Distribution System with Storage (UI-ASSIST). The work done under the MacArthur grant was presented at the 25th International Conference on Electricity Distribution (CIRED), held in Madrid, and at the IEEE conference in Jaipur. Additionally, the DSM Action Plan for Mangalore Electricity Supply Company (MESCOM) was launched at World Sustainable Development Summit 2019 in New Delhi.

In the realm of expediting the development of rooftop solar PV in India, TERI has engaged in a multi-dimensional study comprising essential components in areas such as analysis of policies of central and state governments, business models, developer rating system, and developing corporate RE consumption index. In a first of its kind, an evaluation of 50 MW solar thermal power plants in Rajasthan was taken up towards this goal. The Division successfully organized a 3-week international training programme on 'Renewable Energy and Energy Efficiency' under ITEC Programme, Government of India, where 18 delegates representing, 10 countries participated. In December 2018, the Division represented TERI at the Second Global Blockchain Congress held in Kolkata, where it won the third prize on its concepts on applications of blockchain in power distribution. As an extension of our efforts in this area, while recognizing the future with solar power, we are extremely proud that the TERI campus at Gual Pahari has been solarized by setting up a rooftop solar system of an aggregate capacity of 222 kWp on various buildings and, car parking areas. Additionally, with the Centre of Excellence (CoE) project for biofuels from Department of Biotechnology, we also set up of one of the most advanced solar water pump test facilities, besides implementation of a few projects with support from the MacArthur Foundation, Energy Transition Commission India, and Norwegian Framework Agreement.

The year 2018/19 saw the successful completion of the two studies under the Distribution Utilities Forum (DUF), on the impact of rooftop solar of distribution, utilities cost of supply, while a third one is underway. Currently, as one of our ongoing projects, in association with GERMANWATCH, TERI is working on MAP (Multi-Actor Partnership) project to identify and map the risks involved in the solar sector. Mitigating measures or de-risking are being worked out in Indian Solar Energy Programme with a view to contribute capacity additions for achieving national targets. The project is sponsored by the German Ministry (BMZ).

In 2018/19, our Industrial Energy Efficiency (IEE) Division continued working closely 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). On May 1, 2018, TERI organized the India–Japan Industry & Energy Seminar in New Delhi to focus on enhancing technology cooperation and business opportunities in the field of energy and environment between the two countries. We have contributed to the global urban discourse and curated sessions on implementation of the new urban agenda and SDG 11 in South Asian cities at HABITAT III and UN's World Urban Forum 9 in Quito and Kuala Lumpur, respectively. Further, in India, we also conducted a series of national

and regional policy dialogues to facilitate discussions on critical urban issues, and Australia–India knowledge exchange workshops for elaborating on smart energy management initiatives in cities.

In the bioremediation area, regarding the issues of oil-spilled environment and oily sludges from oil companies, our team of experts and researchers undertook extensive work to ascertain the agricultural soil fertility of ONGC oil fields of Ankleshwar, Gujarat. In this study, the soil fertility loss caused by ONGC exploration and exploitation of hydrocarbons was assessed through field investigation, soil sample collection, and analysis. The analysis data were compared with the soil quality of unpolluted agricultural fields from the same region. Test samples submitted to ONGC IDT Dehradun, as a joint venture agreement, accomplished all the required parameters of drilling oil companies in October 2018.

Under Agriculture and Rural Extension Division, we have fortuitously worked towards the socio-economic development of women in Kamrup and Udalguri districts of Assam through Eri silkworm rearing and spinning. The area is also carrying out plant diversity assessment in Borail Wildlife Sanctuary, Assam under a DBT, Government of India-sponsored project. The area provided consultancy services to FREMAA (Flood and River Erosion Management Agency of Assam), Government of Assam, for executing projects on livelihood enhancement.

Exposure workshops for senior officials of urban local bodies from Bihar, West Bengal, and eight north-eastern states were organized in six batches in Imphal, Rajgir, Kolkata, and Gangtok to acquaint with and implement Solid Waste Management Rules, 2016 under Swachh Bharat Mission (SBM). Interpersonal communication and focus group discussions (FGD) on sanitation for the population without access to toilets were mapped using android app-based geotagging for 75,000 households in 11 districts of Assam under SBM-Gramin programme. As far as improved sanitation is concerned, our centres have installed 100 prefabricated biotoilets with FRP (glass fibre reinforced polymers) materials in 100 schools of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. With NABARD's support, the digitization of self-help groups from the six coastal talukas of Goa is also in progress. The TERI Coastal Education Hub was officially inaugurated this year, which will spread awareness on coastal technologies to more schools.

Participation by TERI's project beneficiaries in Mahalaxmi Saras Exhibition-sale Umed–MSRLM, Government of Maharashtra, was a success that aimed to provide SHG women, who are entrepreneurial and own small businesses, with the opportunity to sell their products, thereby providing these women with market linkages and an additional livelihood source. This year, it was held from January 23 till February 4, 2019 and two SHG groups from Pathardi participated in the exhibition and sold spinach-fortified snacks and spirulina (a nutritious algae)-fortified chocolates, amongst other nutritious snacks, which were very well received by customers and print media.

'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?' is one of the pertinent questions our research teams strive to answer and this is where the Integrated Policy Analysis (IPA) Programme informs on policies on the critical sustainability issues of our time through in-depth and inter-disciplinary research. Through TERI's KAS Resource Dialogue V – The Emerging Global Maritime Order–India's Strategy, held in March 2019 in Chennai, a reference report on resource efficiency, formulated by our Division, served as the basis for preparing a draft policy on resource efficiency by the Ministry of Environment, Forest and Climate Change (MoEFCC). Our Division also worked towards raising awareness on the issue of natural resource efficiency among the different stakeholder groups. It also took up a study to prepare a resource efficiency strategy for Goa. We worked with the 15th Finance Commission to examine how inter-governmental transfers can work as an effective instrument of forest conservation and promote clean air in India.

With growing urbanization, the air that we inhale has become toxic. In order to help policymakers to implement strategies to tackle air pollution problems and achieve the air quality standards in Indian cities, we are already engaged in ongoing studies in many cities and other 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, etc. We worked towards compiling the Air Quality Status Report that provides a decadal overview and analysis of the quality of air recorded across all the Ambient Air Quality Monitoring Stations (AAQMS) in Maharashtra. This report, which documented the daily, seasonal, and annual trends in concentrations of air pollutants such as SO_2, NO_x, RSPM, CO, CH_4, and ozone in Maharashtra, was unveiled on June 4, 2019, on the occasion of World Environment Day, by Chief Minister Hon. Shri Devendra Fadnavis.

Linking Climate and Development Policies–Leveraging International Networks and Knowledge Sharing (CD-LINKS) is another milestone project of our Division, supported by the European Commission under the Horizon 2020 framework focuses on linking climate and development policies. The project aims at conducting joint research and share experiences, methods, and data between leading research institutions and key stakeholders from G20 countries. The objectives of this project are 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. In 2018/19, our Division contributed significantly to Global Environment Outlook (GEO) 6, a publication by the UN Environment Programme (UNEP), which informs environmental decision-making by providing an integrated assessment on state trends, and outlooks of environment and facilitates interaction between science and policy.

In the arenas 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, TERI joined many international collaborations with institutions of global repute to ensure there is exchange of knowledge and expertise, and strengthening of the core competencies within the areas. Project FLOW (Facilitating Learning on WASH), a Bharti Infratel Ltd and TERI initiative that culminated in 2018 reached out to approximately 750,000 school students and communities in Bhubaneswar, Ranchi, Indore, Jammu, Panipat, and Guwahati. The Water, Sanitation and Hygiene (WASH) project, supported by Sony India Software Private Limited in Bengaluru, was designed to impart transformative learning through adequate resource materials and innovative strategies. We also hosted the 4th India Water Forum on the theme of 'Water for All: Options for Safe, Sustainable and Resilient Future' to facilitate the achievement of SDG on water amongst various stakeholders by way of reducing their water footprints and promoting the adoption of 'water neutrality' approach. The Division also released a booklet on its work titled Water Resources Division–Facilitating Water for All and also initiated the 'Water Sustainability Awards' at the event.

Our centres extended their research and capacity-building activities to other developing countries and emerging economies through a strong research-based collaborative programme in Fiji. For the ensuing years, we will prioritize research on managing hydrological disasters, sub-national actions through State Action Plans on Climate Change in India, market-based mechanisms for climate change mitigation, and efficient refrigerant transitions. The pilot implementation of India's Forest NAMA in Assam is one of our landmark projects. GIZ and MoEFCC are implementing an Indo–German bilateral project 'Development and Management of NAMAs in India' with a focus on two sectors – waste and forestry. Together, we aim 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.

Within the sphere of biodiversity and upholding the concept of ecotourism, TERI's Forestry and Biodiversity Division has focused on the sustainable management of forest ecosystems and the conservation of biodiversity for over two decades. In the past year, tourists visiting the community-conserved areas developed at Nagaland during our Second Biodiversity Meet. A community-managed homestay at Yuksam was also based on the principles of ecotourism. Moreover, the project under the flagship programme of SECURE Himalayas funded by UNDP India aimed at identifying the baseline on the impacts of tourism activities in the snow leopard landscapes of Khangchendzonga and upper Teesta landscape in Sikkim, Govind-Gangotri and Darma Byans landscape in Uttarakhand, Lahaul-Pangi and Kinnaur landscape in Himachal Pradesh, and Changthang in Jammu and Kashmir.

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.

This year, a novel holistic wastewater management approach for the recovery of water, energy, and nutrients from urban wastewater has taken shape as local treatment of urban sewage streams for healthy reuse (LOTUSHR). By adhering to reclamation steps, the water quality needed for safe and healthy reuse for various applications will be determined. Innovative but proven robust technologies will be incorporated in a modular pilot treatment plant along the Barapullah drain. TERI has set up anaerobic membrane bioreactor with ash-based ceramic membranes and is also involved in socioeconomic studies related to treated water reuse. Based on the on-site test results, the pilot plant design has been proposed and is under finalization.

During 2018/19, TERI carried out maintenance of a green belt, covering an area of 20 acres on chlor-alkali waste. This project will demonstrate a mechanism to carry out effective reclamation of jarofix dumps in 23 hectares and an establishment of green cover that could trap various benefits and improve the local environment.

TERI–Deakin Nanobiotechnology Centre (TDNBC), in partnership with SERB organized the 2nd International Conference on 'Nanobiotechnology for Agriculture: Detection, Conservation and Responsible Use of Natural Resources' in December at National Institute of Solar Energy and TERI Gram, Gurugram. The conference highlighted the message of how nano-enabled systems will help address contemporary issues in agriculture related to efficient delivery of fertilizers, pesticides and nutrients, post-harvest management and catalysis as well as diagnostic methods.

Our teams successfully executed more than 100 events in the financial year 2018–19, including the 10th GRIHA Summit and TERI's flagship event—World Sustainable Development Summit 2019. The WSDS strives to provide long-term solutions for the benefit of the global community by assembling the world's most enlightened leaders and thinkers on a single platform. The 2019 edition of the Summit was inaugurated by the Hon'ble Vice President of India, Venkaiah Naidu, and the theme was, 'Attaining the 2030 Agenda: Delivering on Our Promise', in consonance with our mission to create action frameworks to resolve some of the most urgent challenges facing developing economies. The Summit offered a wide variety of participatory options and has, to date, hosted 47 heads of state and government, 13 Nobel laureates, ministers from over 76 countries, over 1600 business leaders, and 1800 speakers, and over 12,000 delegates from across the world.

The bygone year (2018/19) has been fruitful and deeply satisfying for each and every TERI member. Activities and achievements shall continue at their own pace. But, as a growing family, we are now motivated than ever before in our endeavour and pledge to move forward to a society that makes sustainable choices and contributes to an environmentally secure future to ensure the well-being of successive generations.

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 Hemendra M Kothari

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

Dr Ritu Mathur
Integrated Assessments and Modelling

Dr Prodipto Ghosh
Earth Science & Climate Change

Dr Annapurna Vancheswaran
Sustainable Development Outreach & Youth Education

Dr Ashvini Kumar
Renewable Energy Technologies

Mr Girish Sethi
Industrial Energy Efficiency

Mr Amit Kumar
Social Transformation












Mr Pronab Dasgupta
TERI-SRC

Dr Banwari Lal
Environmental & Industrial Biotechnology

Mr A K Saxena
Electricity & Fuels

Mr Anshuman
Water Resources

Dr Alok Adholeya
Sustainable Agriculture

Mr Sanjay Seth
Sustainable Habitat

Ms Minni Sastry
Sustainable Habitat

Dr Suneel Pandey
Environment & Waste Management

Dr Syamal Kumar Sarkar
Water Resources

Mr Pradeep Kumar
Sustainable Habitat

Dr Anjali Parasnis
Nutritional Security

Mr Debajit Palit
Social Transformation

Ms Livleen K Kahlon
Sustainable Development Outreach & Youth Education














Dr G R Narasimha Rao
Industrial Energy Efficiency

Col (Retd.) Sanjai Joshi
Administrative Services

Ms Divya Datt
Integrated Policy Analysis

Ms Rishu Nigam
Sustainable Development Outreach & Youth Education

Mr Puneet Chandra
Growth, Diversification & Commercialization Unit

Dr Dipankar Saharia
Environmental & Industrial Biotechnology

Dr Vibha Dhawan
DGO

TERI'S DISTINGUISHED FELLOWS

Mr S Sundar
Distinguished Fellow & Professor, TERI University; Former Secretary, Ministry of Surface Transport, Government of India

Dr Prodipto Ghosh
Distinguished Fellow, TERI; Former Secretary, Ministry of Environment and Forests, Government of India

Air Commodore (Retd) M M Joshi
Distinguished Fellow and Former Director, TERI

Mr Shri Prakash
Distinguished Fellow, TERI; Former Member (Traffic) Railway Board, Ministry of Railways, Government of India

Mr K Ramanathan
Distinguished Fellow, TERI; Former Member, Central Electricity Authority

Mr Ajay Shankar
Distinguished Fellow, TERI; Former Secretary, Department of Industrial Policy and Promotion, Government of India

Mr S Vijay Kumar
Distinguished Fellow, TERI; Former Secretary, Ministry of Mines, Government of India

Dr Syamal Kumar Sarkar
Distinguished Fellow, TERI; Former Secretary, Ministry of Water Resources and DoPT

Amb. Ajai Malhotra
Distinguished Fellow, TERI; Former Ambassador of India to the Russian Federation

Mr Pronab Dasgupta
Distinguished Fellow and Director, Industrial Energy, Southern Regional Centre, TERI; Former Member, TDSAT

Dr Vibha Dhawan
Distinguished Fellow & Senior Director, TERI

Mr RR Rashmi
Distinguished Fellow

Mr Dipak Dasgupta
Distinguished Fellow, TERI; Former Principal Economic Adviser, Ministry of Finance, Government of India

Mr C Dasgupta
Distinguished Fellow Emeritus

Prof. S L Rao
Distinguished Fellow Emeritus

Mr G S Gill
Distinguished Advisor

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, transport, housing, 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 (EP) 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.

The Energy Programme has three broad divisions, which work in the domains enumerated herein:

- The Electricity and Fuels Division (EFD) carries out a 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, demand side management (DSM), and other related aspects in the electricity sector. The Division has considerable experience of working with regulatory bodies, public and private utilities, ministries and government departments.
- The Renewable Energy Technologies (RET) Division provides cost-effective and sustainable RE-based technological solutions for diverse user-groups in the industrial, commercial, and rural sectors. It has developed and disseminated technologies for conversion of biomass into gaseous energy, electrical energy, crude bio-oil, etc. The Division also focuses on research-oriented activities, consultancy projects, and testing facilities aimed at developing and promoting solar (including solar rooftop) and wind energy.
- The Industrial Energy Efficiency (IEE) Division works closely with the corporate sector and provides energy audit services to industrial clients in sectors such as cement, chemicals, pulp and paper, iron and steel, thermal power plants, food processing, glass and ceramics, 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 of TERI works on cross-cutting themes of the electricity sector with allied focus on fuels, such as coal and natural gas, used in the sector for power generation. Most of the research, consultancy, and capacity building activities of the Division pertain to the demand and supply sides of the electricity sector. During 2018/19, the Division continued its interesting work on energy transitions, which entails change of great scale, complexity, and uncertainty for the bulk power systems. This work is being carried on a theme-based platform under the aegis of the Energy Transitions Commission (ETC), which was established during 2017/18 with the objective to build and disseminate knowledge, and guide the path for energy transition for the country. Moreover, TERI is involved in a multi-stakeholder project for the ETC, headquartered in the United Kingdom. TERI hosts the secretariat of the ETC India and the Electricity and Fuels Division, in coordination with other divisions of TERI. It leads a diverse group of stakeholders to enable 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, Growald Family Fund, and Shakti Foundation with partial support from NTPC, Siemens, CLP India, BRPL, and Giriraj Renewables.

The ETC India project aims to develop a narrative for the policymakers to adopt low-carbon pathways so as to enable a 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 2030. Accordingly, the project has been divided into five work-streams that will look at demand, supply, grid-balancing, investments, and policymaking for the energy sector. The first year of the programme focused on fostering the adoption of low-carbon pathways in the power sector and ensuring that the findings assist the government in its decision-making. The second year progressed with substantial work on generation siting, demand estimation, and a very significant work on dispatch modelling is underway that will act as a shot in the arm with reference to the project deliverables. Till date, the project has published reports on demand forecasting to 2030, supply-side scenarios to 2030, assessments of the flexibility requirement to integrate variable renewables, and dispatch modelling to simulate the operation of the power system under a high share of renewables.

The Division's activities have been tailored to fall under the central theme of transitioning towards low-carbon pathways and are structured so as to support and facilitate this transition.

In the domain of power distribution, the Division moved ahead with distribution system studies with support from MacArthur Foundation for assessing the technical impacts of large-scale integration of rooftop solar systems on the distribution system, and suggested possible mitigation measures to the distribution utilities in the states of Delhi (BRPL), West Bengal (WBSEDCL), and Andhra Pradesh (APSPDCL). TERI worked with Central Electricity Authority (CEA) to draft charging standards for electric vehicles (EVs) in India and prescribed appropriate charging standards that India can adopt in the future (TERI is an Associate Member of CharIn, Berlin in India). EFD 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. Recently, TERI was appointed by WBSEDCL, West Bengal's nodal agency for EV implementation, to assist the state in working towards infrastructural development and EV tariff modelling. Accordingly, the Division's research activities involve detailed modelling of distribution feeders and distributed RE-based generators, simulation studies, such as load flow, short-circuit and harmonics, and protection coordination impact studies to recommend possible system upgrades to accommodate increasing RE and EV penetration. The Division also works on sizing battery energy storage systems (BESS) for various grid-scale applications at the distribution network level, modelling of EVs as mobile, distributed energy storage, and simulation of the various services and benefits that they can provide to the distribution grid and for planning, designing, and facilitation of pilot-scale BESS implementation on distribution feeders. During 2018/19, the Division performed a significant amount of work on distribution-level BESS, after being awarded many projects by WBSEDCL (under MacArthur grant) and CESC, in addition to carrying forward its work under the US–India Collaborative for Smart Distribution System with Storage (UI-ASSIST), which was awarded in 2017.

The UI-ASSIST is a multi-partner research project that focuses on research, development, demonstration, and pilot-scale implementation of BESSs at the distribution grid level for various applications under the smart grid paradigm. The project partners include institutes, industrial organizations, and utilities, both from India and the US. Institutions such as WSU (US lead), MIT, Texas A&M University, Idaho National Lab, LBNL, and organizations such as ETAP, GE, ABB along with some start-ups are involved on the US side. TERI is one of the partner institutes on the Indian side along with five IITs, namely

» Reports published under the ETC India Platform

IIT Kanpur (India lead), IIT Delhi, IIT Roorkee, IIT Bhubaneswar, IIT Madras, and NTPC NETRA; industrial partners, such as Customized Energy Solutions, GE Global, Panasonic India, Synergy System Solutions, and utility partners such as POWERGRID, UPPCL, and BSES Rajdhani Power Limited (BRPL). TERI has also partnered with BRPL for installation of grid-scale BESS on distribution feeders, catering to three categories of consumers, including institutional premises, gated residential colonies, and apartments.

The sizing, siting (at LT feeder-level or DT-level), and design parameters will be determined as part of the pilot implementation activities, in a phased manner over the project horizon of 5 years. The project also has a research and development (R&D) component wherein TERI will work on the design, development, and testing of Battery Management System (BMS) control logic for coordinating various grid-scale applications, such as peak shaving, power backup, voltage support, etc. During 2018/19, the project progressed with the finalization of sites for pilot implementation, sizing, and operational control logic development for all the three applications and preparation of the tender document.

The study with WBSEDCL under the MacArthur grant focuses on pilot-scale implementation of BESS at both DT and feeder levels while the CESC study undertaken was a techno-economic analysis of implementing BESS for overload management of a DT and managing load in critical facilities.

Development of an open-source tool to forecast load profiles for one of the distribution licensees of Karnataka, that is, BESCOM to help them manage their day-to-day operations, is amongst the recent activities that have been initiated by the Division. In the emerging domain of smart grids, the Division also works on laboratory hardware including emulators and real-time control hardware/embedded systems for development of effective control systems for battery systems and solar photovoltaic (PV) inverter integration with distribution networks.

The Division also helped install a novel smart grid pilot project with the support of NEDO, in the licensee area of UHBVN, Haryana, India. The smart-grid pilot was inaugurated by the Chief Minister of Haryana.

Capacity building is also one of the activities that the Division undertakes so as to facilitate the provision of skilled/well-trained manpower to the industry.

A series of training sessions for circle-level officers in six DISCOMs (TANGEDCO, APSPDCL, KSEBL, BESCOM, CESCOM, and GESCOM) in the states of Tamil Nadu, Andhra Pradesh, Kerala, and Karnataka on demand-side management, under a project commissioned by the BEE, was successfully completed during 2017/18. In 2018/19, this project was extended for some states of the Northeast. Load research is also one of the components this project covers. It believes in a collaborative and inclusive approach and addresses the concerns of the relevant stakeholders to solve the pressing issues in the electricity sector. During 2017/18, a Distribution Utilities Forum (DUF) was constituted to facilitate dialogue between the electricity distribution companies in the country, by providing them a platform to discuss their issues, share learnings, and come up with collective solutions. The year 2018/19 saw the successful completion of the two studies under the DUF, on the impact of rooftop solar of distribution, utilities cost of supply while a third one, open access, is underway.

» MoU signing ceremony with the Department of Power & Non-Conventional Energy Sources, Government of West Bengal at Bengal Global Business Summit 2019, Kolkata

During 2018/19, the Division was an active participant in TERI's MoUs with the Department of Power & Non-Conventional Energy Sources (DNES), GoWB, and IIT Roorkee. With the DNES, GoWB, TERI is set to work on areas of BESS, EVs, and agro voltaics.

The Division came out with a lot of research publications presented at prestigious international conferences. The work done under the MacArthur study was presented at the 25th International Conference on Electricity Distribution (CIRED), held in Madrid and at the IEEE conference in Jaipur. A presentation was also made at the ICIBESD at TERI SAS, Delhi. In December 2018, the Division entered the domain of blockchain. The Division represented TERI at the Second Global Blockchain Congress held in Kolkata, where it won the third jury prize on its concepts on applications of blockchain in power distribution. Subsequently, the prize money was utilized in funding a pilot project on peer-to-peer trading of rooftop solar energy using blockchain.

» Launch of DSM Action Plan for MESCOM at World Sustainable Development Summit 2019, New Delhi

Renewable Energy Technology Division

India is moving steadily to achieve its renewable energy (RE) targets with wide-ranging policy initiatives at the level of central and state governments. The total installed RE capacity at the end of the Financial Year 2018/19 stands at 78.3 GW, with an additional capacity of solar and wind power at various stages of procurement. 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, namely, research and development, 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 research and development, project implementation, policy research, and consultancy services, besides select training and capacity-building activities. The Division developed partnerships with stakeholders, which included national and international institutions, bilateral and multilateral agencies, user and manufacturing industry, 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 facilities for quality control in partnerships. In the spirit of showing by doing, TERI campus at Gual Pahari has been 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 witnessed a number of important and far-reaching R&D initiatives. This included participation in the Centre of Excellence project for biofuels from Department of Bio-Technology, setting up of one of the most advanced solar water pump test facilities in collaboration with M/s Maxop, besides implementation of a few projects with support from the MacArthur Foundation, Energy Transition Commission India, and Norwegian Framework Agreement. Laboratory infrastructure and technology platform in bioenergy, solar PV lighting product testing - NABL-accredited test lab for PV products testing and certification, smart grid and inverter testing give the RET Division unique advantages to market connectivity.

- Development of a 'Containerized Solar PV Solution' with M/s STEAG Energy Systems, which was inaugurated by Dr Andreas Pinkwart, Minister of Economic Affairs, Innovation, Digitalization and Energy of the State of North Rhine – Westphalia, Germany in the presence of Dr Ajay Mathur, DG, TERI.
- Signing of an agreement between TERI and M/s Maxop Research and Testing Institute Pvt. Ltd for establishment of 'TERI-Maxop Solar Testing and Research Facility' for testing of solar water pumping systems and other solar products in compliance with the Bureau of Indian Standards (BIS) and international standards.
- Conducting studies supported by the MacArthur Foundation for enhancing the use of RE power into the grid, namely:
  - Grid integration study for Andaman and Nicobar Islands with increasing RE share, focusing on the impacts of intermittent PV production, grid stability, and other typical issues that arise in grid operation; the study to strengthen policy planning by the administration to enable meeting 25% of the energy generation through RE sources by 2022.
  - To investigate the technical and financial implications of locating solar PV plants at the tail end of the rural distribution network (at a substation) vis-à-vis central locations such as a solar park.
- Conducting the following specific studies with support from the Energy Transition Commission of India:
  - Potential assessment of floating solar PV (FSPV) in India: It targets mapping of potential waterbodies for setting up FSPV 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, *viz.* analysis of policies of central as well as state governments, business models, developer rating system, and developing corporate RE consumption index for accelerating the deployment of rooftop solar in India.
- A review of various electrical storage technologies, namely batteries, super capacitors, and fuel cells was completed, which was supported by ONGC Energy Centre.
- Implementation of an R&D project sponsored by the Department of Science and Technology under their Mission Innovation Call with the

project title 'Development of a Solar PV-Biomass Gasifier Based Micro-grid with Cold Storage System for Electricity and Livelihood Generation for Rural India'.

- Under the Framework Agreement between the Norwegian Ministry of Foreign Affairs and TERI, a new R&D project was initiated, dealing with biomass gasifier coupled with CHP engine, based on organic Rankine cycle for rural applications. Implementation of ongoing projects on solar micro-grid controller and waste management of solar PV and electrical storage batteries continued in the technical collaboration with the University of Agder, Norway.
- The Centre of Excellence Project sanctioned by Department of Biotechnology as a multi-institution project for the demonstration scale production of second- and third-generation biofuels ('algal biofuels', 'biohydrogen' and' pyrolytic oil') and bio-commodities from non-food competitive feedstocks like algae. The RET Division is also participating in the production of biodiesel and pyrolytic oil from algal biomass under this project, on a demonstration scale.
- Implementation of the UNIDO-sponsored project for setting up biomass power generation was continued. A project based on rice husk in Cambodia has been successfully installed and commissioned, while a bamboo waste-based project in Thailand is under advanced stage.
- A new research project with a private industry was initiated for pilot-scale production of industrial grade phenol and activated carbon from solvent-extracted catechin (SEK) and cutch waste. Some activities have also been initiated for the lab-scale production of acrylates (bio-plastics) from glycerol, obtained as a by-product of biodiesel production (bio-commodities).

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.

- TERI has signed a PPA with Forth Partner for installation of solar rooftop plant at Gual Pahari campus. The total capacity of the solar rooftop system is 223 kWp, spread across five buildings at Gual Pahari campus. Considering the current tariff, TERI will save ₹6.40 lakh per annum by installation of these plants. It can also save a substantial amount on account of saving on diesel consumption since per kWh generated from DG is approximately 3–4 times costlier than the solar tariff.
- Implementation of waste-to-energy plant of capacity 2 TPD at Udaipur Municipal Corporation, Rajasthan. This plant treats the MSW collected from the city to generate electricity. This activity is supported by ICLEI.
- Installed and commissioned a TEAM technology for treatment of food waste generated from school premises.
- In a first of its kind, an evaluation of 50 MW solar thermal power plants in Rajasthan was taken up, and the report was submitted after TERI's recommendation.

Policy Research

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

- Third-generation flexible, ultra-low weight, and very low cost PV technology is being developed

by Power Roll, UK. TERI has been associated with Power Roll in supporting their development by carrying out testing. Introduction of the technology in the Indian market through potential partners is being studied and explored. 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. Mitigating measures or de-risking are being worked out in Indian Solar Energy Programme with a view to contribute capacity additions for achieving national targets. The project is sponsored by the German Ministry (BMZ).
- The Division undertook preparation of a comprehensive paper dealing with manufacturing of solar cells and modules in the country.

Project Management Consulting

- Scoping study on bio-waste and non-ozone depleting substance, non-HFC alternatives in India. This activity was supported by the Embassy of Sweden and Swedish Environmental Protection Agency.
- Strategic planning and stakeholder engagement for Mexico methane emission reduction effort through the Global Methane Initiative.
- TERI, in association with Cadmus, bagged the prestigious project sponsored jointly by GIZ and MNRE; the specific objectives of the project are to capture best practices on solar aggregation (global and national), to conduct local-level campaigns, market development, and build ecosystems (solar policy and programmes) to popularize the SRT systems, and accelerate market penetration. The focus states are Gujarat, Himachal Pradesh, Jammu and Kashmir, and Uttarakhand. Union territories are Dadra and Nagar Haveli and Daman and Diu.
- With the support of IFC, a calculator tool was developed for the textile sector of Bangladesh. This online tool can facilitate the industry owners in the initial stage of decision-making regarding solar rooftop installation from a techno-commercial perspective. It can also estimate the greenhouse gas emissions and generate a high-level bill of materials.
- As a member of International Solar Alliance (ISA) Peru Support Expert Group, TERI helped create three roadmap reports for upscaling solar energy generation in Iquitos, Peru for both grid-connected and off-grid systems.
- TERI was awarded a contract for evaluation of detailed project reports (DPRs) for setting up of biomass-based power projects as envisaged in the Bio-Energy Policy 2018 by Haryana Renewable Energy Development Agency (HAREDA). Six such reports have been completed.

Training and Capacity Building

- Conducted training on municipal solid waste management for more than 176 urban local bodies (ULBs) of Uttar Pradesh with the support of National Institute of Urban Affairs (NIUA) through six numbers of residential training programmes, each for 3 days. The programme included classroom sessions, exposure visits, which were conducted in the cities of Aligarh, Agra, and Jhansi.
- The Division has also successfully organized a 3-week international training programme on 'Renewable Energy and Energy Efficiency' under ITEC Programme, Government of India, where 18 delegates representing, 10 countries participated.
- The Division also conducted three training workshops for state nodal agencies, SLDCs, and

State Regulatory Commissions and Obligated Entities on Operationalization of RPO Portal (Renewable Purchase Obligations). This portal (https://rpo.gov.in/) was entirely developed by TERI's RET and IT teams under the project from MNRE.

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 an 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

textiles, cement, chemicals, laminates, steel, pulp and paper, paints and light engineering as well as in thermal power plants. Nearly 50 such energy audits were conducted during the year. A few prominent groups where IEE rendered services were Ultratech Cements, Ambuja, ACC, Emami Paper, Berger, Jindal, Merino, ITC, and HPCL. The Division continued to provide support under the Perform, Achieve, and Trade (PAT) scheme of BEE for large industrial consumers with regard to Mandatory Energy Audit and Monitoring & Verification (M&V) services. Additionally, TERI also undertook energy conservation studies in plants located in other countries. One of the major projects undertaken by IEG-Bengaluru this year was a detailed energy efficiency audit and pre-feasibility assessment study of water utility of Namangan City, Suvokova in Uzbekistan. This study, supported by the World Bank, identified energy-efficiency investments and strategies to demonstrate, inform, and strengthen the government's ongoing water sector reforms in Uzbekistan. Other international assignments undertaken last year are explained as follows:

- Energy audit of a large polyethylene terephthalate (PET) bottle-grade resin manufacturing facility in Brazil.
- Implementation assistance to Sharjah Electricity and Water Authority (SEWA) for replacement of inefficient pumps with variable speed-driven pumps.
- Implementation assistance to National Designated Entity (NDE) of Pakistan through the Climate Technology Centre and Network (CTCN) for developing the national certification scheme for energy auditors, including preparation of draft rules and regulation for the scheme for large industrial consumers.
- Commissioning of a dual fuel mode 600 kWp power gasifier in a rice mill in Berbice region of Guyana.

