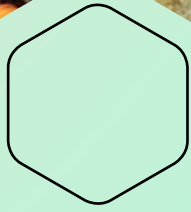
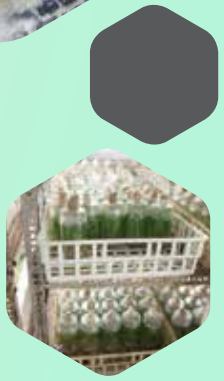
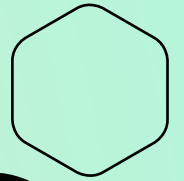


ANNUAL REPORT 2016/17



The Energy and Resources Institute

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

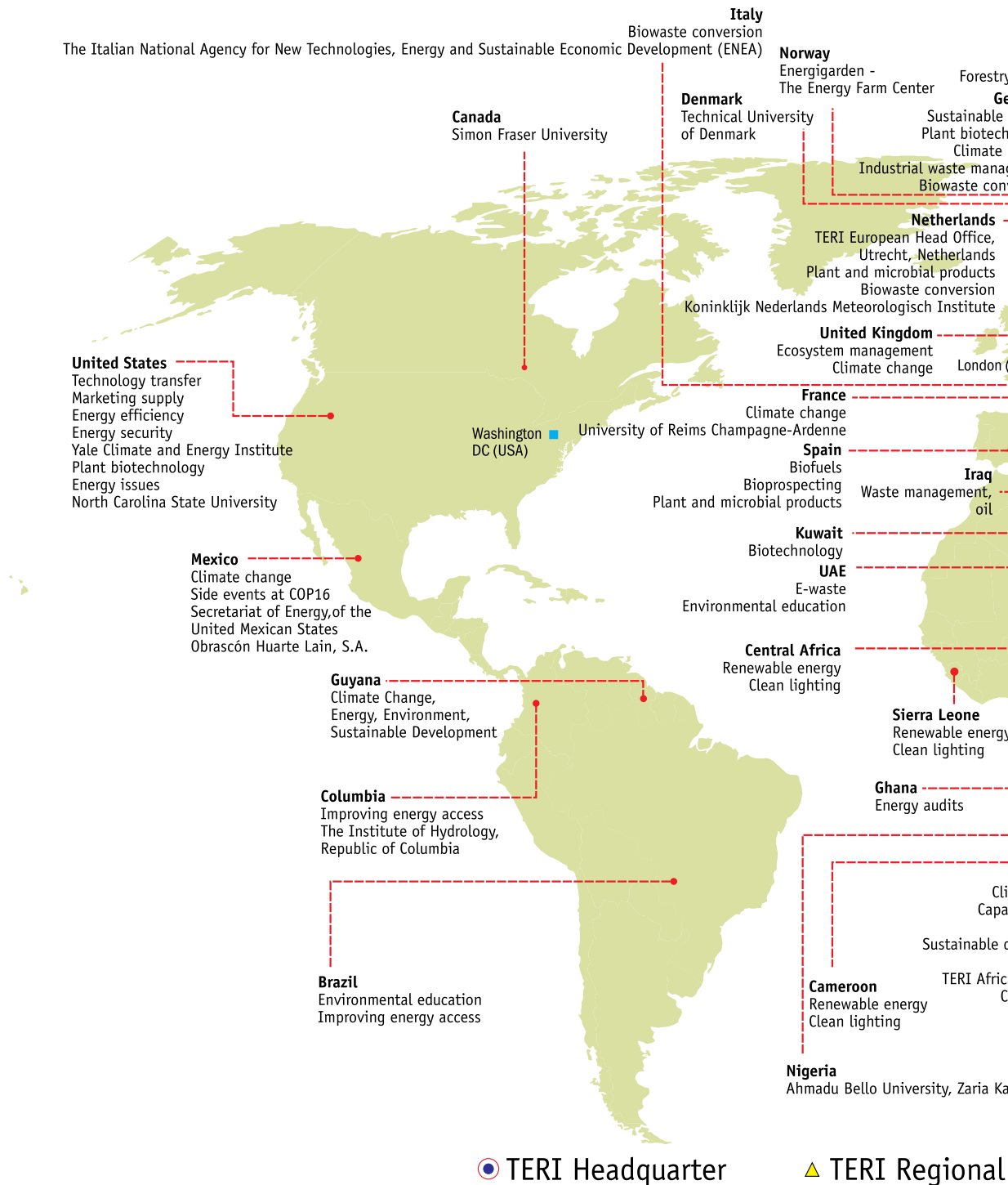
Enhance networking for sustainable interventions