The activities of IEE Division in the MSME sector were primarily supported by the United Nations Industrial Development Organization (UNIDO), the United Nations Development Programme (UNDP), and Shakti Sustainable Energy Foundation (SSEF). The highlights during the year were:

- Expanding the knowledge collation and dissemination activities under the SAMEEEKSHA (Small and Medium Enterprises Energy Efficiency Knowledge Sharing) platform. Regional meetings of this platform were held in Kolkata (for Eastern Region) and Coimbatore (for Southern Region).
- Capacity building of local service providers (LSPs) in six clusters in the country (Coimbatore, Khurja, Morbi, Indore, Belgaum, and Thangarh).
- Promoting energy efficiency and renewable energy in cold storage units in Jharkhand.
- Undertaking investment-grade energy audits for SME units in Jharkhand.
- Assessing opportunities for switching to electrification in industrial processes.

The IEE Division continued working closely 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). To focus on enhancing technology cooperation and business opportunities in the field of energy and environment between the two countries, TERI organized the India–Japan Industry & Energy Seminar on May 1, 2018 in New Delhi. The seminar was organized jointly with the Confederation of Indian Industry and supported by New Energy and Industrial Technology Development Organization and Japan External Trade Organization.

During this year, TERI also developed the Energy Conservation Guidelines for large industries with the support of BEE and Energy Conservation Center Japan. The guidelines will serve the purpose of establishing certain minimum parameters or benchmarks, which can be adopted as a reference by the industries. Similar guidelines for SMEs are also being developed by TERI.

ENVIRONMENTAL AND **INDUSTRIAL BIOTECHNOLOGY**

The Environmental and Industrial Biotechnology Programme (EIB) has been committed towards protection of the environment and development of sustainable innovative technologies and renewable energy options in a fast growing economy for comprehensive commercial application. EIBD focuses on basic and applied research for exploring microbial-based solutions towards the development of bioenergy and biofuel-based programme.

With the state-of-the-art pilot scale bioreactor facility, the Programme has successfully developed best-selling technologies—'Oilzapper' and 'MEOR'—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, whereas MEOR (microbial enhanced oil recovery) technology developed by EIBD with the aid of IRS/ONGC has achieved substantial recognition across public sector oil companies in India for enhanced oil recovery from oil reservoirs by tackling the worldwide problem of oil well stripping. The Oilzapper technology not only helped several petroleum industries (ONGC, IOCL, HPCL, BPCL, Oil India Ltd, Tata Power, BG Exploration Ltd, and Reliance Petroleum) across India in providing a sustainable solution for bioremediation of oil spills and oily sludge-contaminated sites in a cost-effective manner but it also spread its roots in the international arena which helped grab a major project of Kuwait Oil Company (KOC) through a global competitive bid, for the bioremediation of 400,000 tonnes (cu. m) of oil-contaminated soil. After the successful completion of bioremediation work in this project, the Oilzapper technology has bid for a second phase mega tender (KERP Bioremediation at South East Oilfield at Kuwait) for remediation of total petroleum hydrocarbon (TPH) contaminated soil in KOC oil field and for clean-up of oil-contaminated sites.

In the North-eastern region of India, the Programme also focuses on production of quality planting material and provision of rural extension services. Carrying forward its activities, the Programme is now focusing its efforts 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, which has prime importance in generating hydrogen in a sustainable manner from waste without relying on conventional fossil-based resources.

Currently, in partnership with various industries, the Programme is keen on 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 that would displace the methane on coal seams with carbon dioxide, bio-butanol production from lignocellulosic biomass, extraction of essential oil, food testing services, and promotion of organic cultivation, specifically in the tea sector.

Bioremediation Technology Division

Fermentation Technology Research Centre

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

- Bioreactors
  - 3.2 L and 100 L photobioreactors
  - 10 L, 30 L, 100 L, 200 L, 1 kL and 13 kL bioreactors
- Utilities
  - Compressor: 62 CFM/1736 LPM (on standby mode for 1 kL bioreactor) 11 kW, 300 CFM/8400 LPM (on standby mode for 13 kL bioreactor) 55 kW
  - Chiller unit: 10 TR chiller/35 kW (for 1 kL bioreactor), 90 TR/kW (in three units)/315 kW (for 13 kL bioreactor)
  - Boiler (oil fired): 0.6 tonne/h (for 1 kL bioreactor), 3 tonne/h (for 13 kL bioreactor)
  - RO plant: 1000 L/h (for 1 kL bioreactor), 5000 L/h (for 13 kL bioreactor)
  - Soft water plant: 3000 L/h (for entire plant)

  - Ribbon blender (for harvesting) 70 kW: 3000 kg/h
  - Cold room: 5 cold rooms with storage capacity of 50 tonnes, Oilzapper in packed condition
  - Generator unit sets 500, 500, and 320 kVA

Production and dispatch details of Oilzapper in 2018/19

- Total production of Oilzapper = 326,000 kg
- Total dispatch of Oilzapper = 347,120 kg

Pesticides (HCH) degrading culture-related work

- Development and upscaling of *Sphingobium indicum* B90A culture from lab-scale to pilot-scale and industrial-scale bioreactors for the purpose of bioremediation of pesticide-contaminated soil at Barabanki in Uttar Pradesh
- Development of new carrier product for the B90A culture
- Production and dispatch details of B90A culture:

Dispatch details client-wise

S. No.	Client name	Quantity of Oilzapper dispatched (in kg)
1	OTBL, Mehsana, Gujarat	98,090
2	OTBL, Ahmedabad, Gujarat	106,000
3	OTBL Jorhat, Sivasagar, Assam	34,180
4	OTBL Duliajan, Assam	64,000
5	OTBL Nazira, Assam	29,000
6	OTBL Ankleshwar	2,600
7	BPCL Lalur, Punjab	120
8	BPCL Mumbai	2,500
9	BPCL Muzaffarpur, Bihar	380
10	HPCL Visakhapatnam	1,250
11	RIL, Andhra Pradesh	1,500
12	HPCL, Mumbai	2,500
13	SB Industries	600
14	ONGC Mumbai	1,000
15	IOCL Digboi	2,500

Production = 8000 L and dispatched in liquid form
Production = 3500 kg and dispatched in powder form (harvested with lignite coal)

Development of a new carrier material for Oilzapper

- Research work was carried out on the development of a new carrier material for Oilzapper. Testing of the following materials was carried out with Oilzapper:
  i. Aluminium silicate
  ii. Talcum powder
  iii. Bentonite
  iv. Lignite coal powder
- Trial batches of Oilzapper were carried out in 1 kL bioreactor and harvested with the new carrier material aluminium silicate. Product was dispatched to bioremediation site for testing purpose
- Aluminium silicate powder was found to be the better carrier material for Oilzapper

The following are the benefits of aluminium silicate as the carrier product of Oilzapper:

1. Production of 30 tonnes of Oilzapper in only one batch (2 working days). In the existing process, we need to conduct three batches to produce 30 tonnes of Oilzapper in 7 working days
2. Saving in electricity, minimum four-times lesser
3. Three-times lesser requirement of chemicals and salts and other raw materials
4. Lesser manpower requirement
5. Less maintenance of equipment
6. Production capacity may get increased by three-times
7. Diesel may be consumed three-times lesser in boilers
8. Less running of all utility and production units
9. Less RO water requirements

Consultancy service for assessment of soil fertility in Ankleshwar asset, ONGC

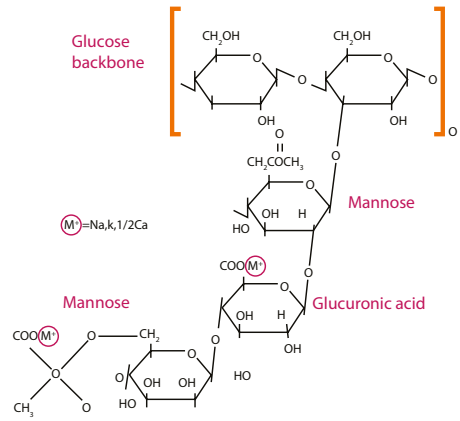
The bioremediation area involved bioremediation of oil-spilled environment and oily sludges from oil companies. The team also had undertaken the study to ascertain the agricultural soil fertility of ONGC oil fields of Ankleshwar, Gujarat. In this study, the soil fertility loss caused by ONGC exploration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

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

XC polymer (xanthan gum) is used as an oil well drilling fluid and for polymer flooding of oil. It is a natural high-molecular weight anionic polysaccharide and an important industrial biopolymer manufactured by the process of fermentation. Owing to its unique properties, it is used in a variety of applications such as food and beverages, oil and gas, pharmaceuticals, personal care and cosmetics, agrochemicals, pet food, textiles printing, and chemical applications, such as adhesives, ceramic glazes, foundry compounds, emulsions, lubricants, paints and coatings, and pesticides.

Industrial-grade xanthan gum is used as an efficient environment-friendly oil drilling mud additive. Oil and gas firms are actively involved in using enhanced oil recovery (EOR) methods to improve crude oil and natural gas production from potential exhausting reserves that can propel industry expansion.

» Study to ascertain the agricultural soil fertility of ONGC oil fields of Ankleshwar



Acting as a viscosifier and stabilizer, it has excellent tolerance to a wide range of temperatures, pH, and salinity. It increases the mud penetration rate and the suspension ability to drill cuttings. It can also reduce the pressure loss during drilling, stabilize the well-bore, prevent any damage to oil formation, and improve the efficiency of drilling, workover, and completion. In India, currently, XC polymer is mostly imported from China. However, the imported product has failed to meet the specific standard quality requirements of drilling oil companies. Also, current restraints experienced by the global xanthan gum market include the reinforced anti-dumping policies by the United States and other developed economies on the import of these products from Austria and China, along with the overall mistrust of the quality of xanthan gum supplied by China, which is the leading producer in the market.

TERI initiated research in 2015 on the development of XC polymer with a view to provide an eco-friendly technology to oil industry to be used for drilling fluid/ viscosifier.

XC polymer is produced by bacterial fermentation along with the addition of selective chemical additives to achieve the drilling fluid standards. The important critical parameters such as rheology, crosslinking, performance solubility, flow ability, and salinity tolerance were standardized. The developed product with different compositions has been analysed at the Institute of Drilling Technology (IDT), ONGC Dehradun, and Oil India, Chemical Laboratory Duliajan, to assess its standard parameters specified by drilling oil companies in India.

» QC instruments in the lab for testing XC polymer

The test sample submitted to ONGC IDT, Dehradun, accomplished all the required parameters of drilling oil companies in October 2018. In connection to this, ONGC requested OTBL to quote for the supply of XC polymer. TERI quoted for the tender for XC polymer development order submitted to ONGC, New Delhi. The total volume of tender is of 1624 tonnes. Further commercialization of the product will be done by OTBL as per the existing joint venture agreement between ONGC and TERI, which will open up new opportunities and revenue stream for OTBL.

Biotechnology for Energy

Development and Demonstration of Enhanced Methane Production from Coal

Coal bed methane (CBM) gas can be present in the coal seams as (a) free gas, (b) dissolved with water, and

(c) adsorbed on coal particles in the coal matrix. The poor permeability of coal makes producing CBM a major challenge for extraction from the coal matrix. The gas present in the coal seams depends on the type of coal and the quantity of gas present could vary depending on the coal. Therefore, CBM is at present a finite resource where *in situ* gas is produced and productivity of a well tends to decline over time.

While CBM gas is sought to be quickly produced from coal seams prior to taking up mining, for deep and unmineable coal seams, there is an opportunity to aim for continuous conversion of coal to methane gas using microbial processes.

In view of this technical challenge, use of microbial process to enhance gas production is considered necessary to make CBM production in India attractive. One of the main challenges in the use of microbial process is that for each variety of coal, the identification of specific microbial communities and isolation are required. Further, it is desirable to perform experiments to evaluate the benefits of enhancement in those blocks that have been relinquished due to very low yields.

The application of biotechnological processes is one of the promising approaches to convert coal into methane. It is recognized that methane-generating bacteria can act on coal seams to produce biogas comprising mainly methane and carbon dioxide gas. Therefore, the development of this technology is considered beneficial for enhancing the performance and efficiency of the methane recovery process from CBM wells.

Recent laboratory and field experiments have shown that not only has microbial CBM been generated in the geologic past and retained in the formation in commercial quantities, but some sedimentary basins have also active, ongoing microbial methane generation. Because methanogenesis is an active process, it might be possible to stimulate the microbial communities that have produced CBM to generate more methane from coal biodegradation on commercially relevant timescales (that is, years).

There is forward exploration and demonstration of microbial methane generation/enhancement from poor to marginal-producing CBM wells (fields) in (of) Bokaro block. The Bokaro CBM block as such is a fairly prospective block with high volatile 'A' bituminous (HVAB) to low volatile bituminous (LVB) rank of coals with high *in-situ* gas content in most areas. However, there are pockets where due to poor gas content, the wells drilled in these areas are poor to marginal producers. Earlier, in a nearby block (Jharia), *in-situ* bio-stimulation and bio-augmentation in two producing wells had resulted in 3–4-fold increase in CBM production. Such encouraging results led to the application of this microbial stimulation technique in poorly producing two wells in two different pockets of Bokaro block.

Producing hydrogen through biological route

Considering the food security issues along with the agricultural waste biomass generation potential of the nation (more than 300 million tonnes), intensive research exploration is being carried out at TERI for hydrogen production from agri-residue woody biomass (second-generation feedstock). This research was funded by the Department of Biotechnology, Ministry of Science and Technology, Government of India. These research explorations led to the development of a pilot-scale process for clean hydrogen production from agri-waste biomass sugars (rice straw, wheat straw, sugarcane bagasse, sugarcane trash, sorghum stover). This process has the potential for further scale-up in pilot and pre-demonstration scale.

Carrying forward these research explorations, this group is now exploring hydrogen production from third-generation biomass (aquatic macrophytes) generated via wastewater treatment.

Industrial Scale Production of Enzymes (Alkaline Protease)

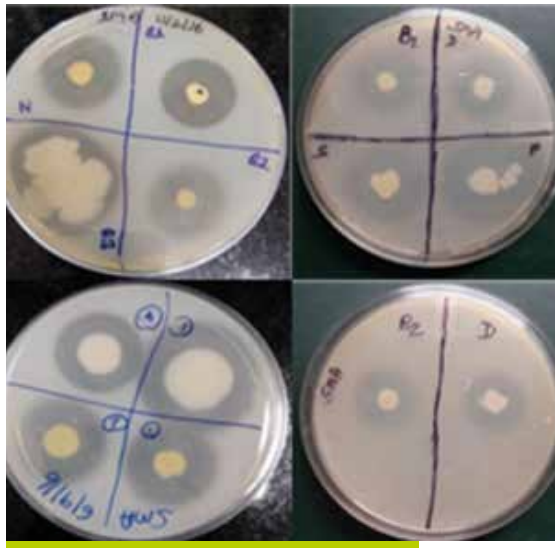
Construction and application of recombinant strain of *Bacillus subtilis* for industrial-scale production of a commercially important enzyme alkaline protease

The current demand for alkaline protease enzymes in industries is growing worldwide due to their eco-friendly industrial applications. The objective of the present study is intended to isolate higher alkaline protease-producing bacteria as well as identifications and optimization of culture conditions for higher alkaline protease production by submerged fermentation. In order to isolate the protease-producing bacteria, soil samples from alkaline-rich environments were collected and screened on medium containing skim milk casein as the substrate. The bacteria showing the maximum hydrolysis was selected and identified by microscopic, biochemical, and 16S rRNA sequence analysis. Purification of crude enzyme was carried out by ammonium sulphate precipitation and dialysis. The maximum alkaline protease production was achieved with 1% inoculum size at pH 10 and 37°C, with sugarcane molasses as the best carbon source and peptone as a better nitrogen source.

As per expected outcome, the current study is the first report on alkaline protease production from *B. licheniformis* RS3 isolated indigenously from local soil samples. Economically produced purified enzyme can be commercially applied in agriculture, textile, food, detergent, and leather industries.

Agriculture and Rural Extension Division

The Agriculture and Rural Extension area of NE Centre of TERI undertakes research and extension activities on



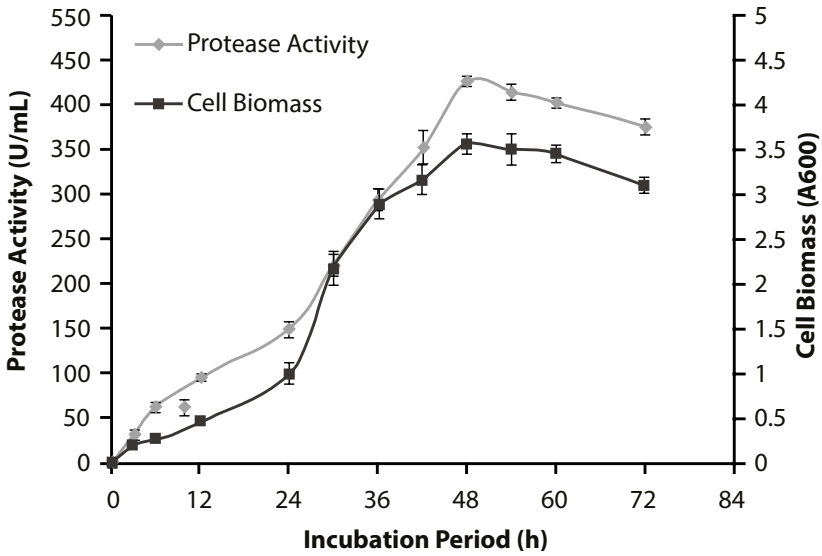
» Screening and production of alkaline protease enzyme by alkaliphilic bacteria on alkaline skim milk agar plate

tribal women in Kamrup and Udalguri districts of Assam through Eri silkworm rearing and spinning. The area is also carrying out plant diversity assessment in Borail Wildlife Sanctuary, Assam under a DBT, Government of India-sponsored project.

The area provided consultancy services to FREMAA (Flood and River Erosion Management Agency of Assam), Government of Assam, for executing projects on livelihood enhancement

the production of quality planting materials and demonstration; sericulture that includes Muga and 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 executed an R&D project on production of disease-free layings (DFLs) and demonstrated Muga food plant cultivation, rearing, reeling, and so on, and socio-economic development of



» Growth and alkaline protease production by *Bacillus* sp. RS3 in standard medium

of the victims of river erosion in the Kamrup (Rural) district of Assam through improved Eri silk spinning and weaving and vegetable cultivation. The area has also been working as a Monitoring, Evaluation, Learning and Documentation (MEL&D) agency for monitoring and evaluation of 47 Integrated Watershed Management Programmes (IWMPs) 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. In the capacity-building initiative of the Centre, TERI-NE with the support of North-eastern Council (NEC), Government of India, organized training programmes for government officials and NGO representatives to equip them with skills in designing sustainable projects for livelihood and income enhancement pertaining to the North-eastern region and ecotourism. The area also organizes different capacity- building programmes, workshops, and training programmes for students, teachers, professionals from NGOs, government departments, farmers, and private organizations on environment, sericulture, sustainable agriculture, watershed, and so on.

» Scale-up of hydrogen production from bagasse hydrolyzed sugar through dark fermentation process in 200 L bioreactor through employment of C5 and C6 sugar co-fermenting microbes *Enterobacter cloacae* DT-1 strain

Biotechnology Guwahati

The biotechnological research of the Centre includes utilization of wastewater for algal biomass production and phototrophic biofilm-facilitated adaptation conditioning of algal and bacterial association leading to easier harvest of biomass. In the molecular biology facility, research has been initiated for transcriptome-driven isolation of unculturable bacterial strains for mitigation of drought stress in tea. In the field of improved sanitation, the Centre has installed 100 prefabricated biotoilets with glass FRP (fibre reinforced polymers) materials in 100 schools of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. Orchid germplasm has been explored in Assam under a network programme and propagated *in vitro* for ornamentally important species. Fungal pectinase for banana fibre extraction and edible coating for enhancement of post-harvest shelf life of a few indigenous fruits have also been initiated. Exposure workshops for senior officials of urban local bodies from Bihar, West Bengal, and eight North-eastern states were organised in six batches in Imphal, Rajgir, Kolkata, and Gangtok to acquaint with and implement Solid Waste Management Rules, 2016 under Swachh Bharat Mission (SBM). Interpersonal communication and focus group discussions on sanitation for the population without access to toilets were mapped using android app-based geotagging for 75,000 households in 11 districts of Assam under SBM-Gramin programme.

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;
- 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;
- Bio-physical 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.

» TERI KAS Resource Dialogue V- The Emerging Global Maritime Order–India's Strategy, March 7–9, 2019 at Welcom Hotel, Kences Palm Beach Mamallapuram, Chennai

Centre for Resource Efficiency and Governance

The Centre for Resource Efficiency and Governance (CREG) serves as a focal point for TERI's work on studies and projects on natural resource efficiency, conservation and sharing, responsible development, and trade in natural resources. Resource efficiency being the key agenda of the Division, continued to remain in the focus. A reference report on resource efficiency, formulated by the Division, serves as the basis for preparing a draft policy on resource efficiency by the Ministry of Environment, Forest and Climate Change. The Division also worked towards raising awareness on the issue of natural resource efficiency among the different stakeholder groups. It also took up a study to prepare a resource efficiency strategy for the state of Goa. It worked with the 15th Finance Commission to examine how inter-governmental transfers can work as an effective instrument of forest conservation and promote clean air in India.

Under the Partnership for Action on Green Economy (PAGE) initiative of the UN agencies, CREG initiated a stocktaking study of green economy policies in India for determining the priorities of the country. Similarly, the Division also embarked on a study to understand the potentials of information and market-based instruments influencing energy demand in the residential sector. It also initiated a study on the challenges that the micro, small, and medium enterprises of the National Capital Region of Delhi face in shifting to cleaner fuels like natural gas. The Division also organized several workshops and seminars including the one on Marine Resources and Blue Economy, a subject that is gaining importance in India.

» Forest Conservation through Fiscal Federalism: Perspective of States, October 9, 2018 at Aranya Bhavan, Hyderabad

» Forest Conservation through Finance Commission Transfers: Perspective of States, August 31, 2018 at Board Room, ICFRE, Dehradun

Centre for Integrated Assessment and Modelling

The Centre for Integrated Assessment and Modelling (CIAM) provides energy-, economy-, and environment-related inputs to researchers, industries, and policymakers at the global, national, and sub-national levels. Towards this end, the Division is continuously involved in the development and use of various tools and modelling frameworks for energy and economic forecasting, techno-economic analysis and scenarios of energy and environmental simulation, and optimization. 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 is currently working on

» Harnessing the Potential of Trees Outside Forests to Meet India's NDC Commitment, November 27, 2018 at TERI, India Habitat Centre, New Delhi

» Primary survey regarding power demand estimation through end-use method under Norwegian Ministry of Foreign Affairs II project

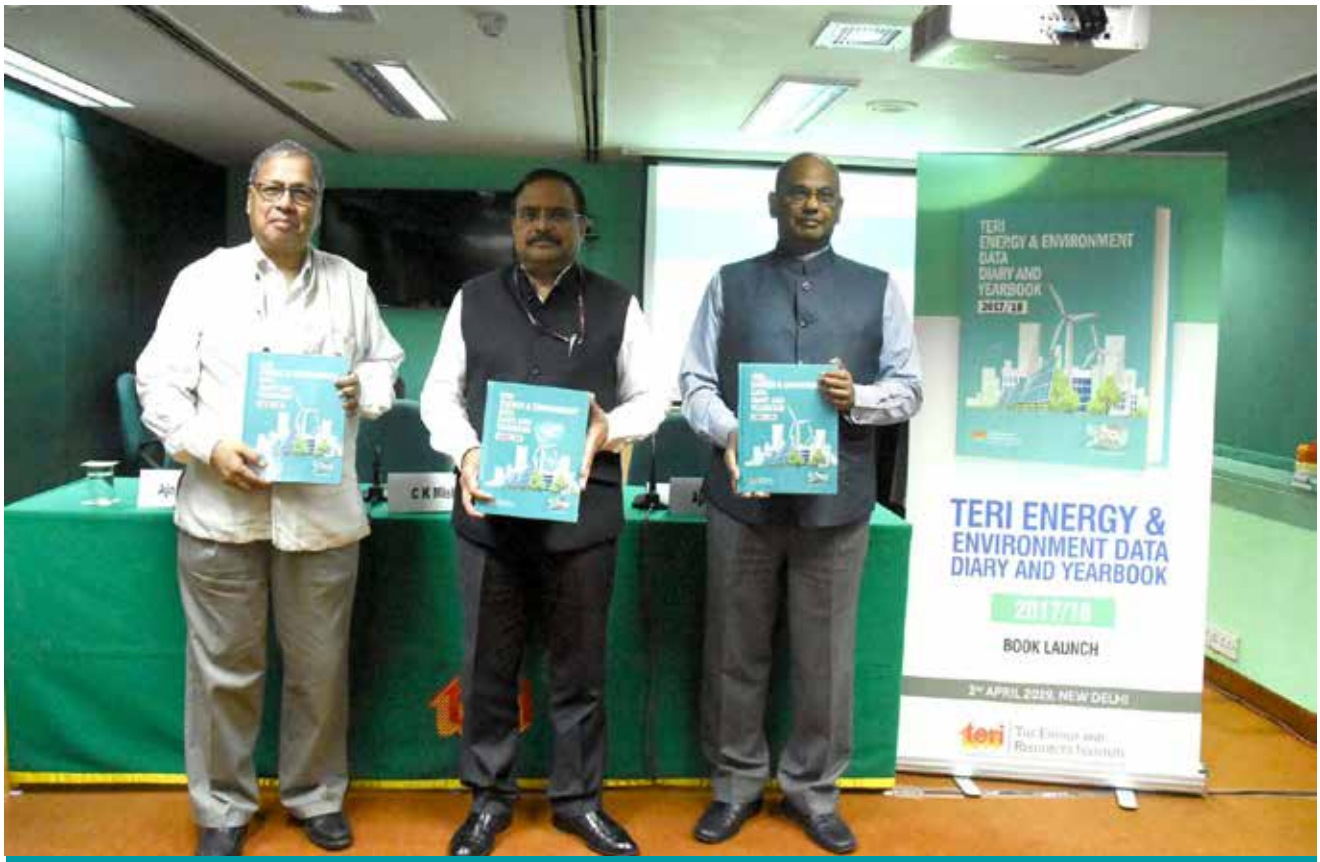
providing inputs on long-term low-carbon development strategies for India, to the Ministry of Environment, Forest and Climate Change, Government of India. This project focuses on undertaking an exhaustive review of existing climate and energy policies to understand the potential of climate mitigation in India. Further, it aims at developing energy-economy scenarios for India to outline a set of mitigation strategies for the country in the long run, which can complement the development that India aspires to achieve.

The Division has successfully completed a project supported by the Norwegian Ministry of Foreign Affairs (NFA). The objective of the project was to get a holistic idea about the power sector in India. The study has estimated the sectoral (residential, commercial, agriculture, industry and transport), regional (five grid regions and statewise), and temporal variation of power demand. This study has used end-use method for estimating power demand in the country and also to forecast it till 2051. This demand estimation will help understand demand variations effectively and adopt necessary policies and measures to control demand and reduce demand–supply gap. This will help India achieve low-carbon and resource-efficient growth.

In another project supported by NFA, we have developed an integrated energy demand-supply model (using TIMES platform) to achieve a resource-efficient and sustainable energy sector.

Another key project of the Division—CD-LINKS—supported by the European Commission under the Horizon 2020 framework focuses on linking climate and development policies. The project aims at conducting joint research and share experiences, methods, and data between leading research institutions and key stakeholders from G20 countries. The main objectives of this project are 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

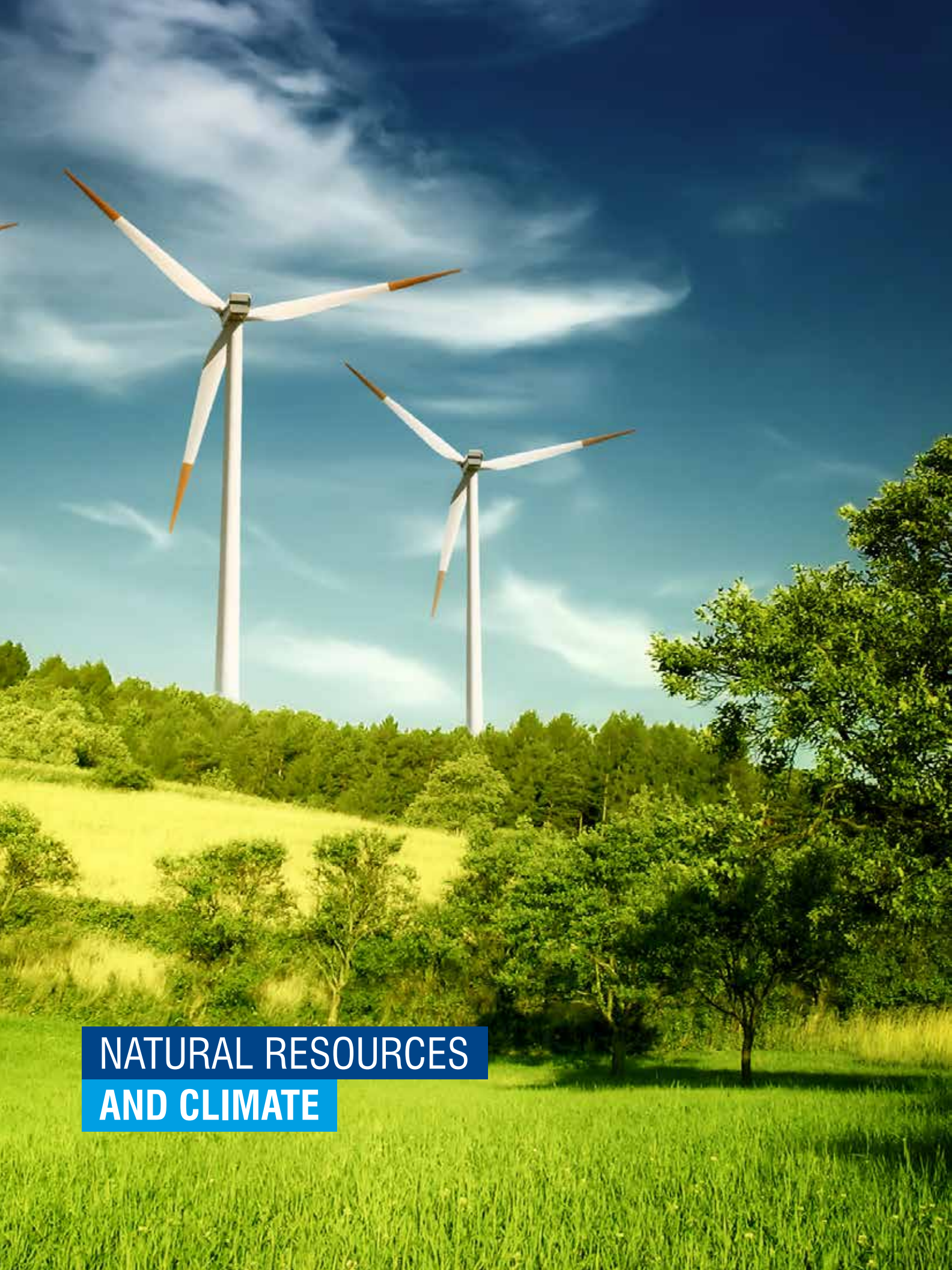
» Linking Climate and Development Policies: Leveraging International Networks and Knowledge Sharing (CD-LINKS) 5th Project Meeting



» Launch of *TERI Energy & Environment Data Diary and Yearbook 2017/18*

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 flagship publication of the Division, *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. The Division has also contributed significantly to Global Environment Outlook (GEO) 6, a publication by the UN Environment Programme (UNEP), which informs environmental decision-making by providing an integrated assessment on state trends, and outlooks of environment and facilitates interaction between science and policy. Besides focusing on issues related to air, water, climate change, chemicals, waste, biota, etc., in 2018/19, the intent was to look into the cross-cutting interactions between energy and each of these environmental domains.



NATURAL RESOURCES **AND CLIMATE**

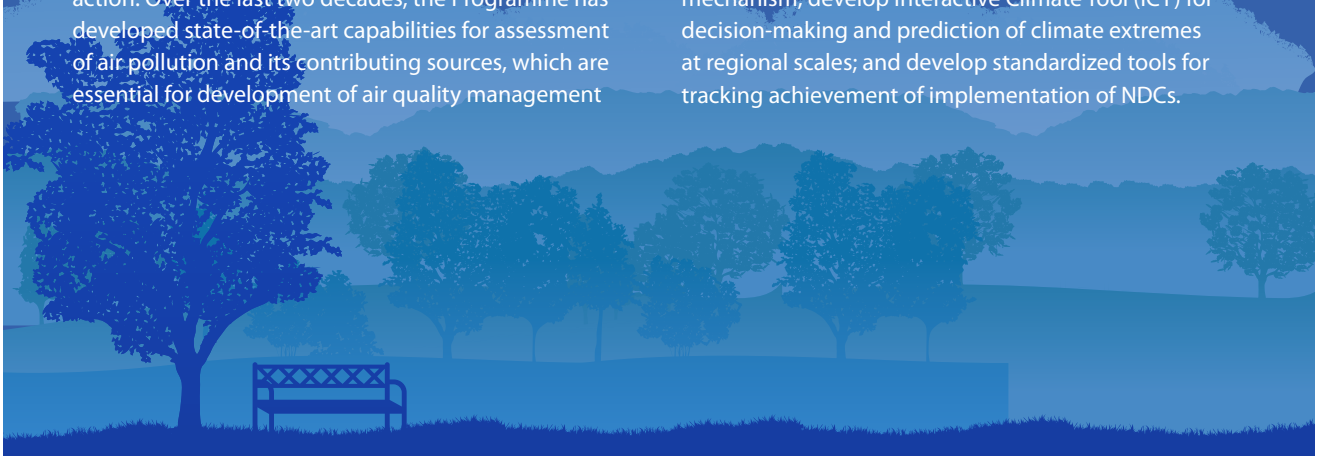
The Natural Resources and Climate (NRC) Programme spearheads research in providing innovative and resource-efficient solutions for management of water resources, waste resources, and bioresources (including application of bioresources); aims to become a global leader in providing scientific knowledge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

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

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

A multidisciplinary team of research professionals in the Programme conducts action research on issues, ranging from regional impacts of changing climate, international climate negotiations to grassroot innovation on climate action. Over the last two decades, the Programme has developed state-of-the-art capabilities for assessment of air pollution and its contributing sources, which are essential for development of air quality management plans. The NRC is also working for sustainable forest management and has been providing solutions to generate finance through carbon trading from forests, fixing minimum support price of minor forest produce, developing quality planting material, establishing the methodology for carbon assessment and community-based ecotourism. The NRC focuses on areas covering policy and regulatory issues, waste management planning and financing, research and development (R&D) and technology deployment for waste processing, recovery and recycling, and material flows and linkages to circular economy. The NRC has comprehensive infrastructure and expertise for undertaking projects in the field of water-use efficiency and water conservation, watershed management, urban water demand management, glacier research, hydrological assessments, rural water supply and sanitation, water quality and pollution studies, and policy analysis. On the issue of nutrition, the NRC is committed to develop sustainable solutions to tackle malnutrition across all sections of society through approaches such as research, policy interventions, and implementation of innovative approaches and technologies.

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



Earth Science and Climate Change Division

Centre for Global Environment Research

The Centre for Global Environment Research has core competencies in research on global, national, and sub-national climate policy, outlining effective policy initiatives that integrate developing countries' concerns in addressing global environmental challenges. The Centre builds on a strong interdisciplinary team comprising economists, physical scientists, engineers, and social scientists to aid in holistic climate change planning and decision-making. The Centre, in 2018/19 was actively involved in advocating policy actions for implementing India's nationally determined contributions. The Centre through its research on the various articles of the Paris Agreement has developed options for operationalizing the agreement. The team is also exploring linkages between climate-induced migration to develop an understanding on the results. The Centre has been regularly carrying out outreach and capacity-building programmes for various stakeholders on different subjects such as mainstreaming climate action in development policies, understanding the role of co-benefits in meeting climate action targets, etc.

The team is also currently assisting various bilateral, multilateral, and government donor agencies in implementing projects related to greenhouse gas (GHG) inventories, domestic monitoring, reporting, and verification of mitigation and adaptation actions, enhancing energy efficiency, assessing the key climate finance models and schemes on achieving climate goals and to understand and provide inputs for developing carbon markers, and developing stakeholder-driven cooling platform for devising techno-economic feasible options for the cooling sector.

The Centre extended its research and capacity-building activities to other developing countries and emerging economies through a strong research-based collaborative programme in Fiji. A number of international collaborations with institutions of global repute have ensured that there is exchange of knowledge and expertise, and strengthening of the core competencies within the area.

For the ensuing years, the Centre is prioritizing research on managing hydrological disasters, sub-national actions through State Action Plans on Climate Change in India, market-based mechanisms for climate change mitigation, and efficient refrigerant transitions.

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 seeks to build its climate modelling skills to effectively use them for a better understanding of the regional changes and their links to policy. The information generated would serve

the purpose for impact and vulnerability, and adaptation assessments. 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 storms).

1 Community Climate System Model by National Centre for Atmospheric Research (NCAR-US)

2 Community Earth System Model by NCAR

3 Global Forecast System

4 Providing Regional Climate for Impact Studies by UK Met Office

5 Weather Research and Forecasting by NCAR

6 Norwegian Earth System Model

7 Coupled-Ocean-Atmosphere-Wave-Sediment Transport Modelling System

8 Advance CIRCulation Model

9 Soil and Water Assessment Tool

10 Decision Support System for Agrotechnology Transfer

11 Danish hydrological model

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. The research has focused on several aspects of the issue of air pollution including regional-scale assessment of air quality, impacts of air pollution on health and agriculture, indoor air quality assessment in rural and urban buildings, management of emissions from transport and industrial sectors, linking air quality to climate change, training and capacity building in air quality, etc. 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 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 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 Government of India and assisted in drafting and designing of N-CAP document. It has also submitted an emergency response plan to both state government and central government, for tackling high

» Road dust collection for emission inventory of India project

» Stakeholder meeting for 'Clean air project in India' by SDC in Nasik city

» Refuse collection for emission test in combustion chamber

air pollution episodes. The group continues to strengthen and build capacity and spread awareness on different environmental issues including air pollution. 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 problems 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, etc.

» Air quality monitoring at a roadside using Indian Oil Corporation's air quality monitoring mobile van for TAQIITA project

Forestry and Biodiversity Division

Centre for Forest Management and Governance

The Centre for Forest Management and Governance Group 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 group is actively working to promote community participation in forest conservation through various institutional, training, research, and policy mechanisms. The Group 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 group is involved in experimental research for afforestation in difficult sites including nursery development and silviculture work.

Amongst 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 group 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 group, thus, endeavours to facilitate the creation and development of models, systems, and concepts for conservation and sustainable utilization of our natural resources. It has also put considerable effort into documenting the research findings on the key issues involved in this sector. Major projects of the Group are:

Pilot Implementation of India's Forest 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 a focus on two sectors – waste and forestry. The group is involved in implementing the Forest NAMA in Assam with major focus on Sustainable Fuelwood Management. The project aims to enhance carbon sequestration and to 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 an increased supply of fuelwood and enhanced 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 alternative livelihood options.

The project is being implemented in four districts of Assam, namely Cachar, Dibrugarh, Nagaon, and Sonitpur amongst the households of tea estate workers, forest villages and forest fringe villages.

» Side event on Forest NAMA: Tool to mitigate climate change at 14th session of the United Nations Forum on Forests, United Nations Headquarters, New York

A side event was also organized at the United Nations Forum on Forests at the United Nations Headquarters, New York by TERI, MoEFCC, and GIZ on May 6, 2019.

Development of forest governance model in context of community forest resource rights

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. Since the country is so diverse, one single model cannot work. In order to develop the governance models, the Forestry Division is conducting 26 Focus Group Discussions (FGDs) in different areas of governance in the country (Schedule V, Schedule VI, and others). As of now, six FGDs have already been conducted in Madhya Pradesh, Maharashtra, and Chhattisgarh. Similar FGDs are scheduled in other states also.

» Focus Group Discussion for developing governance modules for implementation of Community Forest Resource Rights in Gadchiroli, Maharashtra

Capacity building and training of forest officers for assessment of five pools 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 the Forest Department to assess the carbon stocks of forests and has also developed a manual on the carbon stock assessment of forests. Presently, the training has been conducted in Chhattisgarh, Uttarakhand, Punjab, Assam, and Goa. Similar training programmes are scheduled for Maharashtra and in other states.

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 and Environmental Research. The project aims to develop an index to standardize the contribution of co-benefits of biodiversity conservation and livelihood enhancement in protected areas 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 protected area by addressing the issues of human–wildlife conflict and increase in income of the people living in and around the protected area.

» Grassland and wetland ecosystems of Dudhwa Tiger Reserve

» Training and capacity building of Forest Department staff at Haldwani, Uttarakhand

Baseline survey to evolve methodology for fixation of minimum support price for selected 50 minor forest produce

The group has been involved in estimating the minimum support price (MSP) for selected minor forest produce (MFP) with the Tribal Cooperative Marketing Development Federation of India Ltd. The group has completed the estimation of MSP for 50 MFPs. It is pertinent to note here that based on TERI's research, the government has revised the rates for these MFPs.

» Processing of Mahua fruits to extract the Mahua seeds

Nursery activities at Gual 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 acres and supports facilities such as mist chambers, shade houses, hedge gardens, and clonal orchards with a capacity to produce 3000 clonal plants, annually. It also has open area of approximately 1.2 acres for shifting and grading of sapling. 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 (RWA), New Delhi Municipal Corporation nurseries, and various state forest departments.

» Herbal nursery at Gual Pahari

Awareness, exposure visit, training, and capacity-building programmes for farmers and village communities

In order to improve the socio-economic conditions of 1250 farmers residing in 10 villages of Nuteria block of Purulia district, West Bengal, TERI, has been carrying out a project titled 'Agriculture, Greening, Training, Capacity Building, and Income Generation Programme', financed by Coal India Ltd. The Division is involved in executing training, capacity building, and income-generation programmes for farmers and village communities on the system of rice intensification (SRI) method over the conventional method of paddy cultivation, fishery, *bakri palan*, bamboo handicraft, dona plate, lac cultivation, mushroom cultivation, agriculture productivity enhancement, agroforestry, and MFP.

Centre for Biodiversity and Ecosystem Services

Biodiversity, upon which millions of people depend for myriad services, is under unprecedented pressure, threatening to unravel and weaken the resilience of complex and fragile ecological systems, and endanger wildlife populations. TERI's Forestry and Biodiversity Division has focused 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 of Biodiversity and Ecosystem Services (CBES) embedded within the Forestry and Biodiversity Division takes a broad-based view of biodiversity. The focus is not only on species or habitat loss, but on policies, social, and economic issues that are some of the vexing problems the world faces today. Consequently, CBES emphasizes the mainstreaming of biodiversity through enhanced community engagement, involvement of a wide portmanteau of stakeholders and a focus on valuing biodiversity and ecosystems.

1. Mainstreaming community-conserved areas for biodiversity conservation in Nagaland

GEF-Satoyama Project: Mainstreaming community-conserved areas for biodiversity conservation in Nagaland (sub-project under Mainstreaming Biodiversity Conservation and Sustainable Management in Priority Socio-ecological Production Landscapes and Seascapes): The objective of this project is to support community-based conservation by mobilizing support for the formation of Community Conserved Areas (CCAs) including larger networks of contiguous forest patches in Zunheboto district of Nagaland, and developing community-based ecotourism initiatives. The project helped in developing CCAs of 939 hectares in three villages of Zunheboto district, namely Sukhai, Kivikhu, and Ghukhuyi along with the formation of a joint committee Tizu Valley Biodiversity Conservation and Livelihood Network (TVBCLN) to manage the activities of conservation and ecotourism. With TERI's help, two successful biodiversity meets were conducted in the area with participation from several states. The TVBCLN received the 'Special mention' under MoEFCC-UNDP 2018 awards for Sustainable Use of Biological Resources.

» Documentation of the biodiversity with the local communities

2. Conducting a baseline study on existing impact of tourism activities and providing detailed recommendation for sustainable tourism activities with special focus on nature-based and adventure tourism

The project under the flagship programme of SECURE Himalayas funded by UNDP India aims at identifying the baseline on the impacts of tourism activities in the snow leopard landscapes of Khangchendzonga and upper Teesta landscape in Sikkim, Govind-Gangotri and Darma Byans landscape in Uttarakhand, Lahaul-Pangi and Kinnaur landscape in Himachal Pradesh, and Changthang landscape in Jammu and Kashmir. One of the key objectives of the project is to provide recommendations for sustainable tourism activities with special focus on nature-based and adventure tourism in SECURE Himalaya project landscapes that have a direct bearing on improvement of local economy as well as strengthening conservation-related frameworks of the project.

» Tourists visiting the community-conserved areas developed at Nagaland during Second Biodiversity Meet, 2018

» A community-managed homestay at Yuksam based on the concept of ecotourism

» Congregation of hotels in the town of Lachen, North Sikkim to cater to increasing tourists

3. Valuation of ecosystem services of two ecosystems in Fiji

The project funded by the Department of Environment, Fiji under the UNDP Ridge to Reef programme aimed at valuation of ecosystem services for two landscapes, namely Rewa-Waidina sub-catchment and Rewa delta catchment. The key ecosystem services valued for the native forested portions of the Waidina sub-catchment were biodiversity conservation, water supply and purification, provisioning services, carbon storage and sequestration, and potential for tourism. The key ecosystem services valued for Rewa delta were subsistence fishery, artisanal fishery, carbon storage and sequestration, and tourism.

4. Evaluation of the scheme on biosphere reserve

Biosphere reserves (BRs) include parts of natural and cultural landscapes extending over large areas of terrestrial or coastal/marine ecosystems or a combination thereof and are representative examples of bio-geographic zones/provinces. The aim of the project was to undertake

» Sovi basin-protected area - native forested areas of Waidina sub catchment
Photo: Mangroves - part of the coastal and marine ecosystems of Rewa delta

» Stakeholder consultation with forest department at the entrance of Khangchendzonga National Park in Khangchendzonga Biosphere Reserve

evaluation of five BRs in India, namely Khangchendzonga BR, Gulf of Mannar BR, Manas BR, Nandadevi BR, and Kachchh BR. The objective of the project was to assess overall outcomes, impacts as well as cost-effectiveness of the scheme. The project also identified on improving the quality of implementation and determining continuous relevance of the scheme in the context of National Environment Policy.

5. A situation analysis and capacity needs assessment vis-à-vis human wildlife conflict in India under the Indo-German Project, 'Human Wildlife Conflict Mitigation' of MoEFCC and GIZ India

The study adopted a mixed method approach to achieve the tasks and objectives. An extensive review of literature was undertaken and discussions held amongst experts, both within the expert panel and with those across the country. Compensation schemes, management plans, and other local information wherever available were scrutinized. Following this, a draft report in the required format and as described earlier was submitted. A national-level workshop

helped to validate the results and lead to suggestions on the subsequent field survey component.

» Participants of the stakeholder consultation conducted at Gorumara National Park on the issues of human wildlife conflict in North Bengal

» Electric fences installed at the boundary of the forests as a protective measure from wild animals

» Stakeholder workshop conducted to identify the gaps and requirements in assessing the capacity and training needs

The field component helped validate the information and recommendations emerging from the desk study and the workshop.

6. Assessment of capacity and training needs of key government staff and community members/ institutions for long-term effective biodiversity conservation, and development of a framework in Uttarakhand under the UNDP SECURE Himalaya Project

This assignment aims to carry out training needs assessment for various stakeholders in order to develop relevant modules and curriculum on biodiversity conservation, participatory natural resource management, livelihood enhancement, etc., with a focus on project landscapes. Once the modules and curriculum are prepared, the SECURE Himalaya project envisions that various state training agencies will incorporate these modules and impart training as and when required. This will assist in fulfilling indicator 1.2 of the project, which is 'Improved institutional capacities for planning, implementation, and monitoring of multiuse landscape-level plans'.

7. Developing a resource mobilization strategy for implementing the State Biodiversity Strategy and Action Plan 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 GIO-UNDP SECURE Himalaya Project. Under it, Policy and Institutional Review, Biodiversity Expenditure Review, and 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.

Coastal Ecology & Marine Resources Centre, Goa

In its role as a multidisciplinary research centre, the Coastal Ecology & Marine Resources Centre (CEMRC), Goa has been implementing research in the areas of marine and coastal resources, biodiversity mapping, and water resource management. Various environmental awareness programmes, education and outreach projects, and activities are also 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 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 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 coastal villages biodiversity have been carried out with support from Goa State Biodiversity Board (GSBB) for Velim, Chorao and cover seven other villages of Goa. With the support of NABARD, the digitization of self-help groups from the six coastal talukas of Goa is in progress. The TERI Coastal Education Hub was officially inaugurated this year. This will expand the hitherto work of spreading awareness on coastal technologies to a greater number of schools.

Underwater Technology and Management group, riverbank 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 Ramboll-Environ Foundation, USA, was handed over to the panchayats and farmers' association groups. The project funded by the National Health and Medical Research Council (NHMRC), Australian government, for domestic potable water for four villages in Karnataka was successfully completed and handed over to village panchayats and personnel trained to handle the RBF systems. The project funded by DBT, wherein a horizontal flow filtration tank is used to provide clean water, is on the verge of completion; the process of patenting of this technology is under progress. Another project involving RBF technology at two villages (≈2000–3000 population) in Davangere along the banks of Tungabhadra River, Karnataka was implemented, which included hydrogeological investigations, RBF installation, and testing followed by water quality monitoring, health impact and outreach activity funded by the Water Technology Initiative (WTI) under Department of Science and Technology (DST). WTI–DST funded another project on bank filtration for Sal River in Goa and Nauta Lake in Cortalim village for demonstrating sensor-based irrigation system at nearby farms.

In addition to the aforementioned research projects, the CEMRC extensively organizes training programmes and seminars on a regular basis. Organizing educational tours for schools in order to connect students to science and inspire environmental actions is among the key areas of the Centre. Such educational tours enable students to learn about different coastal habitats, traditional practices, and sustainable technologies.

Marine and Coastal Resources

Project 1: Aquaponics

The aquaponics system incorporates a system that combines a conventional aquaculture setup with hydroponics in a symbiotic environment. The setup has tilapia fish raised in an aluminium tank. In a normal setup, build-up of excretions can make the water toxic. In an aquaponic system, water from the aquaculture system is fed to the hydroponic system where the by-products are broken down and absorbed by locally sourced, easy to grow plants like amaranth. The water is then recirculated to the aquaculture system. The aquaponics setup initiated in partnership with NABARD is completed and later opened for demonstration to visitors.

Project 2: People's Biodiversity Register of coastal villages of Goa

The People's Biodiversity Register (PBR) of the coastal villages of Goa is supported by the GSBB. The PBR of Goa's coastal villages constitutes the recording and inventorization, in consultation with the local people, of the occurrence of various species of flora and fauna and resources present in the area. It is an attempt to record rapidly eroding knowledge of the medicinal uses of local plants and to record the management practices of lands. Thus, the PBR provides a platform through which members of a community may initiate steps towards better management of their biodiversity resources.

The development of the PBR has been completed in the coastal villages of Velim and Chorao. Currently, it is being facilitated in Anjuna, Nuvem, Raia, and four other villages under the support of GSBB and GIZ India.

Water Resources Management

Project: Riverbank Filtration Collaborative Project along Krishna River: Improving access to safe water using riverbank filtration technology

The RBF technology works on the principle of creating pressure by pumping action on the polluted water in a river to move to RBF well, enabling filtration and treatment by natural and self-regenerating processes. Compared to other conventional technologies, RBF is inexpensive, mechanically simple, and sustainable. However, its performance depends on local conditions such as geology, hydrology, and water chemistry and hence requires expert advice and community training.

Hydrological conditions along the upper Krishna River, Karnataka, are suitable for RBF well installation even though highly permeable alluvial deposits in this locality are rare. Under grants provided by National Health Medical Research Council (NHMRC) of Australian Government, RBF systems were installed in four villages within the Athani Taluka, Belgaum, Karnataka, to supply water to approximately 2000–3000 people per village. RBF treatment reduced concentrations of *Escherichia coli* bacteria, heavy metals, and turbidity in the water. A continuous supply of water to three of the four study villages was achieved; however, water pressure problems prevented delivery of water to some storage tanks. Discontinuous

Velsao - ward meet

Seraulim - ward meet

Raia - transect walk

» Awareness talks on PBR at the ward levels

Marsh crocodile

Marsh crocodile

Sancoale - transect walk

» Awareness talks on PBR at the ward levels

electricity supply also affected supply—geochemical fingerprinting identified RBF water as a 40% to 50% mixture of shallow groundwater and 50% to 60% river water. Higher river water contributions and better water-quality data resulted when the RBF well was pumped continuously. Hence, future studies evaluating RBF systems should consider relying on solar power or other stable power supply sources.

At the end, four RBF systems with ancillary pipework and tanks were handed over to local communities. TERI organized 1-day dissemination workshop along with project collaborators, Monash University Australia, University of Rhode Island, USA, and stakeholders from Belagavi like National Institute of Hydrology, and Visvesvaraya Technological University, Belagavi wherein advantages and limitations of RBF technology in southern India were discussed.

Project 3: TERI Coastal Education Hub

The objectives include highlighting environmental potential and the incorporation of multiple ecosystems and practices such as:

- **Mangrove ecosystem:** estuarine creeks, traditional net casting and crab catching, identification and exhibition of mangrove roots, leaves, flora and fauna.
- **Khazan ecosystem:** traditionally reclaimed mangroves by construction of 'bunds' and sluice gates. These self-operating setups combine highly complex eco-agricultural and aquaculture aspects along with salt panning.
- **AquaTech Park:** raising of mussels, oysters, and crabs.
- **Organic farming practices:** traditional as well as modern farming practices.
- **Eco-sustainable practices:** managing eco-footprint and how to practice what is learnt.

The Hub brings to the forefront the mangrove and unique Khazan ecosystems—prized wealth of Goa. The Hub is a platform for disseminating ecological knowledge especially on the conservation of our coastal ecosystems and resources, dissemination of sustainable technologies. Additionally, the AquaTech Park showcases live demonstrations and hands-on activities on mussel and oyster cultivation, crab

culture, and cage farming. Several techniques are showcased to visitors (in association with Nave Marg). Having high practical educational potential, the focal points are: organic farming practices, dairy and pig farming, biogas fermentation, and vermicomposting. Guided boat tours and walks expose visitors to the balance of the integrated ecosystems, with presentations and hands-on exercises at the training centre, highlighting coastal wealth and diversity.

Project: COE-Aquafeed

With rising populations, fish is increasingly being looked as a source of protein and beneficial omega-3 long chain polyunsaturated fatty acid. A global survey has revealed that, with overfishing and dwindling fish stocks in the oceans and seas, aquaculture has become an important source of fish and is now one of the biggest contributors to fish production. Although providing nutritional security and gainful employment to millions in the sector, it is an expensive practice with high consumption of fish meal and fish oil, both resource consuming and expensive. Use of algae-derived products as alternative feedstuff is an option. In association with the COE, a pilot set-up of pearl spot fish culture for commercial preparation of artificial fish feed using de-oiled algae has been initiated. Trail runs of aquafeed formulation with various combinations of ingredients, moisture content, and pellets of different sizes have been fruitful. The technology of artificial aquaculture feed preparation is not novel. Currently, aquafeed preparation using algae and its co-products are in its nascent stages in India. Therefore, inclusion of algae and/or similar sources of proteins/nutrients in feed preparation will provide new avenues for existing industries, reduce prices of fish feed, or reduce reliance on fish meal.

Nutrition Security Division

TERI Western Regional Centre, Mumbai

TERI's regional centre in Mumbai was established in 2006 and has since identified various issues in the region that the Centre has been working to address. Food and Nutrition Security, Environmental Resource Management, Sustainable Development for the Creation of an Eco-city, are a few of the areas that the Centre focuses on 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 the government, public sector organizations, academia, and corporate sectors along with citizens.

The highlights of the Centre for the year 2018/19 are:

Website

The Nutrition Security Division created a dedicated website that summarizes the work carried out by the Division in the field of urban and rural malnourishment along with other related projects during the last 5 years. It also includes a first of its kind digital library dedicated to wild edibles and mushroom species available in the western coast of India, listing out over 200 species along with their uses and other useful information.

» Hon. Minister Shri Sudhir Mungantiwar launching the website along with Dr Anjali Parasnis, Dr Ajay Mathur, and Mr M. S. Gill

One of the main objectives of the website has been to make traditional knowledge regarding wild edibles and mushrooms easily accessible to a host of beneficiaries such as rural and urban citizens, researchers, students and academia, and to bridge the gaps in nutritional knowledge available to the masses. The website seeks to positively influence the lives of both urban and rural communities and addresses malnutrition by serving as a guide for existing and potential stakeholders on incorporating measures that could help decrease macro and micro nutrient disorders. The Division plans to make the content available in regional languages, beginning with Marathi, in order to increase its access by local communities.

The website was launched in April 2018 by Shri Sudhir Mungantiwar, Cabinet Minister of Finance & Planning and Forests Departments, Government of Maharashtra in the presence of Dr Ajay Mathur, Director General, TERI and several other dignitaries.

The website link is https://www.teriin.org/projects/nutrition-security/.

Model village: Livelihood and nutrition security

The 2018/19 phase of the Division's ongoing rural development project focused on increasing sustainable livelihood avenues available to the villagers. TERI trained the beneficiary women from the project village, Pathardi in Palghar, to make nutrient-fortified snacks and chocolates. The women were trained in preparing spinach-fortified snacks, ragi-fortified cookies, and spirulina-fortified chocolates as per professional standards by expert resource persons.

TERI also motivated and helped the self-help groups get registered with Umed Programme of Maharashtra State Rural Livelihoods Mission (MSRLM) in order to provide market linkages and also to help the SHGs avail the subsidies that the state government offer.

Participation by TERI's project beneficiaries in Mahalaxmi Saras Exhibition-sale

Umed–MSRLM, Government of Maharashtra, organizes exhibition-cum-sales at various locations in the state to provide SHG women who are entrepreneurial and own small businesses, with the opportunity to sell their products, thereby providing these women with market linkages and an additional livelihood source.

» Hon. Minister Shri. Sudhir Mungantiwar (centre), Dr Ajay Mathar (extreme left), Dr Anjali Parasnis (extreme right) with project beneficiaries from Palghar district

» Women making nutritious cookies in Pathardi

» *Spirulina*-flavoured chocolates

The *Mahalaxmi Saras* is a 10-day long exhibition-cum-sale, organized in Mumbai, for the past several years. This year it was held from January 23 till February 4, 2019 and two SHG groups from Pathardi participated in the exhibition and sold spinach-fortified snacks and *spirulina* (a nutritious algae)-fortified chocolates, amongst other nutritious snacks, which were very well received by customers and print media.

» Customers purchasing the *spirulina* chocolates prepared by Pathardi women at the Mahalaxmi saras exhibition-cum-sale

» The capacity of the waterwheel is around 45 litres, approximately equivalent to the water carried in three standard pots.

The women earned a sizeable revenue over a period of 10 days and were motivated and encouraged to pursue this entrepreneurial venture further.

➢ Distribution of waterwheels

TERI's project village Pathardi is located on a dry and hilly terrain that faces a severe water shortage after the monsoons. Women are sometimes forced to walk over long distances to fetch water for their household requirements. TERI distributed and oriented the villagers in the use of 'waterwheels', an invention by Wello and marketed by Nilkamal that uses rolling water technology to make carrying water convenient and efficient. It can also be used as a mini-storage drum.

» Two youngsters in Pathardi using the waterwheels

The waterwheel has greatly reduced the drudgery of fetching water over distances and also led to a distribution of work with men and children, also taking an interest in using it and fetching water.

Environmental Studies and Resource Management

Air Quality Status Report 2018/19

The *Air Quality Status* Report provides a decadal overview and analysis of the quality of air recorded across all the Ambient Air Quality Monitoring Stations (AAQMS) in Maharashtra. 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 for the past 10 years through illustrations and graphical representations. This information also gets uploaded on the website of the Maharashtra Pollution Control Board.

The *Air Quality Status* Report of Maharashtra 2018/19 was unveiled on June 4, 2019, on the occasion of World Environment Day, by Chief Minister Hon. Shri Devendra Fadnavis in the presence of several other dignitaries. This was the eighth consecutive annual report developed by TERI–WRC for MPCB.

Environment Status Report 2018/19 of Navi Mumbai

The *Environment Status Report* (ESR) is a form of State of Environment Reporting (SoE) that analyses the statistical data and depicts information regarding important growth factors of the city, state of natural resources within and surrounding the city, impacts of human activities on such precious resources, and possible mitigative actions/measures required to tackle/minimize such impacts.

The report is mandatory for all urban local bodies (ULBs) under Class I cities of Maharashtra state to submit their annual ESR report to general body (GB) on or before July 31, as per Section 67 A of the Maharashtra Municipal Corporations (MMC) Act, 1949, substituted for the Bombay Provincial Municipal Corporations (BPMC) Act. The ESR is required to be submitted to the Ministry of Urban Development (MoUD).

TERI–WRC has been preparing the *Annual ESR* for Navi Mumbai for the past 6 years. The report is prepared on the basis of the Driving force-Pressure-State-Impact-Response (D-P-S-I-R) framework. *The ESR 2018/19* of Navi Mumbai not only documented the qualitative as well as quantitative status of resources like water, air quality but also the status of health in the city. It further presented various initiatives taken by the corporation towards sustainable development of city.

Eco-city

As part of the Eco-city project (a collaboration between NMMC and TERI), NMMC commissioned a 25 kWe capacity two-stage biomass gasifier (pilot scale) at Turbhe landfill site. On the eve of World Environment Day, June 5, 2018, NMMC commissioned the pilot plant and the inauguration of the gasifier plant was done by Dr N. Ramaswamy, (IAS), Commissioner, NMMC in the presence of other dignitaries from TERI, NMMC and Swiss Development Corporation (SDC). The technologically advanced two-stage biomass gasifier system for power generation has been developed by TERI in partnership with the Danish Technological University (DTU) and 'Effin'art', a Swiss energy-efficiency consulting firm. The two-stage gasifier power plant is financed by the Swiss Agency for Development and Cooperation under its project on accelerated diffusion of biomass-based clean energy systems in India.

Corporate Urban Farming Training

The Centre developed an urban farm at Capgemini campus, Airoli under the project titled 'GROW'. It involves development of an urban farm through the participation of Capgemini employees. The project was divided into two sections, namely knowledge sharing through the medium of workshops and on-field demonstration through sowing event, where employees themselves have sown the seeds.

The workshop was conducted on February 7, 2018 with approximately 250

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

» A 25 kWe capacity two-stage biomass gasifier commissioning at the hands of Dr N. Ramaswamy (IAS), Commissioner, NMMC, and other dignitaries (Dr Shirish Sinha, Deputy Director of Co-operation, SDC; Mr Mohan Dagaonkar, Chief City Engineer, NMMC, Dr Anjali Parasnis, Associate Director, TERI-WRC) at Turbhe landfill site on June 5, 2018

employees as participants. The sowing event was conducted on February 8, 2018. The TERI team worked on farm design and prepared a list of suitable vegetables that could be harvested in this farm. The farm was developed using waste materials such as used wooden boxes, tires, and gunny bags, as part of a best out of waste initiative.

Selected vegetables were divided into four sections, namely veggie garden (lady finger, brinjal, bitter gourd, and ridge gourd), leafy garden (spinach, fenugreek, cabbage, and red amaranths), *chatpat masala* (mint, chilli, coriander), and salad junction (tomato, cucumber, radish, and garlic). Around 40 employees were randomly selected out of 250 and were given the task of maintaining the farm. The employees have undertaken the responsibility of taking care of the farm and actively participate in gardening activities, and have even started harvesting the produce obtained.