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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TERI made significant contribution to global transition, creating and delivering 'smart' urban development solutions, environmental monitoring and modelling, sustainability in agricultural practices and water management, and application of modern biotechnology in daily life.



Director General's Message

The year 2016/17 has been an immensely significant and rewarding period for TERI. It witnessed a period of consolidation of the Institute's ongoing activities and initiation of several new ventures such that these fall within the ambit of TERI's vision and mission. During the year, TERI continued its work in the field of climate resilience, renewable energy technologies, participatory forest management, and knowledge generation. Besides, TERI made significant contribution to global transition, creating and delivering 'smart' urban development solutions, environmental monitoring and modelling, sustainability in agricultural practices and water management, and application of modern biotechnology in daily life.

In this context, it is significant to mention our work in the development and dissemination of a range of technologies, such as the development of the two-stage gasification of biomass (2SG technology) as a efficient biomass-based power generating technology for remote village electrification. With the intent of sharing knowledge and promoting adoption of biomass gasification technology in the African region, we have also been successful in creating a local platform through the technology transfer route. Our two focus activities—Solar Lighting Lab and the Center of Excellence for Thermal Energy—have been growing

successfully in their endeavour of meeting energy- and environment-related challenges.

During the year, we continued with our work towards building strong capabilities in the electricity and fuels sector, laying special focus on both conventional and non-conventional sources of energy. Of particular importance are the project-related activities in the scope of grid-connected solar rooftop PV for cities in India.

TERI, in collaboration with Electricity Transitions Commission (ETC) and Indian National Academy of Engineering (INAE), prepared and presented an assessment of demand for electricity in the country up to 2030 using econometric modelling and supply-side option of meeting the anticipated demand. The learnings from the study were presented as a report titled 'Transitions in Indian Electricity Sector—Macro Level Analysis of Demand and Supply Side Options' which was released by Shri Piyush Goyal, Hon'ble Minister of State (I/C) for Power, Coal, New and Renewable Energy, Government of India. The study indicates that demand for electricity will continue to grow and with improvement in power supply and reliability of supply, demand projections may undergo further increase as more and more consumers would shift to grid power. On the other hand, there could also be a downward pull due to more rapid increase in energy

efficiency in the future. A key finding of the study was that there is a high probability that we may move from the use of coal-based power plants in India.

During the year, TERI's microbial biotechnology activities also grew steadily in the direction of providing practical solutions. In particular, the extremely successful application of KT-Oilzapper technology in Kuwait continued its work of converting the oil-contaminated soils into ready-to-use plantation soils in a short period of 4–5 months.

During the year, we also continued our engagement with monitoring and evaluation of forestry, biodiversity, and watershed development related activities along with capacity building activities for state forest departments. In a major project undertaken with support of Coal India Ltd, we have focussed on a model for promoting sustainable livelihoods through agriculture, greening, training, capacity building, and income generation activities in Purulia district of West Bengal.

Another effort to make a difference at the grass roots level, involved bringing together the latest in techno-socio-institutional knowledge in order to deliver locally appropriate solutions to address the basic needs of the underserved communities. As of March 2017, Lighting a Billion Lives (LaBL), TERI's flagship initiative, completed 9 years of operations, impacting 5.3 million lives, across 23 states in India and 12 countries in Africa and South Asia. Introducing interventions to interconnect energy around associated aspects of development, such as health, education, livelihoods, empowerment, and mitigating climate change was the significant development of 2016/17.

We continued to set new benchmarks in the domain of industrial energy efficiency in terms of providing services to both large and small industries to improve their energy performance, introduce resource efficiency, and address sustainability considerations from a holistic perspective.