» Capgemini employees participating in the sowing event at CapGemini's campus, Airoli

» Some of the produce grown in farm (clockwise – harvestable ridge gourd, okra, spinach, and mint)

Environment Waste Management

The mandate of the Environment and Waste Management Division includes research on policies, regulation, governance, health, and technological solutions for pollution control and management of solid and liquid waste streams.

Work on water wastewater treatment continued on membrane bioreactors, forward osmosis process, and resource recovery. Forward osmosis studied melanoidins concentration and water recovery in distillery wastewater as well as concentration of sewage.

We have also developed different superabsorbent bionanocomposite by microwave-assisted method for removal of toxic dyes and heavy metals from waterbodies. We have also developed bioinert and biocompatible nanocomposites for tissue-engineering applications. Work is also being done on the development of inorganic–organic hybrid anocomposites for dental restorative applications. On the health front, the Division's work is spread across the country from the coastline of Andhra Pradesh to the floodplains of Yamuna and from mega-cities to quiet hamlets, which includes successfully assessing human exposures to toxins such as $PM_{2.5}$ and phthalates.

Continued efforts are designed towards showcasing hotspots, 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.

During 2018/19, baseline assessment reports and IEC awareness reports for solid waste management were prepared for Varanasi and Panaji under the NAMA project sponsored by Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ) GmbH. 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.

The Division successfully completed the social impact assessment for the 3WAYSTE waste-to-energy plant to be set up in Chikkanagamangala, Bengaluru.

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 planning with focus on waste minimization, recovery, and recycling; studies on waste-to-energy issues include impact assessment; modelling of emissions from solid and liquid waste management practices and exploring reduction in greenhouse gas emission; institutional strengthening and capacity building; material flow, life cycle assessment, and exploring linkages between circular economy and waste recovery/recycling. During 2018/19, the area grew to include international- and local-level projects addressing waste management issues in different spheres.

Resource-efficient Technologies

The activity in water/wastewater treatment focused on membrane bioreactors, forward osmosis process, and resource recovery. Forward osmosis is being studied for melanoidins concentration and water recovery in distillery wastewater as well as concentration of sewage. Membrane bioreactor with ash-based ceramic membranes is being tested over a long period in a school in Guwahati for treating sewage from the toilets. Anaerobic membrane bioreactor was tested on-site at Barapullah drain as part of an Indo-Dutch project; based on these results, scaled-up pilot reactor is being designed. Biomass from phytoremediation is being used as a source for activated carbon, which is being tested for removal of volatile organic compounds. Porous ceramics from biomass and biomass ash are being characterized and tested for different applications.

Environment-friendly plastics such as biodegradable polymers for packaging, biomedical, fire-resistant applications, eco-friendly additives for electromagnetic interference (EMI) shielding are being developed at TERI Bengaluru. High-performance nanocomposites using recycled commingled plastics for fire-retardant applications were developed. We have also developed different superabsorbent bio-nanocomposite by microwave-assisted method for removal of toxic dyes and heavy metals from waterbodies. The group also has well-furbished laboratory for polymer materials, which is fully equipped with all the necessary instruments and equipment needed for processing and to carry out various tests. We have also developed bioinert and biocompatible nanocomposites for tissue-engineering applications. Work is also being done on the development of inorganic–organic hybrid nanocomposites for dental restorative applications.

Implementation of resource-efficient cleaner production (RECP) measures continued for the metal sector in Bangladesh, Nepal, and Sri Lanka as part of the METABUILD project, supported by the European Commission under the SWITCH Asia programme. As of the third year of the project, 402 companies were involved; more than 1800 measures were implemented and 171 showcases, illustrating the business case for RECP were identified. TERI was also involved in replication of RECP implementation in industrial clusters in Delhi. Around 150 companies were made aware of RECP options and benefits; implementation support was provided to 30 companies. The implementation measures led to savings of 37% energy, 51% water, 38% raw materials, and 51% reduction in waste.

Resource-efficient supply chain for metal products in buildings sector in South Asia (METABUILD) 2015CE04

Project description: This project targets enhancement in the use of sustainable production technologies and practices in 400 small and medium enterprises (SMEs) in the metal products supply chain for the building and construction sector in Bangladesh, Nepal, and Sri Lanka. The other target groups include technology suppliers, financial institutions, customers and public officials, and local consultants.

The project is currently working with 402 companies in Bangladesh, Nepal, and Sri Lanka and more than 1800 RECP implementations have been completed. Several RECP measures have been implemented across industries[12] in all three target countries, thereby validating the METABUILD approach.

Local treatment of urban sewage streams for healthy reuse (LOTUS^{HR}) 2017RE21

LOTUS^{HR} aims to demonstrate a novel holistic (waste-)water management approach for the recovery of water, energy, and nutrients from urban wastewater. The required treatment and reclamation steps will be determined by the water quality needed for safe and healthy reuse for various applications. Innovative but proven robust technologies will be incorporated in a modular pilot treatment plant along the Barapullah drain.

The project has established the site for analytical laboratory and demonstration of plants for anaerobic treatment, algal treatment, and wetlands have been set up. TERI has set up anaerobic membrane bioreactor with ash-based ceramic membranes and is also involved in socio-economic studies related to treated water reuse. Based on the on-site test results, the pilot plant design has been proposed and is under finalization.

[12] Details available at https://www.metabuild-southasia.org/resource-centre/showcases

» Technology fair in Bangladesh

» Dissemination event in Nepal

» Workshop at Badli Industrial Area

» Measurement at participating industry

» Implementation at participating industry

Replication on RECP measures in selected industrial areas in Delhi 2018RE21

As part of the Sustainable and Environment-friendly Industrial Production-Environment Improvement in Industries (SEIP-EII) project, 150 industries in Delhi (Lawrence Road, Patparganj, and Mayapuri), Vapi in Gujarat, and Haridwar in Uttarakhand were assessed and among these, 40 industries were supported to implement RECP measures. Based on the previous experience, which covered multiple sectors, replication was done in Badli, Wazirpur, and Naraina Industrial Areas in Delhi. The project engaged with multiple industries to disseminate resource-efficient best practices for optimizing energy, water, and raw material in their respective companies. About 30 industries received one-to-one support and savings obtained were: 37% energy, 51% water, 38% material, and 51% waste.

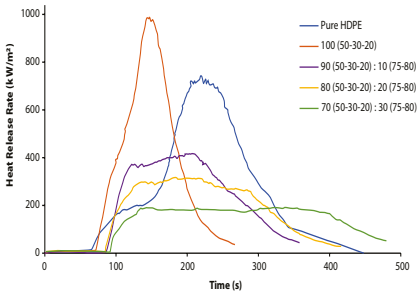
Development of intumescent fire-retardant nanocomposites for medium voltage cable sheathing applications 2016RE23

In this study, non-halogenated fire-retardant nanocomposites are being developed for cable sheathing applications. The commonly used materials are HDPE, EVA, LLDPE, and thermoplastic elastomers like EPDM. These materials have poor flame resistance, and fire-retardant additives have to be added to make them fire-safe materials.

» Testing of anaerobic membrane bioreactor at the Barapullah lab site

Dental nanocomposite resins based on hybrid dimethacrylates: Mechanical, wear, and shrinkage characteristics 2017RE26

This project deals with the development of dental composite resins comprised dimethacrylates along with two hydroxyethyl methacrylate (HEMA), nanobioactive glass (NBG), and methyl methacrylate-modified oxozirconium cluster filler. In this part of work bulk synthesis of NBG has been performed by following the microwave method, and the synthesized glass particle has been ground in a dry ball mill at 400 rpm for 1 hour to obtain fine nanobioactive glass particles. Further, this synthesized NBG has been surface modified with 3-aminopropyl triethoxysilane (APTS). Both silane- treated and untreated NBGs have been characterized by FTIR and SEM. Bulk synthesis of oxozirconium cluster has been initiated by using zirconium butoxide and methacrylic acid.



» Heat release rate of neat HDPE along with nanocomposites

The synthesized oxozirconium cluster has been copolymerized with methyl methacrylate and characterized by SEM and FTIR. Grafting of poly (methyl methacrylate) [PMMA] on nanoclay has been performed by following conventional method at 70°C for 1 hour using TDM as chain transfer agent. Trial synthesis of dental composite with 3-isocyanatopropyl triethoxy silane, dodecanediol dimethacrylate, isobornyl methacrylate along with diurethane dimethacrylate fillers and photoinitiator has been initiated.

» Pure HDPE with no residue and HDPE nanocomposites with formation-thick char layer after cone calorimetry trials (side view and top view)

Development of polyolefin composite loaded with co-microencapsulated intumescent fire-retardant system along with nanosized wear-resistant additives 2017RE23

The use of LDPE, HDPE, and 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 as ammonium polyphosphate (APP) along with pentaerythritol, which has been found to be very effective. However, these are moisture sensitive and their thermal stability is low. In this study, a high-temperature charring

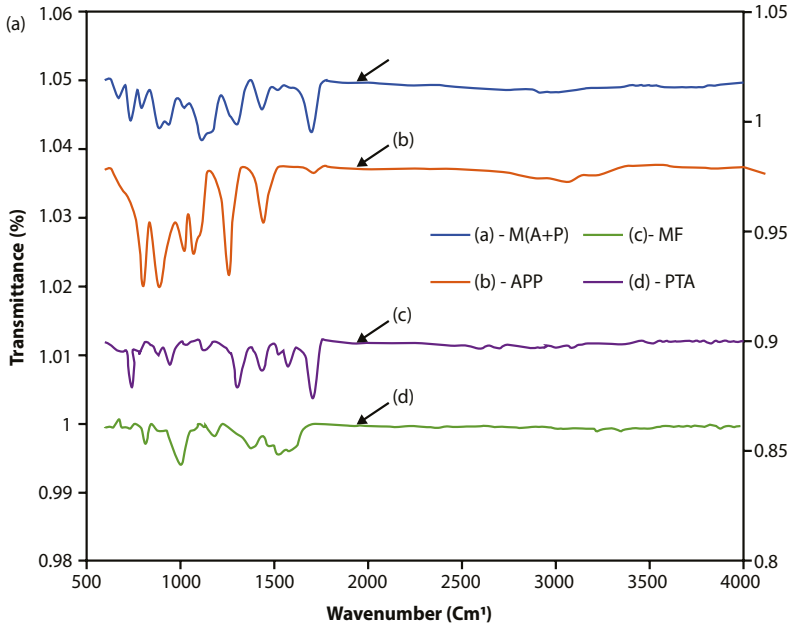
agent, that is, propane terephthalamide was synthesized. This was co-micro-encapsulated with APP in melamine-formaldehyde resin. The microcapsule thus developed was blended along with nanosized silicon nitride in LDPE and HDPE. The microcapsules resulted in enhancing the fire-retardant properties.

Environment and Health Area

The projects sites under Environment and Health have been spread across the country, from the coastline of Andhra Pradesh to the floodplains of Yamuna. They study the population for risk assessments varies from bustling mega-cities to quiet hamlets. They have successfully assessed human exposures to toxins such as $PM_{2.5}$ and phthalates.

Continued efforts are designed towards showcasing hotspots, 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. They strive to build resilience of population health through context-specific interventions by influencing a variety of pathways, be it pollution related, weather linked, or nutrition associated.

They are developing digital platforms to showcase the diversity in exposures, evidence of health effects, to sensitize people and policymakers, thereby, promoting collective thinking and generate action. They bring together departments and ministries that can make a change to better both practices and policies across sectors. They frequently join hands with institutions nationally and globally to enhance capabilities and understanding to reduce harm to health.



» FTIR spectrograph of MF, APP, PPTA, and microencapsulated (APP+PPTA) in MF

» Char formation of neat HDPE and nanocomposites

» Preparation of light-cured composite paste

» Light-cured samples

Other Information

NAMA is a mechanism under UN Framework Convention on Climate Change (UNFCCC), under which developing countries could seek technical and financial support for GHG mitigation. The Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU), Germany is supporting the project on 'Development and Management of NAMA in India' with lead executing agency Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India. The Phase 2 of the waste NAMA focuses on implementation of low-carbon measures to reduce emissions from the solid waste sector in Panaji and Varanasi. The project will look at the implementation of relevant waste management practices such as effective source segregation and establishment or strengthening of existing Material Recovery Facility (MRF), which could house processes like micro-composting and biomethanation among other waste-processing measures. The project would also explore possibilities of implementing technologies such as composting, anaerobic digestion, co-

processing of MSW-based RDF in cement kilns, and other feasible technological options. The objective is to reduce the amount of waste landfills under precarious conditions, which would reduce the levels of GHG emission from the sector.

Tetra Pak-used Beverage Cartons Management Study

Recycling is one of the four Rs (Refuse, Reduce, Reuse, and Recycle) that contribute to sustainable development while protecting the environment. Materials that can be recycled such as paper, plastic, rubber, fabrics, some metals, etc., can be reused in another form thus reducing the amount of waste generation. Beverage cartons that are used in various industries such as food, beverage, medicine, can also be recycled as they are paper-based product composed of 75% paperboard, 4% aluminium, and 21% polymers.

Tetra Pak, a multinational food processing and packaging company, manufactures and packages cartons that are used widely around the world for packaging various food and beverage items such as ice cream, soups, juice, milk, cheese, bread. Tetra Pak voluntarily has been involved in programmes that create awareness amongst various stakeholders to increase the activity of recycling of UBCs in India and, therefore, reducing the pollution.

TERI has been conducting studies funded by Tetra Pak to know the status of UBCs in India and to understand the factors that restrict the scope of recycling of UBCs in various cities. Previously, TERI submitted the project report for the study that was conducted in 2011 and 2015, and this is the third time TERI was engaged to conduct such a study, although with a wider scope in 2019, covering 20 cities of India and the capitals of Sri Lanka, Nepal, and Bangladesh. With an objective to explore the perceptions of stakeholders like waste generators and waste collectors on UBC management and an assessment of quantity of UBCs getting collected for recycling with mixed waste paper through small-and large-scale scrap dealers, the sole purpose of this study is to identify the recycling rates of UBCs and mechanisms that can enhance further recycling of UBCs and make the products more sustainable.

The study conducted by TERI will help not only to achieve the sustainable goal of managing the UBCs but also Tetra Pak to increase the recycling rate of the UBCs by understanding the shortcomings of the system.

Independent Audits for Waste Management Across East Delhi Municipal Corporation

With an objective of finding the insufficiency in management and collection system of solid waste, a third party audit was conducted by TERI in mid-2018. This study, supported by East Delhi Municipal Corporation (EDMC), involved interactions on ground with various stakeholders including residents, institutions, markets, street sweepers, waste collectors, sanitary inspectors, waste transporters, etc., to understand waste management mechanism in selected colonies. The sample size was

» Team interacting with Municipal Council Waste Collector in Colombo, Sri Lanka

» Team visiting dump site in Kathmandu, Nepal

» Coloured polybags used by hotels to segregate their dry waste

» Centralized composting site at LIC, Patto, Panaji

selected to keep the confidence level as >90% and acceptable margin of error as 10%. This study helped EDMC to understand the areas that needed improvements and strict monitoring and helped EDMC better implement the solid waste management systems.

Auditing Mechanical Road Sweeping Machines in North MCD

TERI has been auditing mechanized road sweeping operations for North Delhi Municipal Corporation (NDMC) and South Delhi Municipal Corporation (SDMC) as a third-party to identify the areas for improvements in such operations and enhance the effectiveness of these machines. This was supported by SDMC and NDMC. With the audits of TERI, SDMC and NDMC were able to increase their throughputs substantially. These audits also helped the corporations in waste minimization, resource optimization and also made municipalities aware of environmental records and regulatory compliance.

Social Impact Assessment – 3WAYSTE, Bengaluru

Karnataka government approved the 3WAYSTE-mixed Municipal Solid Waste (MSW) Waste-to-Energy (WtE) processing plant in the Chikkanagamangala facility, South Bengaluru, to process MSW to produce: refuse-derived fuel (RDF) for electricity, compost for agriculture, and raw materials for recycling/

» TERI auditor along with the audited truck

» Interview conducted with Mr Bijendar (SI of Mayur Vihar Phase 1 ward)

reuse industry. The Centre for Waste Management Area at TERI conducted the Social Impact Assessment (SIA) for the proposed 3WAYSTE MSW-processing plant. The study identified economic implications of setting up the plant and MSW management on existing service providers, the informal sector, and the residents; occupational and environmental health and safety implications on workers and residents nearby; potential of WtE to discourage source segregation; managerial impacts including efficiency of technology, benefits from by-products, equitable implication through employment of informal sector and rag pickers; odour and NIMBY concerns related to water, soil, and noise pollution. The

» Photograph captured during audit with GPS map camera

» Interview in progress

study suggested mitigation measures including incorporating the informal sector, their capacity building, increasing awareness, transparency, and clarity on institutional arrangement of 3WAYSTE plant for stakeholders.

Strategy for Fostering Resource Efficiency and Circular Economy in Goa

The overall objective of the preparation of this strategy is to mainstream (material) resource efficiency (RE) and circular economy (CE) in the priority sectors in Goa. This will also enable the state's convergence with India's resource efficiency strategy and help in meeting the SDGs. Enhanced resource efficiency across life cycle stages[13] coupled with re-use of secondary raw materials has the potential to further augment the resource base and foster development of the state. The best practices showcased through the implementation of measures will make Goa a leader in fostering RE&CE at the sub-national level in India and encourage other states of the country to move on a similar path.

Does the air quality from the crop residue burning in close proximity to residential areas adversely affect respiratory health?

Crop residue burning (CRB) is a recurring problem, especially during the months

[13] Life cycle stages of any product are: extraction/mining, design, manufacturing/production, consumption, and end-of-life

» Sample of the residents interviewed as part of the SIA

» Health data collection for respiratory health assessment in Patiala, Punjab

of October–November, in the north-western regions (Punjab, Haryana, and western Uttar Pradesh) of India. In this regard, TERI has undertaken an environmental health study with the necessary support from CPCB to understand and quantify the association of air quality ($PM_{2.5}$) and the respiratory health of community exposed to air pollution from CRB in the study villages of Patiala district in Punjab. Under this study, we have conducted air quality monitoring, surveyed the study population for exposure factors and self-reported health symptoms, assessed respiratory health using spirometry, a standard procedure used to perform lung function tests (LFTs), and to diagnose asthma, chronic obstructive pulmonary disease (COPD), and related conditions during crop-burning and non-burning phases of the study. It is still an ongoing study and we envisage that our study would build evidence of health benefits to the farming community from use of intervention(s) to eliminate crop residue burning. Such evidence would help support policy level intervention(s) in the state and are likely to result in improving air quality in the neighbouring states.

Study to Test, Operationalize Preventive Approaches for Chronic Kidney Disease of Uncertain Etiology in Andhra Pradesh

As part of a 3-year project to study, understand, and prevent the incidence of Chronic Kidney Disease of Unknown (CKDu) origin in Andhra Pradesh, the TERI team examines the Uddanam region in Srikakulam district of the state; the core purpose is to identify environmental factors contributing to the high prevalence of CKDu amongst the population.

The team studies the groundwater, major agriculture produce, sea food, and soil, to determine levels of several toxic contaminants, such as heavy metals, phthalates, and pesticides. Heavy metals, such as lead and chromium VI are known to trigger adverse effects on the kidneys.

The project has been initiated by the Government of Andhra Pradesh under the guidance of the Indian Council of Medical Research.

Water Resources Division

India is facing water crisis and it is increasing because of growing population, escalating demands, overexploitation, inefficient use, and pollution amongst others. With an aim to develop and implement integrated

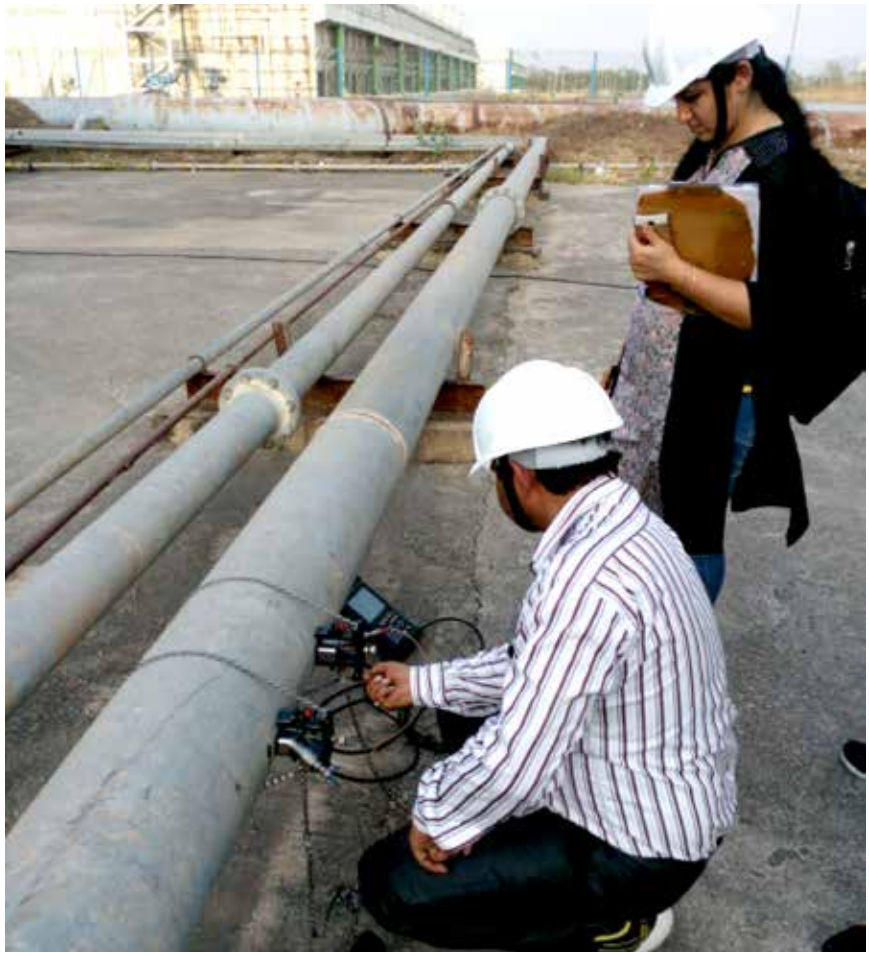
» Crop burning episodes observed during the study in Patiala region of Punjab

solutions for sustainable water management, the Water Resources Division provides services in core areas such as applied research, training, and implementation. The Division has core competencies in quantitative and qualitative assessment of water resources, water audit and water footprinting, water conservation, watershed management, urban water demand management, agriculture water-use efficiency, glacier research, hydrological assessments, rural water supply and sanitation sector, water quality and pollution studies, and policy analysis. The Division has also assisted the corporates in implementing safe water and sanitation interventions and in-pond water rejuvenation.

The group also works on the important issue of water-energy nexus, and drought mitigation. The Division has been actively involved in carrying out various research activities in the high-altitude regions including studies on glaciers and glacier-fed catchments and their impact on downstream community.

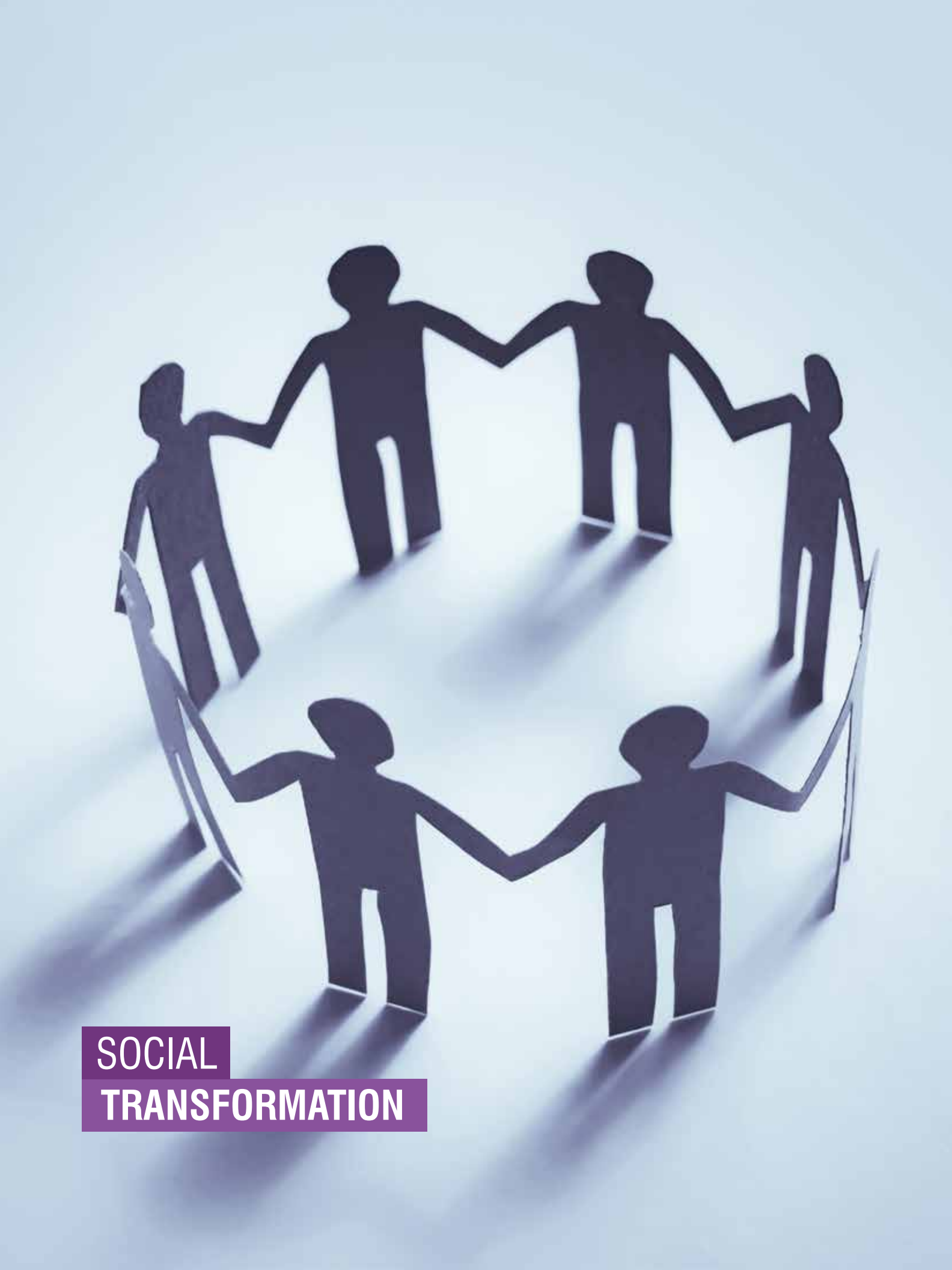
The Division is also a Resource Centre on Water-use Efficiency, jointly hosted by TERI and Jain Irrigation Systems Limited. It has been endorsed as the Regional Knowledge Hub for Water and Climate Change Adaptation by the Asia-Pacific Water Forum.

With a multi-disciplinary team of experts, the Division has been instrumental in providing research-based innovative solutions for sustainable water management as well as policy inputs to assist the goals of the government and SDGs.



The Division also hosted its flagship event, the 4th India Water Forum on the theme of Water for All: Options for Safe, Sustainable and Resilient Future. The 2-day summit was inaugurated by Dr Amarjit Singh, Former Secretary, Ministry of Water Resources RD & GR, Government of India. TERI also signed MoU with WAPCOS Limited to work together on areas of mutual interest. The Division also released a booklet on its work titled *Water Resources Division–Facilitating Water for All*. Valedictory session was presided by Ms Francine Pickup Resident Representative a.i. of UNDP in India. To facilitate the achievement of SDG on water among various stakeholders by way of reducing their water footprints and promoting the adoption of 'water neutrality' approach, water division also initiated the 'Water Sustainability Awards' by launching it during the 4th India Water Forum. Awards will be conferred under various categories evaluated by an experienced jury.

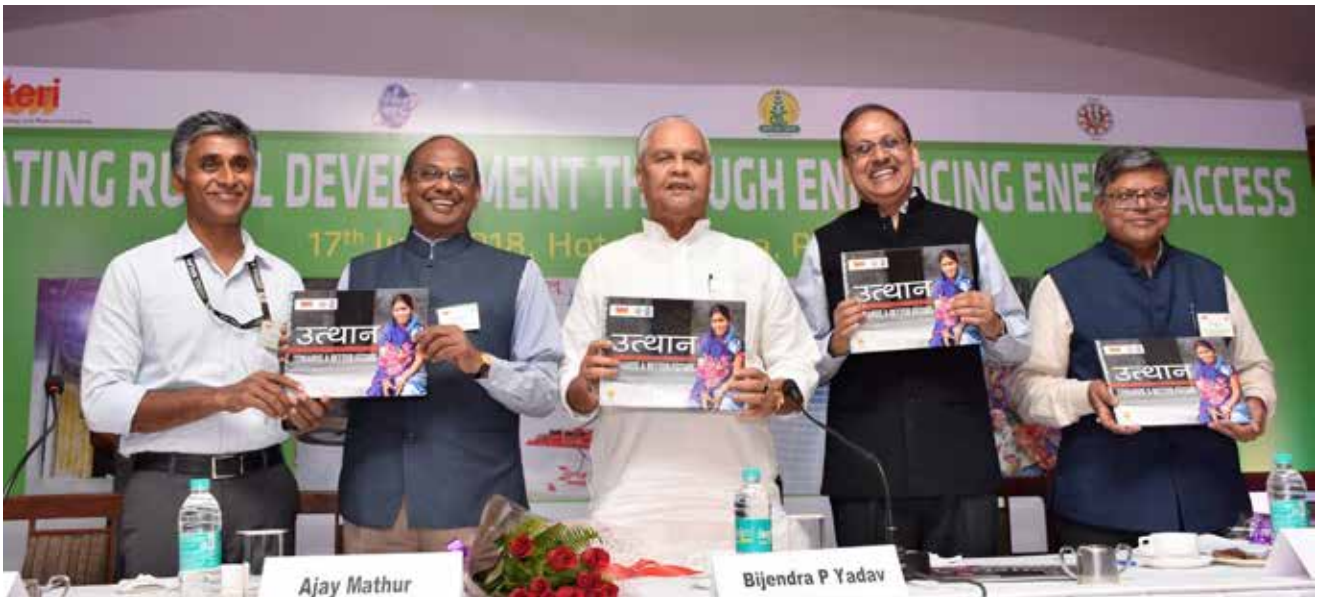
» Paddy sample collection for heavy metal analysis in Andhra Pradesh


SOCIAL
TRANSFORMATION

The Rural Energy and Livelihoods Division of TERI's Social Transformation (ST) Programme focuses on utilizing universal access to sustainable, affordable, reliable, and modern energy as a tool to spur socio-economic development of communities in a gender and socially inclusive manner, keeping SDG 7 as the fulcrum. It works closely with the rural communities on aspects such as use of renewable energy, energy-led livelihoods, enhancement and women empowerment, and efficient utilization of natural resources. In the backdrop of rapid developments in the Indian energy scenario in recent years, the Division is also working on challenges related to reliability and last-mile accessibility of energy supply. Innovations in technological solutions as well as business models, partnerships, and knowledge generation are the cornerstones of its action- and research-based approach.

The Social Transformation Programme's strength lies in developing and nurturing partnerships with grassroots institutions and in its ability of working bottoms-up through extensive stakeholder engagement. It leverages judicious blend of multi-disciplinarity and decades of hands-on implementation experiences ranging from appropriate technologies to markets, policies, and capacity building. Over the years, the group has developed a deep understanding of field-level challenges including consumer behaviour, entrepreneurship development, establishing value chain, and financing at different levels. Its multi-dimensional approach tries to converge evidence-based research with technological, socio-cultural, and economic aspects of the universal energy access.

Under its flagship campaign—'Lighting a Billion Lives' (LaBL), increasingly the efforts are being focused on how can clean energy be used as an 'enabler' for meeting fundamental developmental needs such as health, education, livelihoods, and rural empowerment. This essentially also means leveraging SDG 7 for achieving several other SDGs. Thus, on the one hand, there are solutions like solar-grid hybrid looms and advanced electric outboard motor with solar-charged lithium-ion batteries for boats along with battery-swapping and central solar charging stations in Varanasi. As a result, now, the weavers not only earn about 40%–50% more, they also enjoy a better social life. And, the 'Uttam Urja' boats do not create any pollution, foul air, or noise. On the other hand are initiatives such as provisioning of solar energy infrastructure for reliable energy supply in remote schools and tribal hostels in Jharkhand, enabling better education and living conditions for the children. In Assam, there are solar pump interventions in schools to facilitate effective sanitation and solar streetlight initiatives in remote villages that have heralded a spirit of independence and community bonding even after nightfall. To ensure the sustainability of interventions, LaBL has pioneered the energy entrepreneur model. Over the last more than a decade, energy entrepreneurship—village-level entrepreneurs and cluster-level energy entrepreneurs—is being promoted for both, providing clean energy services as well as sales, service, and awareness generation for lighting and cooking energy in the rural areas. The ST Programme aims to enlarge its global footprint in provisioning of sustainable energy for inclusive development of rural communities and enterprises; besides being a knowledge repository in this field.



Centres for Impact Evaluation and Energy Access

The Centres for Impact Evaluation and Energy Access (CIEEA) in Delhi and Bengaluru have been working closely with communities, government departments, and other key stakeholders on overarching issues related to energy, gender, livelihoods, watershed development, and efficient fuel utilization. The mechanisms of facilitating these include undertaking research and analysis, impact evaluation, need assessment, market studies, and socio-economic surveys.

CIEEA, Delhi, for instance, worked on a variety of research areas encompassing energy access, clean cooking, gender inclusion, replacement of fossil fuel subsidies, health impacts of indoor air pollution, and ways and means to propagate solar pumping amongst others. In 2018/19, it also started working closely with farmer community and utility to develop specific understanding of energy–water–food nexus through the implementation of an incentive-based government scheme in Punjab. Its key clients include DFID, the World Bank, IISD, GIZ, and ENERGIA.

In 2018/19, CIEEA, Bengaluru focused on the monitoring, evaluation, learning, and documentation of the World Bank-assisted Karnataka Watershed Development Project-II (Sujala-3). Implemented by the Watershed Development Department, the work spans 9 districts covering an area of around 46,640 ha. In addition, CIEEA, Bengaluru also completed a rapid assessment of the horticulture component under the same project, which is being implemented by the Department of Horticulture. A project supported by the Department of Science and Technology, which aimed to improve sustainable energy access amongst SC/ST households in Chamarajanagar district in Karnataka, was completed during that year. This project led to several positive outcomes such as improved indoor air quality, access to cleaner light, and

reduced fuel consumption for cooking and lighting as a result of disseminating improved cookstoves and integrated solar domestic energy system to over 425 households. Its impacts include savings to the tune of 43% and 40% in fuelwood consumption and monthly electricity bills, respectively.

Centre for Rural Action

The Centre for Rural Action (CfRA) area brings together the latest in techno-socio-institutional knowledge, to deliver locally appropriate solutions that address energy needs of underserved communities. Over the last few years, the area has worked extensively in the field of 'energy access' to accomplish TERI's commitment towards enabling affordable and sustainable energy services through interventions that address consumptive and productive energy requirements at the household and micro-enterprise levels, specifically in rural, remote, and peri-urban areas. With 'energy access' as its pivotal theme, the area is engaged at two levels. The first one is to ensure that affordable and reliable clean energy solutions, for lighting and cooking, reach rural households. This has been driven through the development and implementation of innovative, responsive, and replicable technologies and delivery models; and through establishing partnerships and collaborations at the grassroots. The area leads LaBL that aims at provisioning of bouquets of bespoke and reliable technology solutions for households and small enterprises alike. LaBL has completed 11 years of operations in March 2019 and it has impacted 5.5 million lives across 23 states in India and 12 countries in Africa and South Asia. In the case of clean cooking solutions, the area has worked towards customizing forced-draft cooking technology to improve quality and to suit consumer preferences. It has resulted in the development of more than 11 variants of forced-draft cookstoves, varying in complexity and costs and dissemination of around 1 lakh cookstoves in different states so far.

The second level of the area's work pertains to weaving 'energy' as a contributor towards other associated aspects of rural development. Going forward, the area is geared up to expand its scope in developing and delivering innovative and integrated solutions, focusing on clean energy and resource-use efficiency with an emphasis on replicable interventions that support rural livelihoods, micro- and small enterprise, and sustainable management of natural resources in a climate-resilient manner.


SUSTAINABLE
AGRICULTURE

The concern for food security is increasing rapidly. With recent projections of global population revised to 10 billion by 2050, the pertinent question that arises is: how do we feed these numbers without degrading the environment further? Sustainable agriculture and efficient land utilization holds the key. Through advanced research, education, societal engagement, small farmer entrepreneurship, transfer of finished products and technologies to industries and stakeholders for wider reach, the Sustainable Agriculture Division of TERI has a vision to identify and develop new ways to farm profitably while conserving natural resources. The Division's initiatives include achieving sustainability in agricultural practices, mitigating environment-related problems such as toxic chemicals and wastes, innovating solutions for cleaner and greener energy, safe natural products to ensure human health, policy research, and cross-cutting research that bridges all areas (water, energy, soil, solid waste, crop productivity, environment, and alternative farming systems).

The Division comprises three areas, each specializing in diverse but related fields with the mission to create innovative and green solutions for the challenges and pressing problems being faced in the field of agriculture, environment, and bioenergy. In view of the stark reality of increasing demand for food production, food security, and nutrient deficiency, mycorrhizae will in the future play a key role owing to its contribution to the plant apropos to all major and micronutrition in agriculture. Mycorrhizae, with its mutualistic, symbiotic association, is of great relevance and significance to problems such as nutrient deficiency, particularly in marginal lands. The Centre for Mycorrhizal Research (CMR) has successfully translated the nutrient-tapping potential of mycorrhizae and developed a technology that eventually produces mycorrhizae-based biofertilizer. The activities of the CMR focus on increasing the productivity and productive capacity of all types of land (including degraded lands) using cost-effective, eco-friendly mycorrhizal fungi. The Nanobiotechnology Centre is using pioneering technologies and solutions to achieve sustainability in agriculture through nanotechnology and next-generation genomics interventions. The Centre has been making significant strides in developing nanofertilizers, nanopesticides, and precision delivery carriers and formulations. Keeping in mind deteriorating soil health, growing demand of food, and water safety as the biggest challenges, the Centre is uniquely poised to develop pathbreaking technologies using biologicals interwoven with nanotechnologies and biocompatible materials. The Community Farming and Livelihood Area is dedicated to providing innovative yet simple technological solutions to marginal farming communities in many parts of our country. The area works on production of quality planting material through micropropagation at the Micropropagation Technology Park situated at the TERI Gram campus. Also, the area is working on enhancement of livelihoods of hill farmers in Uttarakhand through sustainable agricultural practices and technologies. The emphasis is on enhancing land- and water-use efficiency by choosing the right crops and then developing value chains, eventually leading to providing market access. Supi Sugandh is the culmination of TERI's efforts in this direction of achieving livelihood security of small and marginal agrarian communities.

Agriculture, Farming, and Bio-inputs

Agriculture holds the key to the overall development of a country's economy. Keeping in mind that improving soil health, food, and water safety and crop productivity are the biggest challenges in sustainable agriculture, the Division is uniquely poised to develop pioneering technologies and solutions using microbial systems, bio-fertilizers, bio-pesticides, genetic improvement, crop diversification, bioinformatics, nanotechnologies, and biocompatible materials. It offers cross-sectoral, technology-based solutions that are to be implemented in an integrated manner for achieving equitable yet sustainable goals.

CRISPR-mediated High-throughput Genome Editing Tools in *Brassica napus* L.

India's domestic edible oil demand is substantially dependent on import. Rapeseed-mustard (*Brassica* spp.) is the second most important edible oilseed of our country. Rapeseed (*Brassica napus* L., 2n = 38, AACC) is one of the major oilseed crops for edible oil and renewable energy source worldwide. The current project aims at developing high-throughput molecular and genetic tools for *B. napus* agronomic trait improvement using CRISPR-Cas9-mediated genome editing. During 2018/19, optimization of tissue-culture regeneration protocol for *B. napus* was achieved. Computational designing of CRISPR library was done. The library consists of more than 1000 gRNAs (guide RNAs) targets aimed at improving various important agronomic traits, such as enhancing nutraceutical properties, seed traits, reducing flowering time, and improving abiotic and biotic stresses.

Genetic Enhancement of Rice for Nitrogen Fixation and Higher Yields

Nitrogen is a critical nutrient for crop production. World agriculture heavily relies on synthetic nitrogen fertilizers to enhance crop yields to meet food requirements of ever increasing human population. Among all life forms on earth, only a few bacteria are endowed with the ability to synthesize their own nitrogen fertilizer, that too under ambient environmental conditions. Developing a self-fertilizing nitrogen-fixing cereal crops such as rice, maize, and wheat is a long-cherished goal. TERI embarked on a project of converting

rice into a nitrogen-fixing crop through transferring selected nitrogen fixation (nif) genes from bacteria to rice. During 2018/19, TERI developed six different types of transgenic rice plants carrying various combinations of nif genes. Presently, work is in progress to characterize transgenic rice plants, and pyramiding all nif genes into a single-transgenic line for evaluating their ability to convert atmospheric nitrogen gas into nitrogen fertilizer.

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

The project aims to develop technology for highly efficacious nitrogenous fertilizer using the tailor-made mesoporous nanozeolite carrier that can enable the slow release and targeted delivery of nitrogen. During

2018/19, nanozeolite variants have been synthesized and characterized for properties such as optical, zeta potential, hydrodynamic size, structural/morphological, and elemental. 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), two variants were found to be promising for the development of control release fertilizer of nitrogen, phosphorus, and potassium (NPK) nutrients. These nanozeolite carriers will be utilized for the development of next-generation smart and controlled and slow-release specialty fertilizers.

Development of Cost-effective and Eco-friendly Technologies for Food Preservation and Bioremediation

The projects aim to develop water-based formulations from silk proteins for food preservation and nanostructures for environmental applications. During 2018/19, a silk protein-based composite formulation tested on fruit and vegetable peels for adhesion study has shown positive results in terms of retention of surface coating. Silk protein alone and in combination with pollutant degrading enzyme(s) have been found to form nanoflowers and preliminary results on the applicative potentials of these enzyme-loaded nanoflowers for degradation of pharmaceutically active compounds and adsorption of heavy metals (e.g., Pb^{2+} and Cd^{2+}) are encouraging. Further studies are going on for optimization of the process and application parameters.

QTLs for Leaf Curl Virus Resistance in Chilli

Leaf curl virus disease starts appearing by curling and yellowing of the leaves and subsequently leads to stunted and bushy plants with very less or no fruiting. To overcome the disease, the project has used natural resistance source found in the wild chilli accession and developed

» Promising chilli lines in advance generation having resistance against pepper leaf curl virus disease

a mapping population by crossing it to the high yielding chilli cultivar. Identification of loci controlling this trait is important to develop leaf curl-resistant high-yielding varieties for the farmers of India. During 2018/19, analysis of the results from two growth seasons identified five stable quantitative trait locus (QTLs) for pepper leaf curl virus resistance that collectively explained 55% of the total phenotypic variation. The genomic regions of all stable QTLs identified in this study may serve as potential target regions for fine mapping and development of molecular markers for PepLCV resistance breeding.

QTLs for Heat Tolerance in Tomato

Heat stress is a major limiting factor in tomato production. In tropical and subtropical regions of India where temperature can easily reach above 40°C or higher, reproduction, yield and quality of tomato are adversely affected. Identification of QTLs associated with heat stress in tomato would enable breeding of productive varieties for growing under high-temperature conditions. This would in turn increase the availability of fresh produce for a wider window during the year, specifically in regions facing high-summer temperature. The current study aimed at mapping and identification of molecular markers linked to the quantitative trait loci, which are responsible for heat tolerance in tomato. During 2018/19, tomato-breeding experiments were performed between heat-tolerant genotypes. JBT-02 was used as male parent whereas heat sensitive genotype Pusa Rohini was used as the female parent. F1 lines were selfed to get F2 population and a total of 158 F2 lines were sown and transplanted in the field. 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 all individuals of F2 population. Much variations were found among F2 population. F2 population further advanced to F3 population in off season. Currently, F4 population is in the field and will be used for genotyping by sequencing (GBS)-based sequencing and QTLs mapping.

Germplasm Collection and Genetic Diversity Assessment of Kadaknath: An Indigenous Poultry Breed of Jhabua, Madhya Pradesh

Kadaknath is an indigenous poultry breed, native to Jhabua district of western Madhya Pradesh. It is the only black meat chicken (BMC) breed of India and one of the three BMCs in the world. Its black flesh is not only considered a delicacy of distinctive taste but also known for medicinal values. Kadaknath meat is higher in protein and lower in fat content as compared

to other breeds of chicken. The major problem in Kadaknath is its shrinking base population and lowering of genetic diversity, which may lead to its loss of germplasm. Considering these issues, it is important to capture the maximum genetic diversity in Kadaknath to conserve and make this breed sustainable in stressed environments, especially under the current regime of climate change. During 2018/19, germplasm collection survey was conducted throughout all blocks of Jhabua and Alirajpur districts of Madhya Pradesh, and a total of 205 birds were collected. All sampled birds are being maintained at College of Veterinary, Mhow. During different growth stages economically important phenotypic data such as body weight, sex of birds, type of variety were collected. Genomic DNA was isolated from all living birds and GBS was performed for genetic diversity assessment and its conservation.

Unravelling the Potential of Microbes and Microbial Interactions with Relevance to Agriculture

In the previous work, TERI successfully unravelled crosstalk between plant growth regulators—nitric oxide and indole acetic acid—produced by the plant growth-promoting bacterium *Azospirillum brasilense*. In 2018/19, using *in silico,* bioinformatics analysis of high-throughput sequencing data, TERI team identified ~468 small, non-coding RNAs from this bacterium of which ~50 small RNAs are differentially expressed in nutrient stress and are likely to be involved in plant–microbe interactions and improving host plant productivity.

Development of Molecular Tools for Detecting *Arbuscular Mycorrhizal* Fungi

Development of molecular markers for specific identification of isolates of *Arbuscular mycorrhizal* (AM) fungi has remained a challenge due to low interspecies variation in highly conserved rDNA genes, which otherwise serve as a universal marker for other fungal lineages. Investigation on seven functionally relevant phosphate transporter genes was carried out for the presence of SNP and ins/del polymorphisms in 10 isolates of *Rhizophagus irregularis.* Specific combinations of genetic variations were identified, which could sub-group the 10 isolates into 3 molecular haplotypes. Noticeably, the isolates bearing any of the three haplotypes could be conveniently detected in consortia samples. The significance of the research is in identifying the molecular markers for specific detection of isolates of AM fungi that are used in commercial biofertilizer products. In future, these findings may have a broader impact in genetic tagging of AM fungi species of commercial interest.

Identification of AMF Effectome and Concomitant Target Proteins

AM fungi show high promiscuity in terms of host. Effector proteins expressed by AM fungi are found important in establishing interaction with host. However, the mechanistic underlying host-specific interactions of the fungi remain unknown. In the study, TERI aimed to: (i) identify effectors encoded by *Rhizophagus proliferus* and (ii) understand molecular specificity encoded in effectors for interaction with specific plant species. The effectors predicted from the whole genome sequence were annotated by homology search in NCBI non-redundant protein, Interproscan, and pathogen–host interaction databases. In total, 416 small secreted peptides were predicted, which were effector peptides with the presence of nuclear localization signal, small cysteine-rich, and repeat-containing protein domains. Similar to the functionally validated SP7 effectors in *Rhizophagus irregularis*, two proteins (RP8598 and RP23081) were identified in *R. proliferus*. To understand whether interaction between SP7 and the plant target protein, ERF19, is specific in nature, we examined protein–peptide interaction using *in silico* molecular docking. Pairwise interaction of RP8598 and RP23081 with the ethylene-responsive factors (ERF19) coded by five different plant species (*Lotus japonicus*, *Solanum lycopersicum*, *Ocimum tenuiflorum*, *Medicago truncatula*, and *Diospyros kaki*) was investigated. Prediction of high-quality interaction of SP7 effector with ERF19 protein expressed only by specific plant species was observed in *in silico* molecular docking, which may reiterate the role of effectors in host specificity. The outcomes from the study indicated that sequence precision encoded in the effector peptides of AM fungi and immunomodulatory proteins of host may regulate host specificity in these fungi.

In Silico Characterization of Biomacromolecules, and Small Organic and Inorganic Compounds

Understanding the molecular mechanisms of biotic and abiotic stresses in plant plays a pivotal role in developing new chemo-types, which may support the plant to survive in adverse conditions. Under abiotic stress such as drought and salinity, a plant hormone called abscisic acid (ABA) binds to ABA receptor(s), which initiates a series of intracellular signalling and subsequently activates, the downstream effectors in order to support the plant to survive in stressed environment. Here, ABA mimics that perturb ABA signalling can be used for agronomic management of water-use efficiency, drought tolerance, and salinity in plants. During 2018/19, TERI has developed the 3D structure models of three ABA receptors (ABARs) cloned from a drought-tolerant indica rice variety N22. The dock and molecular dynamics (MD) study, using these models, unravelled critical ligand-binding features of these ABARs for the future development of specific agonists/antagonists to modulate the ABA signal transduction. These structure models could serve

as *in silico* tools to identify new leads for the development of potent ABARs modulators for diverse agricultural application such as ameliorating drought tolerance, regulating seed germination, seed priming for better root elongation in rice and other crops.

High-quality superior tissue culture plants

The Micropropagation Technology Park, a state-of-the-art facility established at Gual Pahari almost three decades back with the generous support from 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 2018/19, 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. TRISHA's initiatives have helped the local farmers to look beyond their conventional farming system and bring about successful diversification of crops. The farmers of the area have been able to overcome the adverse impact of climate change by adopting cultivation of medicinal and aromatic herbs, spices, millets, and pulse crops that require less input of water as well as have an assured source of income round the year. It has also helped them in developing village-based microenterprise capability for improving their economic gains. During 2018/19, TERI built low-cost water harvesting systems in four army schools in Rajouri and Poonch districts in Jammu and Kashmir for miscellaneous needs of the students and the school. Additionally, these systems were installed in a remote army unit near the border which will be very useful in meeting the non-potable needs of the soldiers such as bathing and washing. Two such units were also installed at the posts of the Border Security Force.

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

Nanomaterial-based enzyme—immobilizaeon—is emerging as a promising technique for enzyme stability and reusability. The main hurdle for commercialization is high-enzyme cost; however, immobilization can dramatically reduce the cost, increase the catalytic efficiency, and solve the problems related to downstream processing. It is in this backdrop that the project envisions to develop a nano-immobilized enzyme-based system to hydrolyse lipids for efficient enrichment of omega-3 fatty acids from the renewable microalgal bioresources. During 2018/19, different nanomaterial variants were synthesized using different approaches and characterized the structural, morphological, and elemental. The synthesized nanomaterial variants are being used for the development of nano-enabled lipase system, and nano-enabled lipase system would be useful for cost-effective production of omega 3-fatty acid through concentration from polyunsaturated fatty acids.

Bioactivity-guided Isolation and Identification of Novel Secondary Metabolites from Indigenous Bioresources

Bioactive secondary metabolites from natural origin have tremendous potential for their use in food, pharmaceutical, and cosmetics industries due to their useful biological properties such as antioxidant, anticancer, and antifungal activities. Among the various alternatives of natural origin, the research focuses majorly on three indigenous bioresources such as endophytic fungi, microalgae, and lichens as a potential resource for the bioactive molecules. The research programme addresses aspects of discovery, isolation, and identification of metabolites with potential as nutritional/functional food agents and phytomedicines. The overarching aim of the research is to isolate active metabolites from the bioresources for food and other related applications. Another target is to increase the potency and physical properties of the identified active compounds through nanointerventions. A phytochemical screening of the extracts based on

standard protocols and its relation with the biological activities has been established.

Evaluation and Validation of Anti-cancer Metabolites

The natural products, either as pure compounds or as standardized extracts, provide unlimited opportunities for the development of novel drugs because of the great diversity in their chemical structures. Studies by different research groups have established lichen metabolites as potential candidate for anti-cancerous agent. However, a limited number of compounds have been studied so far and there is an inadequate understanding of the underlying molecular mechanisms. Still, there is a lack of research evidence to evaluate and validate the anti-cancerous potential of lichen metabolites. Thus, the present work has been undertaken to isolate and identify novel and efficient lichen-based anti-cancer agents and development of a soluble and safer biodegradable polymeric nanoformulation, comprising therapeutically active lichen metabolite. The group has developed an extraction methodology for the extraction of bioactive polyphenolic compounds. Besides that, we have also isolated a few active metabolites from sample collected from Trans-Himalayan region, which will be then taken forward for the development of a biodegradable polymeric nanoformulation.

Genomics and Next-generation Genetic Engineering Technologies for Value Addition

The proposed approach is based on the promise of modern genetic engineering technology for the production of biopharmaceuticals, proteins, high-value nutraceuticals, and flavours. For instance, this project aims to introduce and express Laz—a lipid-modified azurin protein—encoding gene from *Neisseria meningitides* in tomato fruits via chloroplast and *Agrobacterium*-mediated nuclear transformation. Azurin is a redox protein that preferentially penetrates human cancer cells and exerts cytostatic and apoptotic effects by binding to p53—a tumour suppression protein. Similarly, industrial application of plant cell suspension culture systems for sustainable production of pharmaceuticals, nutraceuticals, cosmeceuticals, and high-value chemicals is gaining considerable attention. A rice cell suspension culture system is a powerful platform to produce these high-value compounds. During 2018/19, transgenic tomato plants overexpressing Laz peptide has been developed, chloroplast transformation technology established in tomato using pRB96 empty vector control, and rice cell suspension culture system have been established.

Environment

Development of Sludge-free, Clean, Green and Cost-effective Technology for Wastewater Treatment

This technology development platform is created to encourage the role of nanotechnology in water and wastewater treatment. The work involves end-to-end treatment of real textile and dyeing industry effluent using Advanced Oxidation Nanotechnology. During 2018/19, TERI filed complete patent towards development of a technology for treatment of industrial wastewater, municipal sewage wastewater, and mixed streams containing high colour, dissolved organics, non-biodegradable, and persistent organic pollutants. The technology has been successfully tested at a small pilot for adequately treating sewage and industrial effluents of highly polluting industries like textile and dyeing, chemical and pharmaceutical industries. Technology is ready to be undertaken for feasibility studies and pilot installations at commercial level.

Green Belt Development on Industrial Dumps

TERI is promoting cost-effective, environment-friendly alternatives for higher plant productivity in marginal lands, unproductive lands as well as in the reclamation of wide categories of wastelands and industry-created wastes. TERI uses the beneficial group of microorganisms, known as mycorrhizal fungi, which forms association with the roots of higher plants and has established its worth globally and has developed many other technologies involving mycorrhiza in the reclamation of industrial wastelands, namely fly ash overburdens, alkali chlor-laden sites, distillery effluent discharge sites, phosphogypsum ponds, and coal mines. During 2018/19, TERI carried out maintenance of a green belt, covering an area of 20 acres on chlor-alkali waste. The new project has also been initiated for the reclamation of jarofix waste at lead–zinc smelter at Rajasthan. This project will demonstrate a mechanism to carry out effective reclamation of jarofix dumps in 23 hectares and establishment of green cover that could trap various benefits and improve the local environment.

Energy

Algae Biofuels and Commodities for Renewable Fuel Production

Microalgae are one of the promising options for renewable fuel production in future. To realize viable production scenario, value-addition commodities must also be co-produced from algae along with biofuel lipids. The long-term vision is widespread deployment of algal biofuels and related commodities to curb carbon emissions and reduce crude oil imports. To achieve this, specific areas such as collection of promising

algal strains, improved outdoor growth system, algal harvest, viable lipid recovery method, and nutraceutical co-production have been the focus areas.

During 2018/19, the sunlight distribution-based improved productivity outdoor algal growth system (10,000 L) was tested successfully, employing local mixed culture with dynamic seasonal composition. The efficiency of lipid recovery from wet algae (avoiding the need for energy-intensive drying) was improved from 80% to 100% at lab scale. An integrated production process based on a 100,000 L marine algal production system (Mumbai) in combination with development of value-addition co-products (animal feed, nutraceuticals, platform chemicals, bioplastics) is being set up.

Outreach

NanoforAgri 2018

TERI–Deakin Nanobiotechnology Centre (TDNBC), in partnership with SERB organized the 2nd International Conference on Nanobiotechnology for Agriculture: Detection, Conservation and Responsible Use of Natural Resources on December 13–14 2018 at National Institute of Solar Energy and TERI Gram, Gurugram.

The conference highlighted the message of how nano-enabled systems will help address contemporary issues in agriculture related to efficient delivery of fertilizers, pesticides and nutrients, post-harvest management and catalysis as well as diagnostic methods. It also highlighted why studies on the fate and prevalence of nanomaterials in soil, the current strategies, and the need for development of life cycle assessment pipelines and toxicity data for these nanomaterials are important.

It offered a dynamic, an international, an interdisciplinary platform to share knowledge and scientific discussions on nanoscience and nanobiotechnology including advances of the agricultural market. The conference showcased talks

by national and international experts along with budding young researchers in five thematic sessions and mapped knowledge, highlighted the current challenges faced in this sphere, and opportunities that exist for translation/innovation. Discussions focused on the critical and yet unexplored field of environmental fate of engineered and applied nanomaterials, keeping in mind the need to ensure the safety and the success of these new technologies. The participants were benefitted from robust panel discussions where speakers and invited discussants initiated discussions on the thematic sessions. Industry viewpoints were heard in the Stakeholder's Discussion. The conference brought together nearly 130 participants and provided an interactive platform for budding young scientists from research and development institutes, academia, and the industry from across the globe for the purpose of scientific discussion on current practices and future scope of nanotechnologies in the agricultural space.

Disruptive Translational Research Workshop

Celebrating 25 years of engagement in India, Deakin University, Australia in association with TERI and Department of Biotechnology, Government of India organized an international workshop on 'Disruptive Translational Research in Nano-biotechnology: Advancing Sustainable Food Systems and Human Health Solutions' on March 13, 2019 at India Habitat Centre, Lodhi Road, New Delhi. The objectives of the workshop were to highlight new nano-biotechnologies used in agriculture and the food supply chain, environmental science, and health and biomedical research, and provide a platform to discuss and enhance multi-stakeholder partnerships in the advancement of new technologies and their applications. The format of the workshop was consultative where over 100 participation represented large number of principal investigators from Department of Biotechnology (DBT)-supported programmes, significant participation from Indian and multinational industries, giving diverse and most relevant perspective to the workshop. The workshop also had PhD students' participation from across India including 28 PhD students from TDNBC. The startups and members from farmers' association were also present at the event. The workshop was inaugurated by Dr Renu Swarup, Secretary, Department of Biotechnology, Ministry of Science and Technology, Government of India.


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. Establishment of Sustainability Cell at Andhra Pradesh Capital Region Development Authority (APCRDA) to review and advise on the development of upcoming new capital township of Amaravati on sustainability aspects.
2. Established Mahindra–TERI CoE to develop energy-efficient innovative solutions, tailored to the Indian buildings sector and climates.
3. Established the TERI–UTC (United Technologies Corporation) CoE on building energy diagnostics and evaluation for improving energy efficiency in existing buildings.
4. Developing a building material directory tool for the use of efficient building materials in India.
5. 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).
6. GRIHA in partnership with Public Works Department (PWD), Maharashtra, has pushed the agenda to shift towards resource-efficient buildings, both for the new and existing buildings in Maharashtra.

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 system 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 NDCs submitted to UNFCCC. At present, there are more than 2000 projects registered under the GRIHA rating system with a green footprint (built-up area) of 75,000,000 m^2.

The last year saw the signing of a landmark agreement with the PWD, Government of Maharashtra, resulting in the registration of 486 new and existing buildings; of these, 141 buildings have been rated in the state. The agreement also led to the training of more than 500 PWD officials by the GRIHA Council on design, construction, and operation of buildings. It was for the first time since the existence of GRIHA Council, that the 10th GRIHA Summit was co-created with an international academic institute of repute, the University of New South Wales (UNSW), Sydney, Australia. Other premier national and international agencies such as Bureau of Energy Efficiency (BEE) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH also partnered in putting together the GRIHA Summit around the theme 'Fostering Partnerships for Sustainable Habitat'. The Summit platform was leveraged to showcase collaborative research and development between TERI, GRIHA, and UNSW in the built environment cutting across various thematic areas.

» Launch of *GRIHA for CITIES Rating* at 10th GRIHA Summit on December 10, 2018 at Taj Palace, New Delhi by Ms Harindher Sidhu, Australian High Commissioner to India; Mr Abhay Bakre, DG, BEE; Prof. Ian Jacobs, President and Vice Chancellor, UNSW; Dr Ajay Mathur, President, GRIHA Council and DG, TERI; and Mr Sanjay Seth, Chief Executive Officer, GRIHA Council

Sustainable Buildings—Delhi

The Sustainable Buildings—Delhi Group focuses to provide innovative, integrated, and cost-effective solutions to mainstream the principles of sustainability in the buildings sector. The area promotes resource efficiency and optimization in design, construction, operation, maintenance, and demolition of facilities. One of the most important objectives of the area is to create centres of excellence, which aim at stimulating low-carbon development pathways, leading to increased resilience and mitigation potential.

Sustainable Buildings—Delhi Group works with a diverse range of organizations, including nodal ministries/ departments, public sector undertakings, corporates, academia, and international development agencies. In addition, the area presents a mosaic of services catering to both new and existing buildings. Recent engagement with the World Bank has enabled the area to forge ahead in the domain of resilient and safe buildings. The Centre's partnership with city of Amravati to build greener buildings is a leapfrog in the field of 'Sustainability in the World' as it would be one of its kind

» Launch of *Material Handbook on Sustainability* at 10th GRIHA Summit on December 11, 2018 at IHC by Mr Sanjay Seth, Chief Executive Officer, GRIHA Council; Prof. Ian Jacobs, President and Vice Chancellor, UNSW; Dr Ajay Mathur, President, GRIHA Council and DG, TERI; and Dr Winfried Damm, Director, IGEN, GIZ GmbH

» Inauguration of the 10th Regional GRIHA Summit, June 14, 2019, Nagpur by Hon'ble Minister, Mr Nitin Jairam Gadkari, Ministry of Road Transport and Highways and Ministry of MSME, Government of India

» Hon'ble Minister, Mr Nitin Jairam Gadkari, Ministry of Road Transport and Highways and Ministry of MSME, GOI and Mr Sanjay Seth, Senior Director – SHP, TERI and CEO, GRIHA Council during the 10th Regional GRIHA Summit.

cities to have sustainability concept from inception to commissioning in India. The iconic campuses of the Indian Institute of Management, Raipur and the British School, for which TERI was consultant, have been rated as exemplary buildings in the realm of green buildings in India. Sustainable buildings area has further developed decision-support tool to assess and compare building technologies based on 17 socio-technical attributes, and helps users to choose the best building technology as per their requirement. The Mahindra–TERI CoE for Sustainable Habitat, inaugurated in July 2018 is a state-of-the-art laboratory to assess thermal efficiencies of building materials, using one-of-a-kind equipment available in India. In collaboration with IFC the area is also engaged with the Sustainable Housing Leadership Consortium (SHLC) programme established under the European Union—India Cooperation on Clean Energy and Energy Efficiency, along with five major private developers, contributing to the growth of India's green buildings—the social housing segment, for identifying and prioritizing cost-effective building technologies relevant to green housing in India, making it a global PPP model. Charles Darwin University under the India–Australia exchange grant programme collaborated with the area to bridge the knowledge gap on construction and demolition waste in India and Australia, and the delegation from India was led by Mr Sanjay Seth (Senior Director, Sustainable Habitat Programme, TERI).

The impact of the area's work is significantly enhanced by leveraging to its association networks and presenting at the Multi-Advisory Committee (MAC) of Sustainable Buildings and Construction programme under UNEP being an MAC member, Global Alliance for Buildings and Construction, UN Habitat, ISHRAE, and many other such associations.