Emphasizing on knowledge generation, creation, and its dissemination, we engaged in developing value-added sectoral knowledge products, such as industry trend reports. We also conceptualized customized knowledge resources—from children's books to higher education and professional reference titles and magazines to journals—based on creating awareness in the areas of environment, energy, and sustainable development.

Carrying forward our vision of achieving sustainability in agriculture while conserving natural resources, the TERI Deakin Nanobiotechnology Centre uses nanotechnology and next-generation genomics interventions to devise ways of farming profitably.

In our constant endeavour to create resilient, sustainable, and 'smarter' cities via policy analysis, sustainable urban planning, capacity building, and knowledge creation, TERI has been recognized as a Centre of Excellence by the Ministry of Urban Development, Government of India. We have been empanelled as a consultant for the Smart Cities Mission of the Government of India. In this context, it is significant to note that TERI provided technical assistance to Dharamshala in the preparation of its Smart City Proposal. Dharamshala emerged as one of the top 3 cities among the list of winner cities selected in the Fast Track Round Challenge of the Government of India's Smart Cities Mission in May 2016.

Amidst the challenges posed by climate change, transition to cleaner and more energy efficient buildings is the need of the hour. In keeping with this need, the Eighth Edition of the GRIHA Summit was held in March 2017. The two-day Summit served as a platform for facilitating multi-stakeholder partnerships and networking among governments, academia, civil society organizations, and professionals from different disciplines, such as architecture, engineering, and construction management.

As part of our mandate towards policy analysis and technological development for management of solid and liquid waste, we implemented resource efficient cleaner production (RECP) measures and extended this work to 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.

During the year, we continued our pioneering work on the quantitative and qualitative assessment of water resources, water audit and water foot-printing, watershed management, glacier research, and urban water demand management. We undertook both implementation and awareness generation related activities in the Water and Sanitation Hygiene (WASH) sector. Building on our core competencies in environmental monitoring and modeling, impacts assessment, and policy analysis, we played a proactive role in suggesting measures to improve air quality at the urban and regional scales and advocating policies for clean and sustainable transport in the country.

In 2016/17, we continued our outreach and dissemination activities to spread TERI's message to varied audiences, including governments, academic and research institutions. We also expanded our network of schools and colleges in India to promote environmental education and awareness. As part of our school outreach efforts, we designed effective pedagogy to promote sustainability practices around water,



We also conceptualized customized knowledge resources—from children's books to higher education and professional reference titles and magazines to journals—based on creating awareness in the areas of environment, energy, and sustainable development.





Significantly, the International Centre for Climate Governance (ICCG) has rated TERI as the 2nd Top Climate Think Tank in the Rest of the World (i.e., outside Europe and the US).



sanitation, and hygiene in nearly 100 schools across the country.

In 2016 TERI's flagship event—Delhi Sustainable Development Summit (DSDS)—evolved further and unveiled in its new form as the World Sustainable Development Summit (WSDS), which was hosted during October 5–8, 2016. The event was organized under the broad rubric of 'Beyond 2015: People, Planet & Progress'. The event witnessed participation by various heads of state and senior ministers; heads of large multinational corporations, UN agencies, and bilateral and multilateral agencies; scientists who focused attention on the challenge of sustainable development and addressed issues pertinent to the future of humanity. The Hon'ble President of India Mr Pranab Mukherjee inaugurated the first edition of the WSDS. Congratulating TERI on organizing the summit, Mr Mukherjee said, "TERI has been consistent in its endeavour to find solutions and create new knowledge on issues relating to environment, climate, resources, and sustainable development." The Conference was among the first international platforms to discuss the new development agenda post adoption of the Sustainable Development Goals (SDGs) and signing of the Paris Agreement at the 21st Annual Conference of Parties (COP21). The event helped us enormously in continuing our efforts to be an agent of change towards sustainable development. TERI maintains that sustainability should not be a peripheral activity but should become a mainstream movement and that now is the time to translate all the promises to action. We aim to continue to expand the space for the sustainable development agenda in the years ahead.

In order to be better prepared for tomorrow, it is important to be able to understand, visualize, and explore the possible scenarios for future. The International Conference on Digital Libraries (ICDL) 2016 was organized with the objective of

addressing these issues to create a smart future. The ICDL 2016 was organized under the broad theme of 'Smart Future: Knowledge Trends That Will Change the World'.