» Signing of MoU between GRIHA Council and PWD regions (Aurangabad, Amravati, Konkan, Mumbai, Nashik, Nagpur, and Pune) during the 10th Regional GRIHA Summit

Demonstration of GHP System Integrated with RE System at Kimin, Arunachal Pradesh

TERI is implementing a geothermal-based heat pump system for space cooling and heating at Community Health Centre, Kimin, Arunachal Pradesh. The project is a technology demonstration for the entire Northeast region. The complete system being demonstrated at Kimin is first of its kind system, which includes a geo-exchange loop, a heat pump machine, and solar photovoltaic (PV) system. This system is being showcased as a replicable model for remote locations of Arunachal Pradesh.

» Launch of the Mainstreaming Sustainable Social Housing in India Project final project report at the 10th GRIHA Annual Summit

Ground source heat pump (GSHP) systems, also referred to as geothermal heat pump or geo-exchange systems, are electrically powered space-heating and cooling technologies that take advantage of the earth's (or surface water's) relatively constant temperature, below certain depths, to provide building space conditioning (the subsurface is a source of heat in winter and an efficient heat-rejection medium in summer). GSHP systems are clean (there are no on-site greenhouse gas emissions, because the systems do not combust any fuel), energy-efficient technologies that can effectively replace conventional heating and cooling technologies and improve building comfort. The primary benefit of installing a GSHP system is reduction in energy consumption and a resultant decrease in utility expenses. In terms of heating, a GSHP system with variable speed compressors can have a coefficient of performance of 6.0 or higher. This means that for every unit of energy consumed, six units are generated (i.e., GSHP systems are 600% or more efficient as compared to electric heating). In comparison, the efficiencies of most boiler-based heating systems are 80% or less. Other GSHP system benefits include increased conditioned space comfort, heat pumps run almost constantly, ramping heating and cooling up and down as needed (i.e., there are no on–off fluctuations), provide superior humidity regulation, and are quiet. GSHP systems

» Site survey team at CHC, Kimin (representatives from TERI, APSCST and medical officers)

» First GRIHA Existing buildings-rated Project Certificate

» Onsite fabrication of geothermal slinky

» Installation of geo-exchange loops

» Panorama view of Power-Grid Project—residential quarter in second phase

work optimally in climate regimes where heating and cooling are relatively balanced. However, they are versatile, and with minor system adaptation, modification, or hybridization, GSHP systems can be deployed effectively in heating-dominated or cooling-dominated climates.

Sustainable Buildings—SRC Group

Sustainable Buildings—Bengaluru at TERI's Southern Regional Centre has been working with real estate developers, private sector organization, public sector organization, 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 2018/19, the Centre took forward the ongoing research on dynamic shading and radiant cooling technology funded by the Government of India, through the Department of Science and Technology. Under funding of Department of Biotechnology (DBT), the area continued the research on design and engineering of cold storage containers using biowaste as an energy source. The ITC Residential Project at Guntur, for which the Centre provided GRIHA consultancy, became the largest residential project in India to receive the highest GRIHA rating. The Centre also organized several training programmes, which witnessed the participation of nearly 100 students and 50 professionals from the Indian building industry and paved the way for future collaboration with industry on research and development. Institutional engagement to disseminate research work has been carried out in partnerships with educational institutes, such as NIT Trichy and SJB SAP.

ITC Residential Campus, Guntur

The residential campus developed by ITC in Guntur has 3BHk and 4BHk residential units with club house and restaurant facility. The project has been provisionally rated as 5 star as per GRIHA rating system. The project encompasses the best of green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting, water re-use from sewage treatment plant (STP), rainwater, and solid waste management.

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 has been provisionally rated as 4 star as per GRIHA rating system. The project encompasses the best of green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting, water re-use from STP, rainwater, and solid waste management.

» ITC Residential Campus, Guntur

» Students and faculties who participated in the 3-day training programme

Student Training Programme at SJB School of Architecture, Bengaluru

Sustainable Buildings-SRC organized a 3-day Building Programme Simulation Workshop at SJB School of Architecture and Planning, Bengaluru from November 13 to 15, 2018. The intent of the programme was to meet the shortage of trained manpower to undertake sustainable development and green building practices in India. The 3-day programme comprised sessions on concepts of Sunpath and Principles of Optimizing Building Geometry for Sun Control, using Solar Tool for Designing Shading Devices, Fundamentals of Light and Visual Comfort, using Ecotect and Radiance Tools to Predict Daylight Distribution in Interiors, Concepts of Airflow and Natural Ventilation and using IES Tool to Design Naturally Ventilated Spaces to Maximize Thermal Comfort. There were hand-holding sessions in which the participants were trained to use various software and calculation tools for building optimization.

Astra Microwave Products Ltd, Bengaluru

The technical campus developed by Astra Microwave Products Ltd has three types of buildings: administrative building, one canteen-cum-guest house, and laboratory spaces. The project has been registered for GRIHA rating system. The project encompasses the best of green design as per sustainable sites, passive architecture, efficient HVAC system and artificial lighting, water re-use from STP, rainwater, and solid waste management.

Transport and Urban Governance

Urban areas play a pivotal role in the growth of Indian economy and are projected to account for more than 50% of the country's population by 2050. In cognizance of the increasing importance of cities, TERI has a flagship programme on urban planning and governance with a dedicated research centre focusing on urban issues. TERI provides technical assistance to urban local bodies (ULBs) in developing sustainable, smart, and resilient cities, and places a special focus on strategic planning, sustainable urban infrastructure, and policy and governance frameworks. It delves into urban research and policy analysis for strengthening capacities and partnerships of cities for improved and informed decision-making in alignment with global urban sustainability goals. By developing research reports, articles, and policy briefs, TERI aims to influence the policy arena as well as fill knowledge gaps to promote sustainable and low-

» Astra Microwave Products Ltd, Bengaluru

carbon urban growth.

Given the significant role that the transport sector plays in supporting sustained economic growth in the country, TERI is dedicated towards promoting low-carbon sustainable transport which will meet the mobility requirements of a populous developing country like India. TERI undertakes research regarding the evaluation of existing/proposed policies in the transport space and makes recommendations to improve the implementation and effectiveness of such policies. TERI also prepares long-term energy and emission inventories of transport modes/sectors to ensure informed policymaking.

TERI aims to strengthen and reinforce the mainstreaming of climate change action at the city level. To this end, TERI works in collaboration with various stakeholders including local, national, and international governments, public utilities, non-governmental organizations, bilateral and multilateral agencies, foundations, research institutes, corporate and financial institutions, civil society, academia, early career professionals and practitioners to bridge the existing knowledge gap, and facilitates awareness of generation and capacity building for informed decision-making.

Centre for Urban Planning and Governance

With the growing urban population of India, perpetually dealing with a range of complex challenges, the Centre for Urban Planning and Governance 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 actively in 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 HABITAT III and UN's World Urban Forum 9 in Quito and Kuala Lumpur, respectively. In India, TERI has conducted a series of national and regional policy dialogues to facilitate discussions on critical urban issues, and Australia–India knowledge exchange workshops for elaborating on smart energy management initiatives in cities. As an empanelled consulting firm under Smart City Mission and empanelled training agency under AMRUT for Government of India, TERI is supporting implementation and review of national urban missions through capacity building programmes.

» Release of *Making Liveable Cities: Challenges and Way Forward for India* by Shri Durga Shanker Mishra, Secretary, MoHUA, GoI and H.E. The Ambassador Peter Taksoe-Jensen, the Royal Embassy of Denmark in India

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

Centre for Sustainable Mobility

In the face of high population growth and rapid urbanization, the Centre for Sustainable Mobility focuses on policy analysis and emission modelling to develop the country's transport sector in an energy-efficient, environment-friendly, sustainable, and inclusive manner.

TERI has conducted detailed studies focused on analysing the future prospects of electric mobility in India. In partnership with the World Bank and the International Transport Forum, TERI

» Release of *Benefits of Cycling in India – An Economic, Environment, and Social Assessment* by Shri Suresh Prabhu, Hon'ble Union Minister for Commerce and Industry and Civil Aviation

» Parcels waiting to be loaded in trains

has developed a city-level model, which evaluates the decarbonization potential of different transport investment strategies. TERI has also successfully completed a study on estimating the carbon footprint and enhancing climate resilience of national highways for the Ministry of Road Transport and Highways. TERI has conducted a Life Cycle Analysis of transport modes in India for the National Transport Development Policy Committee and has also evaluated the trends and economic benefits of Non-Motorized Transport for the All-India Cycling Manufacturers' Association. To estimate the energy and emission impacts of high speed rail in India, TERI has conducted a detailed study for the Ministry of Railways and also undertakes studies to promote modal shift of freight movement towards rail. TERI also conducts road safety audits for the Supreme Court Committee on Road Safety.

TERI is a member of the Sustainable Low Carbon Transport (SLoCaT) partnership, a global partnership hosted by the United Nations Department of Economic and Social Affairs (UN-DESA), and, also, is a member of the Sub Committee on Fuel Economy Norms for Medium and Light Commercial Vehicles, established by the Ministry of Petroleum and Natural Gas.

DOMESTIC AND GLOBAL OPERATIONS

DOMESTIC AND **GLOBAL OPERATIONS**

DBT–TERI Centre of Excellence in Advanced Biofuels and Bio-commodities

The Department of Biotechnology (DBT) established its fifth bioenergy centre of excellence—DBT–TERI Centre of Excellence in Advanced Biofuel and Bio-commodities—at TERI. The Centre aims at development of technologies for production of advanced biofuels; algal biodiesel, pyrolytic oil, biohydrogen; and bio-commodities; 2,3 butanediol, acrolyn, high-value pigments, bio-plastic, aqua feed and animal feed, from 3rd-generation feed (algae and aquatic macrophytes) in a bio-refinery approach. This is the first biorefinery project established by DBT–TERI with a goal to achieve the zero-waste discharge by effectively utilizing the co-products of different processes as feed to produce value-added bio-products that would aid in closing loop along with addressing the challenges of economical feasibility of producing advanced biofuel in a sustainable manner.

To achieve this, the research is done intensively at TERI's different programmes (Environmental and Industrial Biotechnology Division, Nano Biotechnology Centre, Renewable Energy Technologies Division, Resource Efficiency and Governance, Earth Science and Climate Change and the Coastal Ecology and Marine Resources Centre) and at collaborating institutes, namely Indian Institute of Technology, Guwahati, Indian Agricultural Research Institute and Transtech, Jaipur. To demonstrate algal cultivation in 100,000-litre scale, large-scale bioreactor is being established and the selected indigenous saline algal strain is being adapted to grow in a coastal site. The goal is to use algal biomass for production of biodiesel, pyrolytic oil, and other value-added products as highlighted above. Further large-scale cultivation of Azolla microphylla in domestic grey water is being demonstrated in outdoor ponds at TERI Gram campus (in the area spanning approximately 0.01 ha). This aids in treatment of wastewater along with generation of value-added biomass to be used as feed for clean hydrogen production. Crude glycerol, which is the co-product of biodiesel production is being explored for production of 2,3 butanediol (by novel strain *Enterobacter tabaci*) and acrolyn, the value-added industry platform chemicals. Azolla and water hyacinth biomass, presently, are being explored for hydrogen production through use of select C5 and C6 sugar co-fermenting microbe. The algae biomass is explored for extraction of high-value biopigments, for formulation of aqua feed, and cattle feed. Additionally, the algal biomass is also explored for fabrication of biodegradable cellulose nanofibre for downstream application in production of biodegradable plastic in an integrated manner.

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 Division 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 Northeast 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 Forum). 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 include:

World Sustainable Development Summit

The World Sustainable Development Summit (WSDS), TERI's flagship event, is a glorious reiteration of the erstwhile Delhi Sustainable Development Summit (DSDS) that continues the Summit Series' decades-long run in bolstering India's claim to international leadership on climate action, cementing its

place amongst the most responsible environmental stewards.

The WSDS strives to provide long-term solutions for the benefit of the global community by assembling the world's most enlightened leaders and thinkers on a single platform. Themed, 'Attaining the 2030 Agenda: Delivering on Our Promise', the 2019 edition of the Summit sought to create action frameworks to resolve some of the most urgent challenges facing developing economies. The Hon'ble Vice President of India, Venkaiah Naidu inaugurated the Summit, and during the three days, over 2,000 delegates participated in the Summit proceedings, including policymakers, researchers, think tanks, diplomats, and corporates from around the world. These delegates represented the leaders in the development, energy, and environment sectors. The Summit programme offered a wide variety of participatory options and has, to date, hosted 47 heads of state and government, 13 Nobel laureates, ministers from over 76 countries, over 1,600 business leaders, 1,800+ speakers, and over 12,000 delegates from across the world. An important feature of the WSDS is its pre-events, which are held prior to the Summit at the national and international levels. The discussions from these international and regional dialogues are brought forward to the main WSDS stage where they are further matured and discussed in-depth by experts and practitioners from relevant fields – lending the Summit deliberations an important ability to weave regional and international insights, simultaneously.

Environment Education and Awareness Area

The Environment Education and Awareness area's flagship programme, 'GREEN Olympiad' is an annual international-level examination for school children being organized since 1999. Students from across the country participate in this programme, which also has a global outreach with participation of schools from Nepal, Singapore, Kenya, Indonesia, Iran, Bhutan, Sultanate of Oman, United Arab Emirates, Kuwait, Qatar, Kingdom of Saudi Arabia, Russia, Fiji, Mexico D.F., and the Bahamas, thus reaching out to approximately 2,00,000 students (annually). The Green School is supported by Tata Steel and is implemented in Jharkhand and Odisha. The project aims to create awareness among students on climate change and the ways in which adopting a sustainable lifestyle can help mitigate the adverse impact of climate change, and was represented at the United Nations Climate Change Conference (COP24) in Poland.
TERI-NCSTC Eco Next Investigation for Youth supported by National Council for Science and Technology Communication, Department of Science and Technology, Government of India aims to create a cadre of youth who are

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 setup 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 the financial year 2018–19, including the 10th GRIHA Summit and TERI's flagship event—WSDS 2019.

aware, innovative, and ready to create a difference for nature conservation, eco-restoration, nature-based solutions, co-creation, and innovation.

Project FLOW (Facilitating Learning on WASH), a Bharti Infratel Ltd and TERI initiative that culminated in 2018 reached out to approximately 750,000 school students and communities in Bhubaneswar (Odisha), Ranchi (Jharkhand), Indore (Madhya Pradesh), Jammu (Jammu and Kashmir), Panipat (Haryana), and Guwahati (Assam). The Water, Sanitation and Hygiene (WASH) project, supported by Sony India Software Private Limited in Bengaluru, was designed to impart transformative learning through adequate resource materials and innovative strategies.

In Green Hackathon-18, supported by WeRise Foundation, more than 100 college teams participated with state-of-the-art hacks, to promote, engage, and showcase critical thinking and problem-solving skills amongst students to address prevailing environmental issues of Bengaluru by the use of technology.

Creative Content

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

TERI's work on energy access in rural India, nutritional security in Maharashtra, and improving biodiversity in Assam were in the spotlight. An assessment report on the benefits of cycling in India hit the headlines across all media platforms. During the WSDS 2019, TERI's research findings on energy transitions and its partnership with Bloomberg for addressing air pollution received wide attention in both print and online media. A number of researchers wrote opinion pieces in leading newspapers on topics such as renewable energy, biodiversity, water conservation, and urban waste management. Press releases and media interactions on these topics received a positive response.

Social media activities, managed by the team, continue to play a vital role in promoting published content and key events. With an increase of nearly 70% in Twitter followers, 40% growth in Linkedin followers, and regular Facebook

engagements, the team has committed to circulate TERI's work as per relevant digital trends. The group has also entered a content partnership with Factiva, a global provider of business information. This partnership gives TERI the ability to disseminate knowledge-based publications across millions of Factiva subscribers from various global industries.

Kumaon Vani community radio produced and broadcast a short programme series 'Mera Mat Mera Adhikaar' on voter awareness for the 2019 Lok Sabha elections in association with the Election Commission of India. The radio station also broadcasts a 90-episode series 'We Learn English' to enhance the language skills of students of Classes 4 to 6 in the community with support from the Centre for Learning Resources, Pune.

The group also produced a number of videos and films, notably on productive uses of solar energy in the power looms of Varanasi and on watershed management–livelihood linkages in Uttarakhand.

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 eBooks; 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.

TERI CBS organized the meeting of Chief Sustainability Officers on August 28, 2018 at TERI Retreat, Gual Pahari. India's leading chief sustainability officers engage with TERI to strengthen the business case for sustainability for the corporate whilst ensuring onground implementation of co-created project ideas on issues of materiality for respective organizations. The meeting had two sessions: Knowledge sessions provided insights on emerging trends and global developments on sustainability; Action and consultation sessions provided access to tools, methodologies, and practices for the Sustainability Officers.

On May 1, NEDO held the India-Japan Industry & Energy Seminar in coordination with the Japan External Trade Organization, the Confederation of Indian Industry, and TERI. The Energy Session in this seminar featured two panel discussions by experts in the public and private sectors.

Frost & Sullivan and TERI co-hosted the 'India Sustainability Leadership

Summit 2018' and 'Sustainability 4.0 Awards 2018' on June 1, 2018 in Mumbai. The Summit saw industry experts and dignitaries from numerous establishments and government bodies deliberated ideas, solutions, and technologies across industry vertical towards building sustainable economies.

The ninth edition of Sustainability 4.0 Awards recognized 19 winners showcasing transformational growth focusing on environment and sustainability. The Sustainability 4.0 Awards assessment model comprises 4 major parameters (4P - Model) and 13 sub-parameters, recognizing the efforts of front runners via a thorough benchmarking process. Sustainability 4.0 Awards were presented to companies in three major categories: Leaders, Challengers, and Believers. Reliance Industries Limited received the highest accolade - Sustainable Corporate of the Year Award along with Mahindra & Mahindra Limited which received the Sustainable Factory of the Year Award. It also won the Safety Excellence Award - Mega Large Business, Automotive Sector.

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 license 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 Co. Ltd.', Bareilly related to TERI's novel Pyrolysis Bioreactor Technology.

b. Collaboration Agreement with 'Maxop Research and Testing Institute Pvt. Ltd' to establish a state-of-the-art 'TERI-Maxop Solar Research and Test Facility'.

c. Technology Development/ Dissemination agreement with M/s Perfact Researchers Pvt. Ltd 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 (MoEF&CC) as part of the 'World Environment Day' celebrations. TERI actively participated at this exhibition that took place on 3rd–5th 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. 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 core competency of the KRC professionals also lies in proactive engagement in multi-stakeholder research projects; conducting capacity-building programmes for external

and internal research and information professionals; web content and database development; bringing out peer-reviewed publications and knowledge products on contemporary issues. TERI KRC has set up many specialized information centres on thematic areas, such as transport, renewable energy, *mycorrhiza*, and climate change.

During this year, the KRC executed many knowledge-based projects from government and international organizations consisting of online database on R&D equipment, digital repository of S&T publications and National S&T Survey supported by the Department of Science and Technology, Government of India; development of compendium of case studies of scientific and industrial research organizations supported by Department of Scientific & Industrial Research, Government of India; Mycorrhiza Information Centre supported by the Department of Biotechnology, Government of India; and developing transport statistical database from International Transport Forum, Geneva.

The Knowledge Resource Centre 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 works relentlessly towards knowledge development and dissemination for policy-making, organizing workshops and skill development programmes, and conducting environmental surveys. Under the Green Skill Development Programme (GSDP) of the government, the RP initiated the course on 'Sustain and Enhance Technical Knowledge in Solar Energy Systems' for skill development to enable India's youth to get gainful employment and/or self-employment. The first 240-hours course with 30 students was conducted in Purnia, Bihar during September–October 2018. The RP celebrated World Environment Day at Vigyan Bhawan on June 3, 2018 in collaboration with Centre for Media Studies, New Delhi and Thiagarajar College of Engineering, Madurai. The RP has also actively engaged in National Environment Survey (NES), where primary and secondary data on different parameters are being collected at district level from Haryana using geographic information system platform, which will be helpful for policymakers.

As part of the capacity-building programme for think tanks, supported by the Think Tank Initiative of IDRC, a series of webinars and workshop on project management was organized by TERI and CSTEP. The Centre organized the workshop on Research Data Management Tools and Techniques on January 17 and 18, 2019 aimed at enhancing the skills of researchers and other stakeholders for managing and visualizing research data. KRC also conducted the World Sustainable Development Summit Thematic Workshop on Data to Policy: Date-Driven Smart Transport Safety Policies on February 11, 2019. The objective of the workshop was to help formulate data systems, which will improve the measurement of India's road traffic safety challenges.

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

Information Technology (IT) plays a key role of an enabler, a catalyst, or a facilitator to achieve strategic goals of TERI. The IT team's core long-term objective is to securely deliver anytime, anywhere access to all IT services on any device and adopt new-age technologies in time-bound and cost-effective manner to:

- Add value to research and support functions
- Improve institutional efficiency and productivity
- Improve time to market
- Enhance user experience

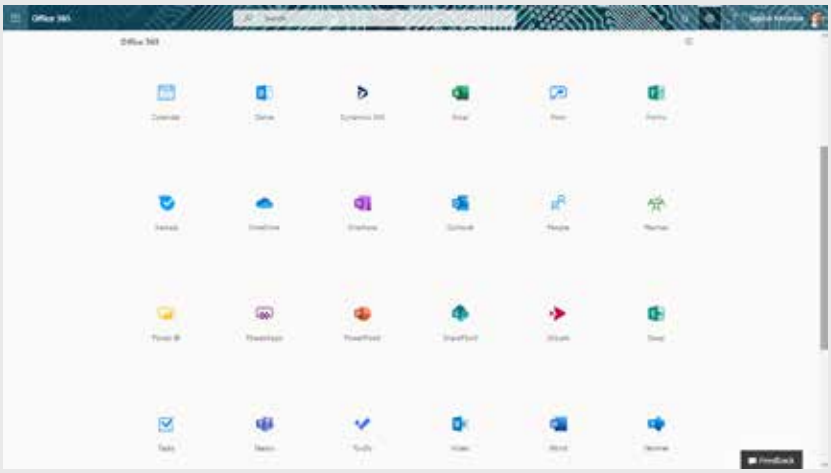
The TERI IT Team formulated various IT policies to create a governance framework of IT operations to facilitate carrying out of research and professional activities in an efficient and effective manner by TERI employees, consultants, interns, guests, and any other person/organization that uses the institute's Internet facility. The key clauses of policies are categorized into three: (i) official use of IT resources for research work, administrative, support, communication, and other work-related activities, (ii) limited personal use, and (iii) unacceptable use. These policies are made available on intranet under 'Policies and Guidelines' section.

A cloud-based ticketing system is implemented for IT Help Desk services. The key features include its accessibility from anywhere 24x7, templates for most frequent tickets instead of typing it again, auto conversion of an email into a ticket, mobile app to raise your ticket even in case the system is down or while you are on the move, email updates to keep user informed about progress on the ticket, and many more.

An Event Database Management System (EDMS) is developed to effectively organize and manage various events across the institute. This system is in use in conjunction with CRM and used to manage the biggest event, that is, the World Sustainable Development Summit for website as well as mobile app.

For modelers, the supercomputing facility was made available and accessible from outside network, which enabled them to work at any time. Cloud technology is adopted to meet quick and frequent requirements of IT infrastructure for research projects, which is flexible to use, readily available, and easy to scale up and scale down. It helped in saving the cost and time of procurement to meet such requirements.

The IT team developed an innovative framework for timesheet integration with Outlook Calendar. It imports Outlook



Microsoft Office 365

TERI has shifted to new and widely recognized mailing and collaboration system from IBM Lotus Domino to Microsoft Office 365. The new infrastructure has provided wide range of tools such as Mailing System (Web, Client, and Mobile version), Skype for Business for audio/video communication, OneDrive for file storage, Yammer for enterprise social networking, online office suite, Stream for enterprise video sharing and streaming, and many more. The system is available from anywhere and anytime.

National Portal for Renewable Purchase Obligation

The National Portal for Renewable Purchase Obligation (RPO) (https://rpo.gov.in/) serves the long-standing need for effective reporting and monitoring mechanism for RPOs. RPO mechanism was developed under the provisions of Electricity Act, 2003, to create markets for renewable energy-based electricity. This portal is a national-level portal for uniform and transparent reporting of RPOs. The key objectives include the following:

- To establish a centralized monitoring mechanism for RPO compliance through a web-based portal for all states and union territories
- To enlist obligated entities and assess their RPO compliance
- To ease out the process of monitoring the renewable energy (RE) transactions of obligated entities
- To develop database that would become a tool for State Electricity Regulatory Commissions to audit RPO compliance
- To enhance transparency in RPO compliance process
- To create user interfaces for obligated entities to provide data on RE purchase
- To create user interfaces for monitoring agencies to cross-verify the data provided by obligated entities
- To prepare database for the system and analytics modules to analyse the effectiveness of the RPO regulations in the states

Calendar entries into timesheets to save time in filling timesheet entries. It requires a declaration from end user to synchronize timesheets with Outlook Calendar. In addition, users can also manually import calendar entries into timesheet by clicking on 'Import Calendar Entries' button.

Uttarakhand Disaster Recovery Project for Business Process Re-engineering

Business Process Re-engineering (BPR) plays a major role in establishing an efficient and a transparent building control process, with minimized transaction costs for land use and administrative and building code requirements, and is an important condition to incentivize builders to comply with regulations. Through BPR, there has been a channelized effort towards improving process efficiency by reducing transaction costs for applicants and local agencies involved in building control activities, improvement in transparency, and attaining greater levels of formalization.

The methodology used to undertake BPR for the Map Approval Management System (MAMS) was to study first-hand the existing MAMS to get a basic understanding about the system and its processes. Interactions were scheduled with stakeholders and end users to get their valuable inputs with respect to their experience with the system. An analysis was further undertaken on two fronts, that is, the observations made by the project team with respect to their study of MAMS and feedbacks obtained from stakeholders. This was then benchmarked against best practices followed in the domain of online building map approvals by other jurisdictions in India and the world over. All these inputs were then used to arrive at the 'To-Be' system, the final

Greendom: a Digital Board Game on Energy (http://thegreenschoolproject.com/)

In present times, India suffers from the ever-increasing demand for electricity and water. Existing garbage dumps are coming closer to exceeding their limits as tonnes of garbage are disposed-off every day. Therefore, families living in the peripheries of big cities are struggling to gain access to what is required for their everyday existence. However, equipped with the modern education and technological knowhow, today's generation has the utmost ability and potential to bring about a change in the society. Considering the aggravating problems with respect to improper waste and water management, energy usage, and the facilities provided to this generation, a digital game is developed to (a) create awareness, (b) promote use of alternative sources of energy by playing and doing, (c) make students think about cost minimization, (d) inculcate good habits to learn to have a balanced life style, and (e) to learn to have a basic financial intelligence.

This digital game is developed in the form of Monopoly where players roll two perfect dice to move around with the option of buying and trading properties (home, office, hotel, and resort) and provides various messages on energy efficiency, water, and waste management. Players not only get chance to collect rent from their opponents, but also upgrade their property to increase its rental and resale value with the goal being to drive them into bankruptcy. Money can also be gained or lost through banks; players can end up in jail if they have a penalty, or may have to pay a visit to hospital in case of negligence. The game will have a specific set of rules, which will be mentioned. Monopoly has become a part of international popular culture and played in more than 103 countries.

desired system, which could cater to the requirements of all stakeholders.

GRIHA Tool for Affordable Housing

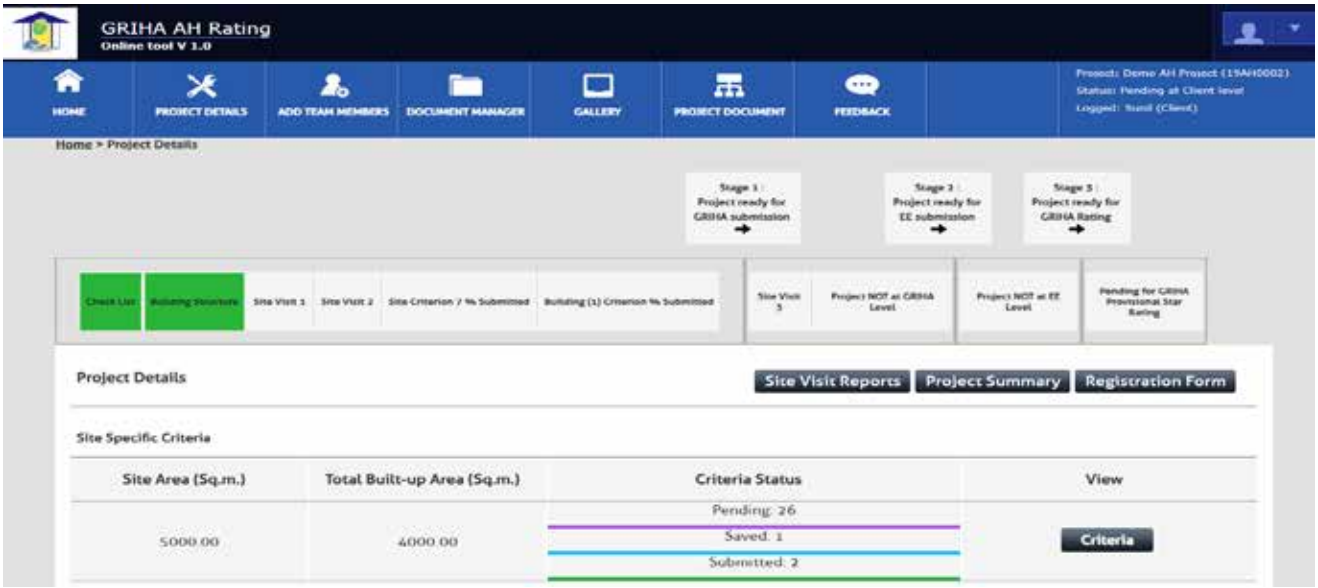
GRIHA for affordable housing rating is the cloud-based rating system developed for GRIHA council. It helps people assess the performance of their building against certain nationally acceptable benchmarks. It evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'.

The rating system has the following key features:

- **Secure** – only authorized user can access the system
- **Web-based** access from anywhere, anytime
- **Profile-based access** for clients, coordinators, external evaluators, and consultants
- **Online registration of projects**
- **Online data entry forms** – the data entry forms for building registration, evaluation, and progress monitoring are designed and developed in user-friendly formats. These forms will provide the common functionalities to submit the documents with relevant criteria. These forms also comprise calculators to be used in various criteria
- **Notifications and alerts** – the system will send automated e-mail notifications and alerts at different stages of the processes for better involvement of the users such as clients, consultants, coordinators, and evaluators
- **Administrator control** – the system will be controlled by a system administrator who would be able to configure/add/edit any user by providing control information (login details). This panel will also have the details of the projects registered, projects initiated, their relative users involved, etc.

National Survey on Resources Devoted to Scientific and Technological Activities 2018–19

The National Science and Technology Management Information System (NSTMIS) is a survey tool developed for Department of Science and Technology (DST), Government of India to collect data on resources devoted to Scientific and Technology (S&T) activities (mainly



R&D) in the country. Based on survey data, a number of S&T reports are published, providing vital information on national R&D indicators, which serves as an evidence base for S&T assessment and policy formulation.

Key features:

- **Web-based** access from anywhere, anytime
- **Secure** – only authorized user can access the system
- **Online data collection**
- **Administrator control**
- **Reports –** various types of reports to help the admin to assess the national expenditure on R&D

GRIHA Revamped Website

The GRIHA website was totally revamped using Drupal, that is, Content Management System, and the key enhancements carried out are as follows:

- Clear, user-friendly navigation – allows visitors to quickly find the information needed, important links are easy to find, and includes easy-to-understand labels
- Simple and professional web design
- Mobile friendly
- Improved search functionality and search engine optimization
- Improved speed
- Switched to a new Content Management System, that is, Drupal
- Increased security
- More structured compared to the previous website
- User friendly
- Administrator control for website and product catalogue – the system is controlled by a system administrator who can configure/add/edit any user/content by providing control information (login details)
- Fee calculator for public use

Nanoforagri 2018 Website

A website for Nanoforagri 2018 is developed with following key features:

- Clear, user-friendly navigation – allows visitors to quickly find the information needed, important links are easy to find, and includes easy-to-understand labels.
- Simple web design
- Call for papers/abstract submission online forms
- Online registration form
- Latest information for the event available

Sustainability 4.0 Awards

Sustainability 4.0 Awards, instituted jointly by TERI and Frost & Sullivan, involve 360-degree evaluation of all elements of sustainable development, that is, purpose, people, partnership, and planet. Participating organizations provide a set of services and forums for knowledge sharing and learning as part of the awards. In the 2019 edition of the awards, a Special Mention Award category is being introduced to recognize programmes or initiatives that have resulted in environmental protection, social well-being, and/or economic prosperity within an organization's operations and in the community. Information about the programmes and how they go about in protecting environment through their processes is captured through this initiative. Applications are submitted through the online application process.