We also engaged actively in creating interest and promoting TERI solutions and services and in exploring potential opportunities for collaboration with major funders in the OECD countries, central and state government agencies, large corporates, and CSR funds. During the year, TERI was granted a patent in India for developing a process to produce a novel biopesticide. Patents were also granted in Australia and South Africa for this product.

Overall, the year 2016/17 was a rewarding one for all of us at TERI. Significantly, the International Centre for Climate Governance (ICCG) has rated TERI as the 2nd Top Climate Think Tank in the Rest of the World (i.e., outside Europe and the US). It is a moment to cherish for all of us, particularly for the climate change team and all colleagues who have been working in areas related to climate change, and Indian and Global responses to the climate change. Their dedication and hard work has led to this recognition. Now, we need to focus towards the goal of reaching the pinnacle by becoming the topmost climate think tank in the mentioned category.

We have introduced a number of transformational and re-organizational changes that would enhance our effectiveness in implementing our priorities, our business drivers, our ways of working, and most importantly our people priorities and practices. A major reorganization has been designed as a result of several studies and assessments, and will be effective from April 1, 2017 (This new organizational structure is available on our website <<http://www.teriin.org/>>). These changes will help us in strengthening our capabilities through synergizing our domain competencies.

Ajay Mathur
Director General, TERI



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Who's Who at TERI



Mr Ashok Chawla
Chairman



Mr Deepak S Parekh



Dr Shailesh Nayak



Mr Hemendra M Kothari



Dr Henrik O Madsen



Dr Ajay Mathur



Dr Naushad Forbes



Prof. (Ms) Basabi
Bhaumik



Prof. (Ms) Laurence
Tubiana



Dr (Ms) Leena Srivastava
(Up to 30.10.2016)



Ms Naina Lal Kidwai
(Up to 04.05.2016)

The Management Team



Dr Ajay Mathur
Director General, TERI

Mr I H Rehman
DGO

Mr Prabir Sengupta
Knowledge Management

Ms Minni Sastry
Sustainable Habitat

Ms Akshima Tejas Ghatge
Sustainable Habitat

Mr Dinesh Varma
Human Resources

Mr Girish Sethi
Industrial Energy Efficiency

Dr Ritu Mathur
Integrated Assessments
and Modelling

Dr Prodipto Ghosh
Earth Science & Climate Change



Mr Pronab Dasgupta
TERI-SRC

Dr Banwari Lal
Environmental & Industrial
Biotechnology

Dr Alok Adholeya
Sustainable Agriculture

Ms Suruchi Bhadwal
Earth Science & Climate Change

Ms Rishu Nigam
Sustainable Development
Outreach & Youth Education

Mr Amit Kumar
Social Transformation

Dr Annapurna Vancheswaran
Sustainable Development Outreach
& Youth Education

Mr Anshuman
Water Resources

Mr Sanjay Sethi
Sustainable Habitat

Dr Suneel Pandey
Environment & Waste Management

Gp. Capt. (Retd.) Dr Rajiv Sethi
TERI University

Ms Livleen K Kahlon
Sustainable Development
Outreach & Youth Education

Mr Pradeep Kumar
Sustainable Habitat

Dr Anjali Parasnis
Sustainable Habitat

Ms Divya Datt
Integrated Policy Analysis

Dr Syamal Kumar Sarkar
Water Resources



Dr G R Narasimha Rao
Industrial Energy Efficiency

Col (Retd.) Sanjai Joshi
Administrative Services

Mr Shirish Garud
Energy Environment
Technology Development

Mr A K Saxena
Electricity & Fuels

Mr Debajit Palit
Social Transformation

Mr Puneet Chandra
Growth, Diversification &
Commercialization Unit

Dr Dipankar Saharia
Environmental & Industrial
Biotechnology

Dr Vibha Dhawan
DGO

TERI's Distinguished Fellows



Amb. C Dasgupta
Distinguished Fellow Emeritus,
Centre for Global Agreements,
Leg. & Trade Green Growth and
Resource Efficiency Division, TERI