Greenhouse Gas Calculator

To develop an online tool for decision by the user on preliminary selection of the cost-optimal system configuration to meet energy demand and estimation of greenhouse gas through a grid connected rooftop solar photovoltaic system.

Analytic Hierarchy Process MaS-SHIP Survey

The project aims to identify the impacts and benefits of housing production at scale, such that of the *Housing for All by 2022* mission, for our environment, our economy, and our communities – and to provide a method for identifying the most optimal building materials and construction technologies.

The project aims to develop a sustainability index built on a multi-criteria decision support system to provide the targeted beneficiaries with evidence-based performance information that would aid decision-making in their choice of building materials and construction technologies.

The intent of the survey is to evaluate relative importance or preference of criteria associated with choice of a building material and construction technology to mainstream sustainable social housing in India.

The survey is based on the analytic hierarchy process. This would help the project team to establish relative weightages of the attributes comprising the sustainability index.

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. In today's environment with a need for a high employee engagement and capability development, Human Resources's role is not only to identify and acquire the desired 'talent' for TERI, but also effectively manage and retain them. 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. Regular internship opportunities facilitated by the Human Resources Division give TERI first pickings of the creme-de-la-creme of the pool of fresh graduates from the best of institutes in the country who assist researchers on various research projects.

Colleagues across the Institute are exposed to training interventions on a variety of behavioural and technical capability areas. These programmes are aimed at furthering leadership skills for junior and mid-level employees, enhancing personal effectiveness and building their people management skills. Our employee-friendly policies for higher studies provide an opportunity to researchers to pursue PHD programmes from the top universities across the globe.

TERI has an over-riding commitment to health and safety, therefore, workshops for employee safety and security are routinely organized by Human Resources to improve safety management skills and encourage employee participation in safety. 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 2018/19, are listed in this section.

Governments & Public Sector Undertakings

Partner	Profile	Focus Area	Type of Association
Agarkar Research Institute, Pune	Government of India	Microbial biotechnology	Partnership network
Andhra Pradesh Capital Region Development Authority (APCRDA)	Government of Andhra Pradesh	Sustainability Partner to Andhra Pradesh Capital Region Development Authority (APCRDA) for the new capital city of Amaravati, Andhra Pradesh	Sustainability partner / funding Support
Andhra Pradesh Southern Power Distribution Company Ltd (APSPDCL)	Government of Andhra Pradesh	Solar PV grid integration studies, demand side management (DSM), energy efficiency (EE)	TERI's partner utility in the MacArthur Foundation-funded project on technical studies on rooftop SPV grid integration. TERI also conducted four capacity-building programmes on DSM and EE for circle-level officials of APSPDCL.
Arunachal Pradesh State Council for Science and Technology	Government of Arunachal Pradesh	Research and technology development	Funding support and knowledge partner
Asian Cities Climate Change Resilience Network	International Network	National partner to the Asian Cities Climate Change Resilience Network (ACCCRN)	Knowledge 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
Assam Agricultural University, Jorhat	Government of Assam	Microbial biotechnology	Collaborating project partners
Assam Forest Department	Government of Assam	Capacity building for assisting the State Project Management Unit in the implementation of JICA project	Funding agency
Assam Power Distribution Company Ltd	Government of Assam	–	BEE Capacity building on DSM and EE, and load research

Partner	Profile	Focus Area	Type of Association
Assam Science Technology and Environment Council (ASTEC)	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 of Assam	Microbial research	Funding support
Bangalore Electricity Company Ltd (BESCOM)	Government of Karnataka	DSM and EE	TERI conducted four capacity-building programmes each on DSM and EE for circle level officials of each of these utilities
Bharat Petroleum Corporation Ltd (BPCL)	Public sector undertaking company	Bioremediation of oily sludge, contaminated soil	Funding support
Biotechnology Industry Research Assistance Council (BIRAC)	Government of India	Research support	Funding support
British High Commission	Diplomatic mission of the United Kingdom in India	Strengthening Corporate Green Leadership in India	Funding
BSES Rajdhani Power Ltd (BRPL)	Government of India	Design and implementation of solar rooftop systems. Battery energy storage systems (BESS), Solar PV grid integration studies, electric vehicles (EVs)	Partnership
Bureau of Energy Efficiency	Government of India	Demand side management; standard and retailers training programme in 34 North-eastern cities	Funding support
Bureau of Indian Standard (BIS)	Government of India	Standards on BESS and RE integration	TERI is a member in the BIS ETD-46 Sectional Committee on 'Grid Integration of Renewables' and ETD-52 committee on 'Electrical Energy storage systems'
Cairn Energy Ltd, Gurugram	Public sector undertaking company	Microbial biotechnology	Funding support/partnership network
Cairn Oil & Gas, Vedanta Ltd	Public sector undertaking company	Microbial biotechnology	Partnership networking

Partner	Profile	Focus Area	Type of Association
Central Electricity Authority	Government of India	Electric Vehicles	TERI performed simulation and measurement studies on vehicle to grid concept and EV charging harmonics to contribute to the technical report of the BIS ETD-51 standard on 'electrotechnology in mobility' whose sub-committee on grid-related aspects of EV charging is headed by CEA
Central Glass and Ceramic Research Institute, Khurja	Government of India	Research on ceramic filters for wastewater treatment	Collaborative research
Central Pollution Control Board	Government of India	Air pollution	Funding support
Central Power Research Institute	Government of India	Research and developmental studies EMI shielding nanocomposites for power sector	Collaborative research
Centre for Tropical Crops and Bio-commodities, Queensland University of Technology, Brisbane, Australia	Government of Australia	Microbial biotechnology	Collaborative project partners
CESC Ltd	Government of West Bengal	BESS and EVs	Projects on distribution-scale BESS and EVs
Chandigarh Renewable Energy Science and Technology Promotion Society (CREST)	Government of India	Third-party inspection for the work of aggregate capacity of 520 kWp; rooftop solar PV	Funding agency
Chhatrapati Shahuji Maharaj University, Kanpur	Government organization	Medicinal plants	Collaborating project partners
Climate and Clean Air Coalition (CCAC)	Intergovernmental Coalition	SLCP reduction from MSW management	Implementing partner in India
Climate Change Finance Unit, Ministry of Finance, Goverment of India	Nodal point on all climate change financing matters in the Finance Ministry	Providing inputs to support CCFU on emerging issues on climate finance and green finance	Funder
Coal India Ltd	Government of India	Forest- and agriculture-based livelihood activities	Funding agency and partner in field implementation
DBT-CIAB Centre for Integrated and Applied Biosciences, Mohali	Government organization	Microbial biotechnology	Funding support

Partner	Profile	Focus Area	Type of Association
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 Municipal Corporations (EDMC, SDMC, North DMC)	Government of India	Waste management and sanitation	Collaborative support
Department of Biosciences and Bioengineering, Indian Institute of Technology Guwahati, Assam	Government organization	Microbial biotechnology	Collaborative project partners
Department of Biotechnology	Government of India	Ericulture for upliftment of socio-economic conditions of rural women in tribal villages of Assam	Funding support
Department of Chemical Engineering for Process System Computations, Curtin University, Perth, Western Australia	Government of Australia	Microbial biotechnology	Collaborative project partner
Department of Environment, Ministry of Waterways and Environment, Fiji	Government of Fiji	Prepared three reports under UNDP Pacific R2R (Ridge-to-Reef) project for Fiji primarily focusing on: Developing an INRCM (Integrated Natural Resources Catchment Management) framework Documentation of the Integrated Catchment Management (ICM) Process for Fiji Sustainable Livelihoods: creating iterative learnings from Fiji and implement the conservation focused livelihood projects in Fiji valuation of ecosystem services for two landscapes in Fiji	Funding agency
Department of Microbiology, Central University of Rajasthan	Government organization	Microbial biotechnology	Collaborative project partners

Partner	Profile	Focus Area	Type of Association
Department of Horticulture, Bihar	Government agency	Micropropagation	Supply of plants
Department of Power, Arunachal Pradesh	Government of Arunachal Pradesh	–	BEE Capacity building on DSM and EE, and load research
Department of Science and Technology	Government of India	Research on air pollution and health; design and development of biomass solar electricity and cooling solutions for rural India	Funding support
Electricity Department	Government of India	Environmental and Social Impact Assessment	Funding agency
Electricity Department of the Government of Nagaland	Government of Nagaland	–	BEE Capacity building on DSM and EE, and load research
Energy Efficiency Services Ltd (EESL)	Energy service company (ESCO) of the Government of India	Developing a proposal for TCAF, an international finance facility piloting innovative, results-based carbon market mechanism under Article 6 of the Paris Agreement	Collaborative
Finnish Meteorological Institute, Helsinki, Finland	Government of Finland	Microbial biotechnology	Collaborative project partners
Flood and River Erosion Management Agency of Assam (FREMAA)	Government of Assam	Livelihood enhancement for river erosion victims	Funding support
Forest Department: Uttarakhand, Punjab, Assam, Goa, Maharashtra, and Uttar Pradesh	State forest departments	Carbon stock assessment of forests: capacity building of the forest department	Knowledge partner
GAIL India Ltd	Public sector company	Microbial biotechnology	Funding support
GITA	Government of India	Water-use efficiency	Funding
Global Resilience Research Network (GRRN), pioneered by Global Resilience Institute (GRI), at Northeastern University, Boston, MA	International network	Member of Global Resilience Research Network (GRRN), pioneered by Global Resilience Institute(GRI)	Network member
Goa State Biodiversity Board	Government of India	Biodiversity	Support for projects

Partner	Profile	Focus Area	Type of Association
Goa State Pollution Control Board	Government of India	Pollution	Funding agency/ collaborative research
Green Chemistry Centre of Excellence, Department of Chemistry, University of York, Heslington, York, UK	Government of UK	Microbial biotechnology	Collaborating partners and jointly organized Indo-UK Joint Workshop (granted by Government of UK)
Green Skill Development Council (MoEFCC)	Government	Skill development	Support for project
Ground Water Department, Uttar Pradesh	Government	Sustainable groundwater management	Funding
Gulbarga Electricity Supply Company Ltd (GESCOM)	Government of Karnataka	–	
Haryana Renewable Energy Development Agency (HAREDA)	Government of India	Examine the Detailed Project Reports (DPRs) for setting up of biomass-based power projects as envisaged in the Bio-Energy Policy 2018	Funding
Helmholtz Centre for Environmental Research, Leipzig, Germany	Government of Germany	Microbial biotechnology	Collaborative project partners
Hindustan Petroleum Corporation Ltd (HPCL)	Public enterprise company	Bioremediation of oily sludge, contaminated soil	Funding support
ICFRE	Government of India	Mid-carrier training programme for senior IFS officers	Funding agency
IGNFA	Government of India	Mid-carrier training programme for senior IFS officers	Funding agency
INBIGS, ONGC Jorhat	Public sector company	Microbial biotechnology	Funding support
India Smart Grid Forum (ISGF)	Public–private partnership (PPP) initiative under the Ministry of Power, Government of India	Smart grids	Institutional member under working group: five on renewables and micro-grids
Institute of Bioresources and Sustainable Development, Imphal	Government organization	Biodiversity and bioprospecting	Collaborative project partners

Partner	Profile	Focus Area	Type of Association
Indian Council of Agricultural Research	Government of India	Studies on thermal degradation of crop residues for kinetics, bio-polymeric transitions and value added products	Funding
Indian Institute of Technology (IIT), Delhi	Government of India	Microbial biotechnology	Collaborative project partner
Indian Institute of Technology (IIT), Guwahati	Government of India	Microbial biotechnology	Collaborative project partners
Indian Institute of Technology (IIT), Madras	Government of India	Microbial biotechnology	Partnership network
Indian Oil Corporation Ltd	Public sector undertaking	Bioremediation of oily and acidic sludge	Funding support
Institute of Reservoir Studies, ONGC, Ahmedabad	Public sector company	Microbial biotechnology	Partnership network
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
International Water Association	Association, international	Water	Collaborative and partnership
JEEViKA	Government of India	Livelihood and women empowerment	Local support for project Implementation
Jharkhand Education Project Council	Government of Jharkhand	Education	Support for project
Karnataka Forest Department	Government of India	Forest and biodiversity	Funding
Karnataka State Pollution Control Board	Government of India	Pollution	Funding
Karnataka Watershed Department	Government of India	Watershed management	Funding
KRIDL	Government of Karnataka	Energy-efficient commercial buildings	Funding support
Lawrence Berkeley National (LBNL)	Independent laboratory of the Department of Energy, Government of USA	Demand forecasting and electric vehicles	TERI's partner institute in the US for the UI-ASIST project

Partner	Profile	Focus Area	Type of Association
Maharashtra Forest Department	Government of India	Preliminary study on implementation of FRA and vulnerability of forests and forest-dwelling communities in Maharashtra	Funding agency
MECON	Central Government	Energy-efficient commercial and factory buildings	Funding support
Meghalaya Energy Corporation Ltd	Government of Meghalaya	–	BEE Capacity building on DSM and EE, and load research
Ministry of Environment, Forest and Climate Change	Government of India	Cultivation of packing leaves plant for livelihood enhancement of ST communities and promotion of packing leaves as substitute of plastics in Meghalaya	Funding support
Ministry of External Affairs	Government of India	Renewable Energy	Funding support and partnership
Ministry of Food Processing Industries	Government organization	Infrastructure support	Funding support
Ministry of Housing and Urban Affairs	Government of India	Empanelled Consulting Firm for Smart City Mission	Advisory
Ministry of Mines and Indian Bureau of Mines	Government of India	Conducted national workshop titled Remediation of Mined-out Areas and Abandoned Mines: status and strategies	Funding agency
Ministry of New and Renewable Energy	Government of India	Implementation of national-level RPO portal for RPO monitoring	Funding
Ministry of Tribal Affairs	Government of India	Developing governance models for implementation of community forest resource rights under FRA, 2006	Funding agency
Mizoram University	Government of India	Biodiversity and bioprospecting	Collaborative project partners
Nagaland Forest Department	Government of India	Assess the biodiversity status of CCAs in Nagaland, carrying out GEF Satoyama project titled 'Mainstreaming Community-conserved Areas for Biodiversity Conservation in Nagaland	Partner in field implementation
Nagaland University	Government organization	Biodiversity and bioprospecting	Collaborative project partners

Partner	Profile	Focus Area	Type of Association
National Capital Region Planning Board (NCRPB)	Government of India	Expert member of the study group on environment for National Capital Region Planning Board (NCRPB)	Expert member
National and State Biodiversity Board	Government of India	Consultancy Services for Monitoring and Evaluation of NMPB Schemes, State Biodiversity Strategy and Action Plan under BIOFIN project	Funding agency
National Environmental Engineering Research Institute (NEERI), Nagpur	Research institute	Environmental pollution, wastewater	Collaborative research
National Health and Medical Research Council (NHMRC)	Australian Government	Expert body: supporting health and medical research	Support for projects
National Himalayan Mission Studies	Government of India	Skill development	Support for project
National Institute of Hydrology	Government of India	Hydrology	Collaborative research
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	Government organization	Microbial Biotechnology	Funding support
National Institute of Technology, Rourkela	Government organization	Microbial biotechnology	Collaborating project partners
National Institute of Urban Affairs, New Delhi	Government organization	Capacity building	Funding support
National Renewable Energy Laboratory (NREL)	Independent laboratory of the Department of Energy, Government of USA	Power system balancing, scheduling and dispatch and EVs and HIL testing	TERI's partner in the ETC India project for the work related to power system balancing requirements in 2030. NREL is also partner in UI-ASSIST
National Skill Development Corporation	Government of India	Awareness generation	Funding
National Water Mission, Ministry of Water Resources	Government of India	Water use efficiency	Funding

Partner	Profile	Focus Area	Type of Association
NHPC	Government of India	Valuation of the socio-economic and environmental costs and benefits of hydropower projects in India: case study of two selected projects including Bhakra Nangal Project and the Uri Project	Funding agency
Niti Aayog	Government of India	Drought mitigation	Funding
North Eastern Council	Government of India	Capacity building programme for assisting state government officials in designing sustainable livelihood programmes and ecotourism	Funding support
North Eastern Hill University, Shillong	Government organization	Biodiversity and bioprospecting	Collaborative project partners
Norwegian Ministry of Foreign Affairs	Foreign Ministry, The Kingdom of Norway	Feasibility study: biomass gasifier,heat engine for micro-grid; designing a REDD-plus pilot project in India; developing Country Participation in Addressing Climate Change	Funding
NTPC (APCPL), Jhajjar	Public sector undertaking company	Microbial biotechnology	Partnership networking
NTPC (NETRA), Greater Noida	Public sector undertaking company	Microbial biotechnology	Partnership networking
NTPC Ltd	Government of India	Setting up of biomethanation plant at NTPC Farakka	Funding
NTPC Research Alliances (NETRA) Greater Noida	Government organization	Microbial biotechnology	Partnership network
NV Patel College of Pure and Applied Sciences, Vallabh Vidyanagar, Gujarat	Government organization	Microbial biotechnology	Collaborating project partners
Oil and Natural Gas Corporation (ONGC) Ltd	Public sector company	Bioremediation, consultancy for soil fertility improvement	Funding support
OIL Guwahati	Public sector undertaking	Green building consultancy	Funding support
Oil India Ltd (OIL)	Public sector company	Bioremediation of oily sludge, contaminated soil	Funding support

Partner	Profile	Focus Area	Type of Association
Oil India Ltd, R&D Centre, Duliajan, Assam	Public sector company	Microbial biotechnology	Funding support
ONGC Energy Centre	Government of India	Battery, fuel cell and supercapacitor as bulk energy storage options: study on technological advancements and market readiness	Funding
ONGC Energy Centre, ONGC Laxmi Nagar, New Delhi	Public sector company	Microbial biotechnology	Funding support
Ozone Cell: Ministry of Environment Forest and Climate Change	National Ozone Unit and nodal point for cooling sector	Contributed two chapters in the India Cooling Action Plan (ICAP): cross-cutting policy regulations and air-conditioning in transport Quarterly newsletter for servicing technicians in the air-conditioning sector	Collaborative funder
Planning Commission	Government of India	Consultancy for Impact Assessment-II of HP Mid-Himalayan Watershed Development Project	Funding agency
Public Health Engineering Department, Assam	Government of Assam	Sanitation	Funding support
Punjab State Power Corporation Ltd	Government of Punjab	–	World Bank DBT-E project
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
Sikkim Energy and Power Department	Government of Sikkim	–	BEE Capacity building on DSM and EE, and load research
South Delhi Municipal Corporation	Government of India	Third-party quality assurance for four biogas plants in South Delhi Municipal Corporation	Funding
State Institute of Panchayat and Rural Development, Guwahati	Government of Assam	Consultancy for detailed project report	Funding support

Partner	Profile	Focus Area	Type of Association
State Level Nodal Agency (SLNA), WDC-PMKSY, Assam	Government of Assam	Monitoring, evaluation, learning and documentation of projects implemented under Integrated Watershed Management Programmes (IWMPs)	Funding support
State Level Nodal Agency, Integrated Watershed Management Programme, Uttarakhand	Government of India	Watershed Management Programme	Funding agency
Surat Municipal Corporation	Government of India	Preparation of tender document, technical and financial bid evaluation; smart cities	Funding
Swedish Environmental Protection Agency	Government Agency, Sweden	India–Sweden Strategic Approach to Integrated Management of Bio-waste and Non-ozone Depleting Substance – non-HFC alternatives	Funding
Tamil Nadu Energy Development Agency	Government of India	Training and orientation module on sustainable energy for Tamil Nadu state government officials at strategic, management, and district levels	Funding
Tamil Nadu Generation and Distribution Corporation Ltd (TANGEDCO)	Government of Tamil Nadu	–	–
Tata Steel Ltd, Jamshedpur	Public sector company	Microbial biotechnology	Funding support
Tempere University of Technology, Helsinki, Finland	Government of Finland	Microbial biotechnology	Collaborative project partners
The Tribal Cooperative Marketing Development Federation of India	Government of India	Estimating minimum support Price for 50 minor forest produce	Funding agency
Tripura State Electricity Corporation Ltd	Government of Tripura	–	BEE Capacity building on DSM and EE, and load research
Tripura University	Government of Tripura	Biodiversity and bioprospecting	Collaborative project partners
United States Agency for International Development	Government of USA	Water, sanitation, and hygiene	Funding support

Partner	Profile	Focus Area	Type of Association
University of Eastern Finland	International organization	Partnership for the mid-career training programme for IFS officers Sustainable Bioenergy Solution for Tomorrow (BEST) Rural Biomass Survey	Partner in project implementation
University of Guyana	International organization	Feasibility study for bio-diversity centre at the University of Guyana	Funding agency
Uttar Pradesh Forest Department	Government of India	Preparation of afforestation and reforestation CDM PDD, facilitation of validation, registration and verification. Monitoring and capacity building of UPFD staff on monitoring; conservation of protected areas through carbon finance: implementing a pilot project for Dudhwa Tiger Reserve (DTR)	Funding agency and partner in field implementation
Uttarakhand Biodiversity Board	Government of India	Development of state biodiversity strategy and action plan of Uttarakhand	Funding agency
WAPCOS	Government	Integrated water resources management (IWRM)	Funding
West Bengal State Electricity Distribution Company Ltd (WBSEDCL)	State-owned distribution utility in West Bengal	BESS, EVs, agro-voltaics	WBSEDCL is principal partner in the MacArthur BESS project and for WB EV-related activities
Yale University	International organization	Partnership for the mid-career training programme for IFS officers	Partner in project implementation

Research & Academic Institutions

Partner	Profile	Focus Area	Type of Association
Abt Associates	Research organization	SLCP reduction from MSW management	Partner
Adelphi	International research organization	Climate change research; identification and analysis of good practice examples from international GHG mitigation and adaptation actions; Policy analysis and strategy consulting	Collaborative research; funder
Assam Agricultural University, Jorhat	University - National	Functional validation of genes	Collaborative research
Automotive Research Association of India	Research institute, India	Vehicle and air pollution research	Collaborative research

Partner	Profile	Focus Area	Type of Association
Bharati Vidyapeeth College of Architecture, Pune	Academic Institute, India	Collaboration for Training Programme	Knowledge-based partnership
Birla Institute of Technology and Science	Indian institution	Water remediation	Collaborative research
BMS Institute of Technology	Academic institute, India	Reviews, course works, workshops	Visiting faculty
Centre for Energy, The University of Western Australia, Perth, Australia	University	Microbial biotechnology	Collaborative project partners
Centre for Materials for Electronics Technology	Research institute	Logger and Sensors	Collaborative research
Center for Genomic Sciences, National University of Mexico, Mexico	University - International	Crop genetic enhancement	Collaborative research
Charles Darwin University and University of Melbourne	Academic institute	Construction and demolition waste	Collaboration
CICERO	International research organization	Climate research and environmental science/ environmental studies	Collaborative research
Climate Policy Initiative (CPI)	Independent think-tank and consultancy organization headquartered in the UK	Power system flexibility	TERI's partner in the ETC India project for the work related to flexibility requirements for the power system in 2030
Climate Transparency Platform	Research institute	Global partnership to examine G20 countries on climate action, finance and vulnerability	Collaborative research
CSIRO Energy Transformed Flagship, North Ryde, New South Wales	Research institute	Microbial biotechnology	Collaborative project partners
Deakin University	University-International	Nanobiotechnology	Collaborative research
DBT-ICGEB Center for Advanced Bio-energy Research, Center for Genetic Engineering and Biotechnology, New Delhi	Research institute	Microbial biotechnology	Funding support
DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, Mumbai	Research institute	Microbial biotechnology	Collaborative project partner
DBT-IOC Centre for Advanced Research on Bioenergy, R&D Centre, Indian Oil Corporation, Faridabad	Research centre	Microbial biotechnology	Collaborative partner
Delft University of Technology, Netherlands	University	Wastewater treatment	Collaborative research

Partner	Profile	Focus Area	Type of Association
Department of Environmental Engineering, Korea Maritime and Ocean University, Busan, South Korea	Research institute	Microbial biotechnology	Collaborative project partners
Department of Horticulture, Bihar	Government agency	Micropropagation	Supply of plants
Department for International Development	Academic and Research	Air pollution	Funding
Dr Alxendre S. Kellichenkoo, Director of Polytechnic Research Institute, Belarus National Technical University	Research institute	Microbial biotechnology	Collaborative project partners
Dr Edward McBean	University of Guelph, Canada	Climate change and water resources management	Collaborative projects
Dr HS Gour University, Sagar	University-National	Earthworm	Collaborative research
Dr Michel Mesquita	Uni Research Climate, Bjerkens Centre for Climate Research, Norway	Climate change and water resources management	Collaborative projects
EMPRI	Research Institute	Forest and biodiversity	Funding agency/ collaborative research
Finnish Meteorological Institute	Academic and research: international	Vehicle and air pollution research	Collaborative research
Helsinki Environmental Research, Helsinki, Finland	Institute	Microbial biotechnology	Collaborative project partners
IASS	Research organization	Leveraging the co-benefits from transitioning to renewable energy	Collaborative research
Indian Agricultural Research Institute, Pusa, New Delhi	Research institute	Algae; genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals; Crop productivity; Virtual Joint Centre: India-UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
ICAR–Indian Institute of Rice Research	Research institute	Crop genetic modifications	Collaborative research
Indian Institute of Chemical Technology (IICT), Hyderabad	CSIR Institute, Government of India	Microbial biotechnology	Collaborative project partner
Indian Institute of Technology Guwahati	Research institute	Microalgae	Collaborative research

Partner	Profile	Focus Area	Type of Association
Indian Institute of Technology, Mandi, Himachal Pradesh	Research institute	Microbial biotechnology	Collaborative partner
INESC TEC, Portugal	International R&D Institute	Science and technology	Collaboration on research projects
Institute for Advanced Sustainability Studies	Academic and research institute: international	Air pollution	Funding
Institute of Advanced Studies for Science and Technology, a unit of DST, India	DST Unit, Government of India	Microbial biotechnology	Collaborative project partner
IGES (Institute for Global Environmental Strategies), Japan	Research organization	Collaborated to conduct a climate policy research workshop at New Delhi, on the basis of which a submission for the Talanoa Dialogue, "Maximizing multiple co-benefits How do we get there?" was developed	Research collaboration
International Growth Center (IGC)	Research centre	Solid waste management	Funding support
John Innes Centre, UK	University	Virtual Joint Centre: India-UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
KS School of Architecture, Bengaluru	Academic Institute	Lecture and green building tour	Knowledge-based partnership
London School of Hygiene & Tropical Medicine (LSHTM)	University	Health research	Collaborative research
Metropolia Institute of Technology, Helsinki, Finland	Institute	Microbial biotechnology	Collaborative project partners
MGIRED	Academic institute	Academic course works, reviews	Visiting faculty
Monash University	International University	Research on infectious disease, epidemiology, public health and preventive medicine	Collaborative research
Motilal Nehru National Institute of Technology (MNNIT), Allahabad	Research institute	Microbial biotechnology	Collaborative partner
National Environmental Engineering Research Institute (NEERI), Nagpur	Research institute	Environmental pollution, wastewater	Collaborative research
National Institute of Environmental Health Sciences	Research institute	Health effects	Funding support

Partner	Profile	Focus Area	Type of Association
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	Research institute	Microbial biotechnology	Collaborative partner
National Oceanic and Atmospheric Administration (NOAA)	Research institute	Climate change	Funding support
National Research Centre for Plant Biotechnology	Research institute	Crop genetic modification	Collaborative research
NDC Partnerships	Research and collaboration	UNFCCC and WRI initiative to gather countries and associate members to create repositories of knowledge and enhance cooperation for achieving the NDCs	Research collaboration
Netherlands Institute of Ecology (NIOO-KNAW), Netherlands	Research institute	Wastewater	Collaborative research
NIT Trichy	Academic institute	Academic course works, reviews	Visiting faculty
NITK, Surathkal	University	Consultancy	Collaborative research
North Carolina State University (NCSU)	University	Consultancy	Collaborative research
Nottingham Trent University	University	Sustainable mobility	Collaborative research
Oil India Laboratory, Chemical Department, Duliajan, Assam	Research institute	Microbial biotechnology	Collaborative partner
Oxford Brookes University, Development Alternatives and UN-Habitat	Consortium Partnership	Mainstreaming sustainable social housing in India	Collaboration
PES University	Academic institute	Academic course works, reviews	Visiting faculty
RENAC	Training and capacity building	Leveraging the co-benefits from transitioning to renewable energy	Collaborative research
Sardar Patel University, Bakrol, Anand, Gujarat	Research institute	Microbial biotechnology	Collaborative research
Shakti Sustainable Energy Foundation	Foundation: India	Low-carbon development	Funding
SJB College of Architecture	Academic institute	Academic course works, reviews	Visiting faculty

Partner	Profile	Focus Area	Type of Association
Sofocle Technologies Ltd	Blockchain developer	Blockchain for P2P solar power trading	Prototype development for rooftop solar PV P2P trading
Swiss Agency for Development and co-operation	International development and co-operation	Air pollution research	Funding
Talent Institute of Architecture, Kerala	Academic Institute	Lecture and green building tour	Knowledge-based partnership
The African Centre for Technology Studies (ACTS)	Research institute	Non-state climate action	Research collaboration
The Blavatnik School of Governance at Oxford University, UK	Research institute	Non-state climate action	Research collaboration
The German Development Institute/ Deutsches Institut für Entwicklungspolitik (DIE), Germany	Research institute	Non-state climate action	Research collaboration
Trans-disciplinary University	Research institute	Ecology	Collaborative research
UfU	Research organization	Leveraging the co-benefits from transitioning to renewable energy	Collaborative research
UNEP DTU Partnership	UN Environment collaborating Centre and a leading international research and advisory institution	Climate change mitigation and MRV frameworks	Research collaboration
University of Agricultural Sciences, Bengaluru	University	Agricultural research	Collaborative research
University of Algarve, Portugal	International university	Marine and coastal research	Collaboration on research projects
University of Aveiro, Portugal	University	Developing porous ceramics from waste	Collaborative research
University of California, San Diego, USA	International academic institute	Air pollution on health	Funding support and research partner
University of Delhi South Campus, New Delhi	University - national	Functional validation of genes	Collaborative research
University of Maribor, Slovenia	University	Chemistry and Chemical Engineering	Collaborative research
University of Oxford, UK	University - International	Virtual Joint Centre: India-UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
University of Pannonia, Veszprem, Hungary	Research institute	Microbial biotechnology	Collaborative project partners

Partner	Profile	Focus Area	Type of Association
University of Salerno, Italy	University	Wastewater treatment	Collaborative research
Wageningen University and Research, Netherlands	University	Wastewater treatment	Collaborative research
Washington State University	Academic institution in the USA	BESS at distribution level	WSU is the US lead of the UI-ASSIST project consortium of which TERI is a research partner

Banks & Financial Institutions

Partner	Profile	Focus Area	Type of Association
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been working jointly with partners in India for sustainable economic, ecological, and social development	Rooftop solar PV promotion	TERI, with support from GIZ, provided Project management Consultancy (PMC) support for rooftop solar PV plants installation to one of the distribution utilities in Madhya Pradesh. TERI, along with GIZ, also helped in launching the 'Dwarka solar city' initiative in Delhi
Lavasa Corporation Ltd	Private organization	Biodiversity compliance document for Lavasa	Funding agency
NABARD	Development bank	Capacity building	Support for projects
World Bank	International financial institution	Consultancy services for baseline survey for UDWDP and GEF-SLEM project in Uttarakhand and MHWDP in Himachal Pradesh aided by World Bank	Funding agency
YES Bank	Private organization	Knowledge partnership with TERI for Yes Bank Natural Capital Awards	Knowledge Partner