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



Mr Nitin Desai
Distinguished Fellow, TERI;
Former Under-Secretary-General,
United Nations



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



Mr Prabir Sengupta
Distinguished Fellow, TERI;
Former Secretary, Ministries of
Commerce, Petroleum and
Natural Gas, Defence Production,
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



Prof. S L Rao
Distinguished Fellow Emeritus
Former Director General,
National Council of Applied
Economic Research



Dr Vibha Dhawan
Distinguished Fellow &
Senior Director, TERI



Mr Arvind Kaushal
Distinguished Fellow, TERI;
Former Secretary, ICAR



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



Dr P G Dhar Chakrabarti
Distinguished Fellow, TERI;
Former Director, SAARC,
Disaster Management Centre, India
(Up to 10.10.2016)



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Research and Support Services Divisions

- ❁ Energy Environment Technology Development
- ❁ Electricity and Fuels
- ❁ Environmental and Industrial Biotechnology
- ❁ Forestry and Biodiversity
- ❁ Human Resources
- ❁ Administrative Services
- ❁ Industrial Energy Efficiency
- ❁ Information Technology and Services
- ❁ Knowledge Management
- ❁ Sustainable Development Outreach & Youth Education
- ❁ Social Transformation
- ❁ Sustainable Agriculture
- ❁ Sustainable Habitat
- ❁ Environment and Waste Management
- ❁ Water Resources and Forestry
- ❁ Earth Science and Climate Change
- ❁ Growth, Diversification and Commercialization Unit (GDCU)
- ❁ Integrated Policy Analysis
- ❁ TERI University



Energy Environment Technology Development

The Energy Environment Technology Development (EETD) Division continued its good work during 2016/17 and focussed on taking ongoing research to new heights while adding new frontiers.

- Inauguration of TEAM (TERI's enhanced acidification and methanation) plant by Director, College of Science and Technology, Royal University of Bhutan

Due to the rapid rise in grid integration of renewables, there are increasing concerns about the possible impact of these distributed systems on grid stability and grid operations, including

grid safety. As a forward looking Division, EETD proposed a detailed study on this topic to MacArthur Foundation, US, which duly approved the same. This three-year project will study feeder level impact of roof top solar systems on grid, among other issues. The team working in this area also developed a specialized mobile app and processes for Surat Municipal Corporation to promote roof top solar systems as part of the ongoing Smart City Programme. It is interesting to note that the mobile app attracted more than 4 MWp capacity system bookings within one month of launching. The team is developing similar integrated applications for the Municipal Corporations of Ahmedabad and Hyderabad as part of its ongoing assignments.

Grid-connected solar roof top PV systems are picking up in the country. However, the sector lacks capacity building and training of stakeholders. During the year 2016/17, EETD Division focussed on this aspect and successfully delivered various training programmes to DISCOMs, banks, nodal agencies, and other stakeholders. These were part of the Management Development Programmes and also part of funded projects by MNRE and others.

Our work on the MNRE-funded project on RPO/REC consultancy is going on strong, and we are in final stages of developing national-level integrated web-based portal for RPO Tracking. This portal is likely to be launched soon. As part of technology assessment, our team provided technical consultancy to M/s Power Roll, UK, in market assessment for its revolutionary thin film technology. Our team has also started working on an interesting assignment from Indian Defense Organisation that focusses on technology assessment for remote applications.

Our work on two stage gasifier (2SG) continued in the year under review. The TSBP (TERI SDC–Biomass Partnership) project has successfully introduced an innovative power generation technology based on two-stage gasification of biomass (2SG technology) to provide off-grid electricity for remote villages in India. Through collaboration with international and Indian partners, in both private and public sectors, it has transferred the 2SG technology developed by DTU; adapted its design and performance parameters to meet Indian needs and conditions; and successfully installed two 2SG systems in Odisha and one system in Madhya Pradesh, with work on one more 2SG system under way. The 2SG system has proved its mettle as a efficient biomass-based power generating technology for remote village electrification. It requires minimal maintenance, generates no wastes, and is easy for villagers to operate with basic training.