Domestic & Multinational Corporations

Partner	Profile	Focus Area	Type of Association
Agriculture Insurance Company Ltd	Private	Rural development	Funding partner
Cenergist	Private organization	Energy efficiency	Partner
Chem Fab Ltd	Private organization	Carbon sequestration through plantation activities at Chem Fab Ltd	Funding agency
Coal India Ltd	Coal mining company	Sanitation	Funding
Deccan Chemicals Pvt. Ltd	Corporate	Capacity building	Funding agency
Fraunhofer IBP	Consultancy firm	Energy-efficient cold storages	Knowledge-based partnership
GIPCL	Private organization	Developing action and monitoring plan for reclamation of mine-degraded lands and addressing socio-economic and livelihood issues of fringe populations of Vastan Lignite Mine of GIPCL, Mangrol, Surat	Funding agency
GIS Polymers	Polymer industry	Fire-retardant cable sheaths	Collaborative research
Hindalco Industries Ltd	Private organization	Reclamation of back-filled area of bauxite mines through afforestation activities at HINDALCO, Lohardaga, Jharkhand	Funding agency
Indus Towers	Private	Energy access for promotion of livelihood	Support of project
Infosys-Green Initiatives	Consultancy firm	Efficient cooling systems	Knowledge-based partnership
Interglobe Real Estate Ventures Pvt. Ltd	Corporate association	Green building consultancy	Funding support
ITC	Private organization	Development of clonal propagation techniques	Collaborative research
Jain Irrigation Systems Ltd	Corporate	Irrigation, water-use efficiency	Partner
JMC Pvt. Ltd	Contractor	Green Building Consultancy	Funding support
Larsen & Toubro Company Ltd	PMC and contractor	Green building consultancy	Funding support
L'Oréal	International personal care company	Bio char	Funding
Mahindra Lifespaces	Developer	Energy efficient envelopes and sustainable water use in habitats	CSR
Marico Industries	Private industry	Circular economy	Funding support
Mind Wagon Sustainable Design India Pvt. Ltd	Consultancy firm	Performance of façade systems	Funding Support

Partner	Profile	Focus Area	Type of Association
Network18Media & Investments Ltd	News channel network	Natural resources	Knowledge partner
Nirmal Seeds Pvt. Ltd	Industry	Mycorrhiza	Collaborative research
ONGC-TERI Biotech Ltd (OTBL)	Private	Bioremediation of oily sludge, contaminated soil, MEOR	Funding support
Pune Metal Finishers Association	Association	Resource efficient and cleaner production	Funding support and implementation partner
Ramboll-Environ Foundation, USA	Corporate, foreign	Environmental, health, and social issues	Supports for projects
Reliance Industries Ltd	Private sector corporation	Bioremediation of oily sludge, contaminated soil	Funding support
Royal Haskoning DHV	Consultancy firm	Energy-efficient buildings	Knowledge-based partnership
SABMiller India	Corporate	Manufacturers of beverages	Collaborative research
SB Industrial Engineering Pvt. Ltd	Private organization	Bioremediation of oily sludge, contaminated soil	Funding support
Signify Innovations India Ltd (formerly known as Philips Lighting India Ltd)	Private organization	Clean energy access	Funding partner
Transtech Green Power Ltd, Jaipur	Industry	Microalgae	Collaborative research and demonstration
Tech Mahindra, Hyderabad	Consultancy firm	Efficient cooling systems	Knowledge-based partnership
Tetra Pak India Pvt. Ltd	Corporate, India	Waste management	Funding support
Toyota Motor Corporation	Automotive manufacturer	Air pollution research	Funding support
United Breweries Ltd (UBL)	Breweries	Pond rejuvenation	Funding support
United Technologies Corporation	Industrial firm	Energy-efficient buildings	Funding support
VNV Advisory	Private	Carbon finance	Advisory partner

NGOs & Foundations

Partner	Profile	Focus Area	Type of Association
Adelphi Research, Germany	Not-for-profit research institute	Policy analysis and strategy consulting	Collaborative research and partner in field implementation
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
Centre for fly ash research and management	Not-for-profit organization	Commercialization of fly ash-based flame-retardant nanocomposites	Partner
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	Not-for-profit organization	Resource efficient and cleaner production (RECP)	Funding support
Dhaka Chamber of Commerce and Industry (DCCI), Bangladesh	Not-for-profit trade organization	Promotes private sector enterprises and businesses with advocacy, awareness and policy inputs to government	Collaborative research and partner in field implementation in Bangladesh
EIRC Consultancy Pvt. Ltd	Not-for-profit organization	Consultancy	Collaborative research
Ekal Foundation	Non-government organization	Education and local level livelihood generation	Local support for project implementation
IGSD	Non-government organization	EESL Bulk Procurement program of RACs Kigali Scientific Assessment Study	Funder
International Crops Research Institute for the Semi-Arid Tropics, Andhra Pradesh	Not-for-profit organization	Agricultural research for development in Asia and sub-Saharan Africa	Collaborative research
Krishi Rasayan Group, Kolkata	Not-for-profit organization	Research on development and field trials of encapsulation and sustained release of micronutrients	Collaborative research
MacArthur Foundation	Private foundation	Climate change mitigation, national GHG inventory management system, capacity building and research on enhanced transparency framework (Article 13 of the Paris Agreement) Developing a multi country learning platform for adoption of energy efficient air-conditioners	Funder

Partner	Profile	Focus Area	Type of Association
MS Swaminathan Research Foundation, Chennai	Not-for-profit organization	Agricultural research	Collaborative research
National Cleaner Production Center (NCPC), Sri Lanka	Non-profit company	Consultancy and advisory services, information dissemination, training and capacity building, policy advocacy	Collaborative research and partner in field implementation in Sri Lanka
NRDC	Non-government organization	Climate change: 'Identification of pilotable technology options for cooling sector in India'	Funder
Shakti Sustainable Energy Foundation	Funding agency	Climate change: 'Identification of pilotable technology options for cooling sector in India' Contributing to the chapter in the India Cooling Action Plan (ICAP) Report: "States and Trends of Refrigerant Industry" Tracking Montreal Protocol negotiations	Funder
Society for Environmental and Economic Development Nepal	Non-government organization	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
Wellcome Trust	Foundation	Health research	Funding support

Multilateral & Bilateral Organizations

Partner	Profile	Focus Area	Type of Association
Abt Associates	International organization	Stakeholder engagement and biogas project tracking for India Methane Emissions Reduction Efforts through the Global Methane Initiative	Funding
Battelle Memorial Institute	International organization	Strategic planning and stakeholder engagement for Mexico Methane Emissions Reduction Effort through the Global Methane Initiative	Partnership
Big Solar Ltd	International organization	Unique low-cost scalable PV technology	Funding

Partner	Profile	Focus Area	Type of Association
CharIN	Association of automotive manufacturers and other relevant organizations responsible for development and promotion of the combined charging standard (CCS)	CCS EV charging standard	TERI is an associate member of CharIN and spearheaded the organization of the First CharIN EV India seminar
Climate Technology Centre and Network	International organization	Climate change	Collaborative partner
Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ)	International organization	Study of mini grids in India; conducting situation analysis and capacity needs assessment vis-à-vis human wildlife conflict in India under the Indo-German Project, "Human Wildlife Conflict Mitigation" being implemented by MoEFCC and GIZ India	Funding
Energy Transitions Commission, India	Multi-stakeholder platform	Potential assessment of floating solar PV	Funding
Energynautics GmbH	International organization	Policy and regulatory framework on power generation	Partnership
European Union	Mutilateral organization	Circular economy and resource efficiency	Collaborative research
Germanwatch e.V.	International organization	De-risking investment in solar energy	Funding
INBAR	International organization	International network for bamboo and rattan: feasibility study on livelihood and market potential of Bamboo in north-east of India	Funding agency
ICIMOD	International organization	One day events on REDD+ and carbon financing in partnership with ICIMOD	Collaboration in event and knowledge partners
International Council for Local Environmental Initiatives	International organization	Design, supply, installation and commissioning of 2 tonnes/day capacity biomethanation plant	Funding agency
India Energy Storage Alliance (IESA)	Alliance of major organizations working in energy storage	Energy storage	TERI is a member of the IESA
International Finance Corporation	Multilateral organization	Development of GHG calculator for distributed rooftop solar PV projects	Funding agency
IUCN	International organization	Best practices for watershed development in Indian Himalayan region	Funding agency

Partner	Profile	Focus Area	Type of Association
JICA	International organization	Carrying out JICA-funded projects in Uttar Pradesh, Arunachal Pradesh	Funding agency
KfW Germany	Bilateral agency	Energy efficiency	Funding agency
Madon Applied Sciences	Private organization	Raw substrate analysis for sewage sludge and rice straw for estimation of bio-methane potential	Funding agency
Maxop Research and Testing Institute Pvt. Ltd	Private organization	TERI–MAXOP solar research and test facility	Partnership
MSA Bio-Energy Pvt. Ltd	Private organization	Preparation of feasibility study cum detailed project report for solar PV and biogas systems in three municipalities of Puerto Rico	Funding agency
Shakti Sustainable Energy Foundation	Private organization	Clean energy roadmap for Lakshadweep and Andaman and Nicobar Islands: phasing out existing diesel-based energy systems	Funding agency
Swiss Agency for Development and Cooperation	International company	Accelerated usage of biomass-based clean energy systems	Funding agency
TATA Steel Ltd	Multinational organization	RE assessment and strategy development	Funding agency
The Cadmus Group LLB,Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ)	International organization	Indo–German Solar partnership—PV Roof Top India	Funding agency
The Indian Woods Products Company Ltd	Private company	Feasibility study for potential applications of waste generated from gambier during catechin extraction	Funding agency
The John D and Catherine T MacArthur Foundation	International organization	Integration study for the grid operation in Andaman and Nicobar islands for proposed solar capacity and decentralized solar PV near the rural user end so as to minimize distribution losses	Funding agency
The United Nations Development Programme	Multilateral organization	Energy efficiency	Funding, partnership

Partner	Profile	Focus Area	Type of Association
The United Nations Industrial Development Organization	Multilateral organization	Energy efficiency, renewable energy	Funding support and partnership
UNEP DTU Partnership ICCCAD CSIR-South Africa Government of Colombia	UN environment collaborating centre and a leading international research and advisory institution, research and training centres, government bodies	Climate change adaptation and MEL frameworks	Research collaboration
The United Nations Framework Convention on Climate Change	International organization	Jointly conducted three events on land degradation in the WSDS 2018	Collaboration in event
US Environmental Protection Agency (USEPA)/ Abt Associates	International organization	– Advancing agricultural biogas projects: technology, policy, and financing options – GHG mitigation	Funding support and partnership
World Bank	Multilateral organization	Energy efficiency	Funding agency

KNOWLEDGE
CONTRIBUTIONS

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- Sethi G. Member, Energy Management Sectional Committee of Bureau of Indian Standards (BIS)
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- Bansal K C. Member, Quinquennial Review Team of ICAR- NIBSM, Raipur
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- Bansal K C. Member, Planning and Monitoring Board, National Institute of Food Technology, Ministry of Food Processing Industries, Government of India
- Bahadur N. Vice-Chair, National Executive Committee, International Water Association-India (IWA-India)
- Bahadur N. Member, International Programme Committee, Singapore International Water Week, Singapore
- Bhattacharya S, Balakrishnan M, and Batra V S. Reviewers for various Elsevier Wiley and Springer international journals
- Kumar A. 2019. FEPS United for Climate Justice Steering Committee Meeting. Madrid, Spain.
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- Manuja S. Member, Review Panel, Journal of Packaging Technology and Research, Springer International Publishing
- Manuja S. Member, Review Panel, PHI learning Pvt. Ltd
- Pandey S. Member, Editorial Board, ICE: Waste and Resource Management
- Pandey S. Member, Review Panel, Waste Management, Elsevier
- Sehgal M. Global Health Action
- Sehgal M. Journal of Environmental Pollution and Control (JEPC)
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- Seth S. CEO, GRIHA Council as a Jury Member and Honorary Member – Editorial Advisory Board of Architecture Update, AU Innovation Awards, 2019, Saffron Synergies Pvt. Ltd
- Seth S. CEO, GRIHA Council as a Principal Member – Core Committee Member for Revision of IEQ Standard, ISHRAE, 10 May 2018 onwards
- Seth S. CEO, GRIHA Council as a Principal Member – Core Committee Member for development of ISHRAE's Standard for Commissioning of HVAC systems under the Chairmanship of the Committee, Ramachandran (former President ISHRAE), 30 May 2018 onwards
- Seth S. CEO, GRIHA Council as a Jury Member – French Accelerator Programme 'Smart Cities Connection Days in India', 20 June 2018 onwards
- Seth S. Senior Director, Sustainable Habitat Programme, TERI, Principal Member, National Building Code Sectional Committee, CED 46 under the Civil Engineer Division Council, Bureau of Indian Standards (BIS), 19 April 2018 onwards
- Seth S. Senior Director, Sustainable Habitat Programme, TERI, Mentor for India Smart Cities Fellowship Program 2019–20 (Enhancing Cities Capacity for Emissions Reduction in the Building Sector - MITIGATE), Ministry of Housing and Urban Affairs, Government of India, 8 April 2019 onwards
- Seth S. Senior Director, Sustainable Habitat Programme, TERI, Sub-group Member Green Buildings and Energy, Ministry of Housing and Urban Affairs, Government of India, 31 January 2019 onwards
- Seth S. Senior Director, Sustainable Habitat Programme, TERI, COI Housing Member, SWITCH-Asia SCP Facility, 25 January 2019 onwards

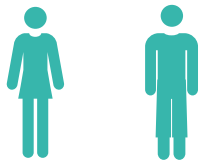
HUMAN CAPITAL AND INFRASTRUCTURE FACILITIES

HUMAN CAPITAL

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

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

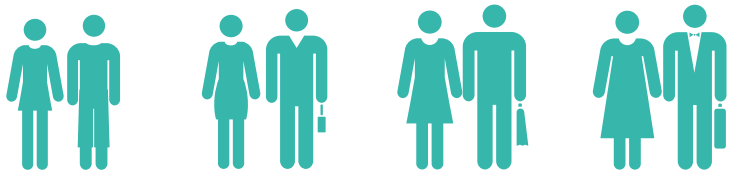
GENDER



32% Female

68% Male

AGE DISTRIBUTION



26% AGE 22-30 YEARS

31% AGE 31-40 YEARS

24% AGE 41-50 YEARS

19% AGE 51 AND ABOVE

QUALIFICATION

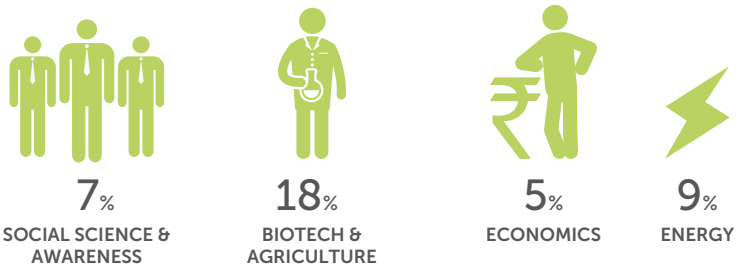
24% GRADUATE

52% POSTGRADUATE

14% PhD

OTHERS 10%

SPECIALIZATION



7% SOCIAL SCIENCE & AWARENESS

18% BIOTECH & AGRICULTURE

5% ECONOMICS

9% ENERGY

15% ENGINEERING

5% INFORMATION & TECHNOLOGY

29% OTHERS

12% ENVIRONMENT

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 2018/19.

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 Gual 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.

In Vitro Mass Production Technology

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

DNA Fingerprinting and Molecular Breeding Lab

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

Plant Genetic Transformation and Functional Genomics Laboratory

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

Micropropagation Technology Park

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

Herbal Garden at Supi

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

TERI–Deakin Nanobiotechnology Research Centre

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

Fermentation Technology and Research Centre

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

Supercomputer to Enhance Climate Modelling Capabilities

TERI has acquired supercomputing facility to boost its activities on climate modelling. The supercomputer consists of 512 cores that can draw a peak performance of 5.5 T Flops. Total RAM is 1,000 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.

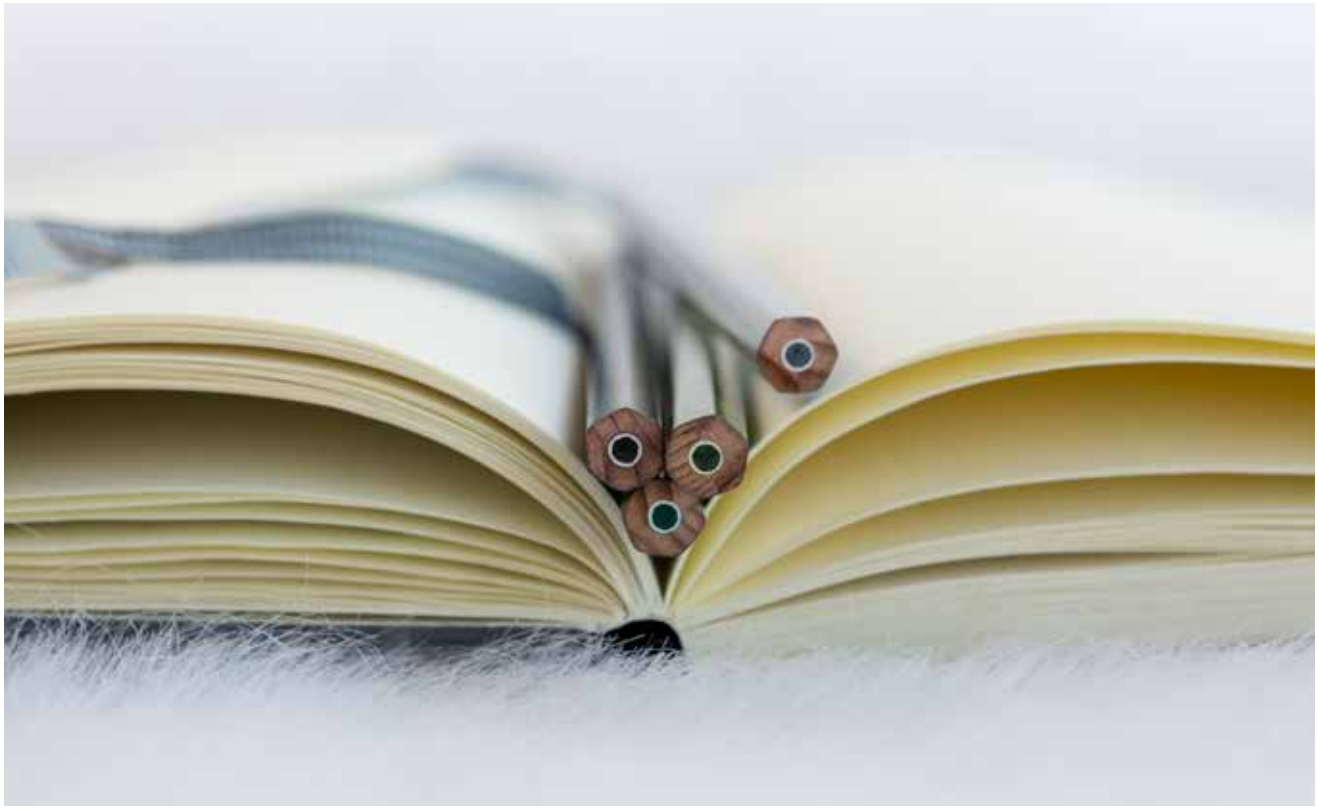
Test Bed Facility, Gual Pahari

TERI and Somfy India Pvt. Ltd have came together to set up a Test Bed Facility at Gual 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



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- Second International Conference for Sustainable Design of the Built Environment: Research in Practice, 12–13 September, London

Sustainable Buildings, SRC Group

- Rahiman R, Jain A. 2018. Policies for Low-carbon Pathway and Role of Non-state Actors in India. In Book 1 (Sector-based Action) of the *Annual Report of the Global Observatory on Non-state Climate Action*, pp. 190–199. Climate Chance Association
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Transport and Urban Governance

- Climate Chance Association. 2018. *Climate Chance*. Sector-based Action: (Transport India) Policies for Low-carbon Pathway and Role of Non-state Actors in India. Details available at https://www.climate-chance.org/wp-content/uploads/2018/12/c1_book_transport.pdf
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- TERI. 2019. *TERI Energy & Environment Data Diary and Yearbook 2017/18.* New Delhi: TERI
- Thakur P, Pal S. 2018. Shifting Towards Clean and Green Technological Solution for Auto- rickshaws in Bengaluru. *TERAGreen.* New Delhi: TERI

Workshops/ seminars

- Chaudhury S. 2018. Presented "Green-field versus M&A: Role of FDI on Economic Growth in South Asia" in 6th EITTF conference in IIFT, Delhi
- Mathur R. 2019. Guest of Honor at ASSOCHAM Summit on Promoting Green, Sustainable and Innovative MSMEs in India, 24 April, Delhi, India Mathur R. 2019. Shell LNG Outlook. 10 April, Delhi
- Mathur R. 2019. Panel discussion titled "Parched Power: s show on water demands, risks, and opportunities for India's Power Sector". Organized by WRI. 15 March, Delhi
- Mathur R. 2018. Speaker in the National Workshop on Energy and Environment modeling, 29 October, New Delhi
- Mathur R. 2019. Presented on "Energy Efficiency Program Design and Implementation: measurement, evaluation, and data systems" in Industrial Energy Show, 3 May, Delhi
- Mathur R. 2019. Session on Climate Change and Energy Security at Young Thinkers' Conference. 12 October 2018, Chandigarh, India
- Mathur R. 2018. Panellist for the TERI-MoEFCC discussion on the IPCC Special Report on 1.5^{0}C. 15 October, New Delhi
- Shekhar S. 2018. Presented "Climate Change Mitigation in India: Short term vs. Long term" in side-event entitled "What a low-carbon world really looks like in the next decades: Modelling Tools Used and Required for Long Term Planning" at 24th Conference of Parties (COP24), Katowice, Poland
- Shekhar S. 2018. Presented "India's Energy-Environment Synergies and Trade-offs" at 11th Annual Meeting of the Integrated Assessment Modeling Consortium (IAMC), Seville, Spain
- Shekhar S. 2018. Presented "Initiatives to Strengthen Modeling Capacities: Experience from India" in the Paris Committee on Capacity Building (PCCB) at 24th Conference of Parties (COP24), Katowice, Poland
- Shekhar S. 2018. Presented "National perspectives on long-term low-emission pathways: India" in side-event entitled "Towards Long-Term National Scenarios: Modeling meets Policy" at SBSTA, Bonn, Germany

Patents

- Patent applied for "An Energy Efficient Solar Hybrid Power Charging Station (Power Source) for Looms and Method".
- Patent application submitted on 31/12/2018 / Docket No.: 104611 / To: Patent Office, IP Office Building, Dwarka, New Delhi 110078

Conferences

- Adholey A. 2018. Speaker, Indo-Caribbean Conference on Development and Optimization of Method for the Analysis of Pharmaceuticals, 18–19 July, Gwalior
- Adholeya A. 2019 (April). Speaker, Biotikos 2019, TERI University, New Delhi
- Adholeya A. 2019. ISRR-10, Exposing the Hidden Half Root Research at the Forefront of Science International Symposium, 7–11 July, Israel
- Adholeya A. 2019 (March). National Conference on Biotechnology and Environment for Sustainable Development (BioESD2019)" in Jaipur, from 29–30 March 2019
- Adholeya A. 2019 (March). Workshop on Biotechnology Start-up Ecosystem in India, BCIL, New Delhi
- Adholeya A. 2019 (May). Speaker, Deakin Agritech Conference Australia
- Adholeya A. 2019. As Speaker National Conference on Recent Trends in Chemical Sciences and RSC Workshop on Periodic Table : Boon for Mankind, Delhi University, Delhi
- Adholeya A. 2019. As Speaker, Leveraging Water Security for Sustainable Agricultural Water Management: Role of ICID. ICID Foundation, New Delhi
- Adholeya A. 2019. Chair, Session 10: sustainable management (agriculture, rangeland and forestry management), *Mycorrhiza in the Global Change Context,* ICOM10, Merida, Mexico
- Adholeya A. 2019. Keynote Speaker, BioAg World Congress on Investment and Sustainable Roll: challenges and opportunities, 20 February, Le Meridian, New Delhi
- Adholeya A. 2018. Speaker, Chemistry for Human Health and Environment (CHHE-2018), 15–16 December at Delhi University, Delhi
- Adholeya A. 2019. Keynote Speaker, International Conference on Building World Class Universities: strengthening of research ecosystem, New Delhi
- Adholeya A. 2019. Speaker, International Symposium on Biotechnology for Food-Nutritional Security and Organic Agriculture, Jorhat, Assam
- Bahadur N. 2018. Invited Speaker, Technical Session: innovating wastewater treatment in India, training programme for Central and State Pollution Control Board Scientists on Future Perspective of Environmental Biotechnology, 4–6 December, organized by TERI
- Bahadur N. 2018. Invited Speaker, EA Water Conclave and International Conference on Innovative and Sustainable Water Technologies and Best Practices, 23–25 August, New Delhi
- Bahadur N. 2019, Chair, Technical Session 1: industrial wastewater treatment, International Conference on Industrial Water, Energy and Environment ICIWE2; Theme: Environment, 25 January, Coimbatore
- Bahadur N. 2019. Invited Speaker, Advanced Oxidation Nanotechnology for Adequate and Sustainable Point Source Treatment of Sewage and Industrial Wastewater, 4th India Water Forum (IWF), 5–6 March, IHC, Delhi
- Bansal K C. 2019. Co-chair, Technical Session 4: Genetic Amelioration of Crop Plants for Better Nutrition**,** XIV Agricultural Science Congress, 20–23 February, NAAS, New Delhi
- Bansal K C. 2019. Keynote Speaker, International Conference on Advances in Biosciences and Biotechnology, 31 January–2 February, Department of Biotechnology, Jaypee Institute of Information Technology
- Bansal K C. 2019. Panellist, Agriculture 2030: Meeting SDGs, XIV Agricultural Science Congress, 20–23 February, NAAS, New Delhi
- Bansal K C. 2019. Speaker, MHRD-sponsored Pandit Madan Mohan Malaviya National mission on Teachers and Training, 16–19 March, Faculty Development Centre, Hansraj College, University of Delhi
- Chanana N P. 2018. Implication of Climate Change – Apple Cultivation in Uttarakhand, Technical Presentation, Summit on Climate Resilient Mountain Agriculture organized by Watershed Management Directorate, Uttarakhand, 2–3 May
- Das P. 2018. 2nd International Conference on Nano Science and Engineering Applications, 4–6 October, Pandit Jawahar Lal Nehru Technical University, Hyderabad
- Dwedi N. 2019. Identification of QTLs for Resistance to Chilli Leaf Curl Disease**.** XIV Agricultural Science Congress at NASC Complex, 20–23 February, New Delhi
  Gehlout S, Pandey A, Das R K, Schultz A, Singh P P. 2018. Biological Synthesis of Iron Oxide Nanoparticles for Agricultural Applications. 2nd International Conference on Nanobiotechnology for Agriculture – detection, conservation and responsible use of natural resources, 13–14 December, TDNBC, TERI Gram, Gurugram
- Goel M, Dureja P, Uniyal P L, Laatsch H. 2018. Lichens: a potential source of antibiotic agents. National Conference on Current Developments and Next Generation Lichenology, 27–28 January
- Kaur P. 2019. Polymeric Nanoformulations for Drug Delivery. Workshop: STC-BME at DCRUST, 14 February, Murthal, Haryana
- Kochar M. 2019. New Insights into Plant Growth Promoting Bacterial Functions: unravelling novel molecules and interactions. Invited Oral Presentation, 1st DBT BioCARe Conclave: women scientists achieving great heights, 8–9 March, New Delhi
- Kumari P. 2018. Oral Presentation on Photocatalytic Efficiency of

Doped Titania film on Stainless Steel Substrates via Electrospraying, 6th International Water Association - Regional Membrane Technology Conference, 10–12 December, Vadodara, Gujarat

- Priyam A, Das R K, Schultz A, Singh P P. 2018. Bio-synthesis and characterization of nanohydroxyapatite for potential use in agriculture as nano-P fertilizer. 2nd International Conference on Nanobiotechnology for Agriculture: detection, conservation, and responsible use of natural resources, 13–14 December, TDNBC, TERI Gram, Gurugram
- Reddy P M. 2018. Determination of influence of rice-secreted di-/tri-carboxylates on the structure and function of root/rhizospheric microbiome and nitrogen fixation. India–UK Nitrogen Fixation Centre Third Annual Review Meeting, ICAR-National Bureau of Agriculturally Important Microorganisms (NBAIM), 13–15 November, Mau, Uttar Pradesh
- Singh N, Singh B, Sharma P. 2018. Bee Keeping: TERI's initiatives towards sustainable development. Current Prospects of Bee Keeping in Uttarakhand

Poster Presentations

- Das P. 2018. International Conference on Nanobiotechnology for Agriculture, 13–14 December, TERI Gram, Gurugram
- Das P, Bahadur N, Dey P. 2018. Toxicity and Risk Assessment of Bare and Modified Titania Towards Safe Germination and Plant Growth. 2nd International Conference on Nanobiotechnology for Agriculture, 13–14 December, organised by TERI–Deakin Nanobiotechnology Centre, Gurugram
- Kaur G, Dhar-Ray S, Reddy PM. 2019. Examining the Role of Lignin Biosynthesis in Conferring Resistance Against Sheath Blight Disease in Rice. XIV Agricultural Science Congress – innovations for agricultural transformation, 20–23 February, National Agricultural Science Complex (NASC), IARI Campus, New Delhi
- Kochar M, Koul K. 2019. New Insights into Plant Growth Promoting Bacterial Functions: unravelling novel molecules and interactions. Poster Presentation, 1st DBT BioCARe Conclave: Women Scientists Achieving Great Heights, 8–9 March, New Delhi
- Nanditha K V, Verma A, Reddy P M. 2019. Optimization of regeneration and genetic transformation of Manipur black rice with citrate synthase gene for enhanced phosphorus uptake from soil. XIV Agricultural Science Congress – innovations for agricultural transformation, 20–23 February, National Agricultural Science Complex (NASC), IARI Campus, New Delhi
- Pandit A, Kochar M, Adholeya A. 2018. Cross-kingdom Interactions Between Mycorrhiza and Soil Bacterial Community in Relation to Host Plant Development. (Abstract No: AM/024). 59th Annual Conference of Association of Microbiologists of India and International Symposium on Host–Pathogen Interactions, 9–12 December, Hyderabad
- Sidhu G K, Reddy P M. 2019. Bioengineering of cyanobacterial CO2-concentrating mechanism (CCM) in rice. XIV Agricultural Science Congress – innovations for agricultural transformation, 20–23 February, National Agricultural Science Complex (NASC), IARI Campus, New Delhi
- Singh A, Altuzar-Molina A, Madina-Andres R, Samano-Lopez M, Reddy P M. 2018. Engineering the Nodulation Signaling Pathway in Rice Plant. 4th International Plant Physiology Congress, Organized by the Indian Society of Plant Physiology at the CSIR-National Botanical Research Institute, 2–5 December, Lucknow

Memoranda of Understanding

- Agreement for establishment of TERI–MAXOP Solar Research and Test Facility
- Agreement between TERI–Chanderpur Works Pvt. Ltd
- Agreement between TERI–University of Agder
- Business consultancy Agreement between TERI–Amplus Energy Solutions Pvt. Ltd
- Power purchase agreement signed between TERI– Fourth Partner Energy Pvt. Ltd
- Memorandum of understanding between TERI–STEAG
- Memorandum of understanding between TERI–BSES Yamuna Power Ltd

Portal

- Implementation of National Level RPO Portal for RPO Monitoring

FINANCIAL SUMMARY

FINANCIAL SUMMARY 2018/19

INFLOWS (₹ in Lakh)

97.29%
₹20,349.61
INCOME FROM PROJECTS

1.42%
₹296.64
INCOME FROM INVESTMENTS

0.86%
₹180.80
SALE OF PUBLICATIONS

0.43%
₹90.37
INCOME FROM OTHERS

TOTAL **100%** (₹ 20,917.42)

OUTFLOWS (₹ in Lakh)

41.30%
₹7580.62
SALARIES

2.24%
₹410.16
EQUIPMENT

0.42%
₹77.40
BUILDINGS

42.97%
₹7887.34
RESEARCH MATERIAL, TRAVEL

8.15%
₹1496.64
RENTAL,UTILITIES, INFRASTRUCTURE AND MAINTENANCE

4.92%
₹902.97
ADMINISTRATIVE EXPENSES

TOTAL **100%** (₹ 18,355.13)

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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