The South–South knowledge transfer component of TSBP Programme was initiated with an intent to share knowledge and promote adoption of biomass gasification technology in the African region. TERI has been successful in creating a platform by establishing local manufacturing capacity, which can provide local services to SMEs in Ethiopia through the technology transfer route. Under this programme, TERI signed a formal arrangement with M/s AFEsol technologies, Ethiopia, for technology transfer and local fabrication of biomass gasifiers in Ethiopia. The knowledge transfer was ensured through structured training on key aspects, such as design, fabrication, commissioning, and operation and maintenance of the biomass gasifiers for thermal applications.

Our team working on bio-methanation technology established an international partnership and network with Royal University of Bhutan, College of Science and Technology (CST), Bhutan, for sharing of know-how about the TEAM technology; establishing a demonstration plant at CST; providing training on biogas technology to officials from universities, ministries, and other government organizations; and capacity building of local manufacturers.

During 2016/17, our senior scientist, Dr Piyali Das received the prestigious Bioenergy Awards 2016/17 for Cutting Edge Research (B- ACER) Fellowship, supported by the Department of Biotechnology, Government of India, and the Indo-US Science and Technology Forum (IUSSTF), to work on the “Sustainable Production of Methanol & DME through biomass Pyrolysis and Gasification” between August 2016 to February 2017.

Further, biodegradable polymers for packaging, biomedical, EMI shielding, and fire resistant applications are being developed at TERI Bengaluru. High-performance nanocomposites using recycled comingled plastics for fire retardant applications have also been developed. The Division has also developed different superabsorbent bionanocomposite by microwave-assisted method for removal of toxic dyes and heavy metals from water bodies. The team also has a well-furbished laboratory for polymer materials, fully equipped with all necessary instruments and equipment needed for processing and to carry out various tests.

Resource savings have been obtained via implementation of resource-efficient cleaner production (RECP) measures and demonstration of acid/rinse waster recovery systems in Indian metal finishing SMEs. This RECP work was extended to 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. In the first year of the project, around 32 pioneering companies were assessed and presently, 50 showcases of the implemented RECP measures are under preparation.

Our two focus activities—(a) Solar Lighting Lab and (b) Center of Excellence for Thermal Energy—are also growing rapidly. The Solar Lighting Lab conducted evaluation of around 25 different products and its accreditation by NABL was extended till November 2018 with the addition of few new tests. The Lab also signed a fresh contract with the IFC for testing of products under the Lighting Africa Initiative. The Center of Excellence on Thermal Storage has initiated few research projects on thermal storage and, as a major milestone, has also received its first sponsored project during the year.



- Release of *Transitions in the Indian Energy Sector—Macro Level Analysis of Demand and Supply Side Options* Report

renewable energy resource assessment studies, technical training, and capacity building projects. Apart from renewable energy sources, the Division also focusses on study of the oil and gas sector.

Since its inception, the Division is engaged in Smart City Projects and has carried out project-related activities in the scope of grid-connected solar rooftop PV for Municipal Corporations of Ahmedabad, Surat, Greater Hyderabad, etc. Demand-side management projects for Jamshedpur and MESCOM under the MacArthur Foundation are the other important projects. The Division has successfully completed a project commissioned by Solar Energy Corporation of India Limited for assessment of solar rooftop potential with respect to over 2,000 government buildings across various states in the country. Work relating to assessment of demand for electricity in the country up to 2030 using econometric modeling and supply side option for meeting the anticipated demand was presented in the form of a report titled, *Transitions in the Indian Energy Sector—Macro Level Analysis of Demand and Supply Side Options*. The report was released by Shri Piyush Goyal, Hon'ble Minister of State (I/C) for Power, Coal, New and Renewable Energy and Mines, Government of India, in the conference titled, “Energy Transitions- The Global Challenges and Opportunities” conducted on February 13, 2017, by TERI, Electricity Transitions Commission (ETC), and Indian National Academy of Engineering (INAE).

The Division is moving forward with an aim to build strong capability in the electricity and fuels sector with focus on both conventional and non-conventional sources of energy.

Electricity and Fuels

Recently created, the Electricity and Fuels Division undertook research on various aspects of the power sector, including demand-side management, policy, regulation and reforms, and new business models for faster adoption of renewable energy. The Division focusses on research and services that are required post evolution and development of renewable energy technology. The key areas of work include demand-side management, tariff regulatory and policy studies, power system studies, project monitoring and consultancy of solar power projects,



○ Top view of 13,000 L bioreactor used for large scale production of KT-Oilzapper



○ Bottom view of 13,000 L bioreactor used for large scale production of KT-Oilzapper

Environmental and Industrial Biotechnology

Rapid industrialization, either directly or indirectly, leads to environmental contamination. With a vision to ensure sustainable availability of energy to meet the rising energy demand and protect the environment, the Environmental and Industrial Biotechnology Division (EIBD) strives to provide practical solutions through application of modern biotechnology.

With continuous innovative research explorations over three decades, the Division achieved core competency in microbial biotechnology domain for decontamination of polluted environment, and for enhanced energy production. Carrying forward, this Division is also actively engaged in development of novel technologies for sustainable production of clean fuels and green chemicals from renewable sources to shift from fossil fuel-based economy to bio-based economy. Extensive research explorations paved the way for development and commercialization of novel indigenous technologies; 'Oilzapper' (defined microbial consortium, for bioremediation of oil spill and oily sludge), 'MEOR' (microbial enhanced oil recovery from matured oil reserves), and PDB (paraffin degrading bacteria for prevention of paraffin deposition in oil pipelines) that are commercialized through the creation of a joint venture 'ONGC TERI Biotech Ltd (OTBL).

Broad spectrum implication potential of the Oilzapper technology has helped several petroleum industries, across India (ONGC, IOCL, HPCL, BPCL, Oil India Ltd, Tata Power, BG Exploration Ltd, and Reliance Petroleum) and overseas, for sustainable bioremediation of oil spills and oily sludge-contaminated sites in a cost-effective manner. The 'KT-Oilzapper' technology, developed by using indigenous microflora (from the contaminated site of Kuwait oil fields), proved to be one of the best three remediation approaches; Indirect TDU (thermal desorption unit), direct TDU, and bioremediation, were implemented by TERI

in the oil fields of Kuwait Oil Company in mega scale for remediation of 2, 20,000 m³ soil contaminated with total petroleum hydrocarbon compounds (under a mega project sanctioned by Kuwait Oil Company, KOC). 'KT-Oilzapper' alone contributed towards sustainable bioremediation of 1,30,000 m³ hydrocarbon-contaminated soil and emerged



- Transport of KT-Oilzapper from production site to the site of application in Kuwait oil field site

as the most effective approach in terms of its remediation potential. The demand for KT-Oilzapper for this mega-scale bioremediation project was catered by producing this at a large industrial scale (at a capacity of 15 tonnes per day) at TERI's state-of-the-art fermentation research centre (that houses a range of 15,000 L, 1,500 L, 300 L, 150 L, 100 L, 30 L, 10 l, and 3L fermenters). Considering the significance of this novel indigenous technology, KOC recently advocated a tender (KERP Bio Remediation at South East Oilfield at Kuwait) for a second-phase mega project for remediation of total petroleum hydrocarbon (TPH) contaminated soil in KOC oil field with the mandate for implementation of bioremediation approach only, for clean-up of oil contaminated sites.

With a goal to cater to the rising energy demand over the years through microbial explorations, this Division developed a couple of new technologies, such as 'enhanced oil recovery from heavy oil reserves', 'second-generation bio-hydrogen production from agri-waste/woody biomass', and coal-bed methane production from un-minable coal'. Considering the fast depletion of fossil fuel sources along with the rising demand of industry platform chemicals, a new technology was developed for the production of 2,3 Butane Diol (a green industry platform chemical) from waste glycerol and agri-waste biomass. In concern with the water issues along with environmental pollution, microbial processes were developed for treatment of 'domestic waste water' (contaminated with fat, oil, and grease); 'distillery industry waste water', that simultaneously helps in energy recovery from waste.



- Fieldwork depicting sustainable management of forests & biodiversity conservation

Forestry and Biodiversity

The Forestry and Biodiversity Division has major research interests in technical and participatory forestry approaches, governance, rehabilitation of degraded areas, clean development mechanism and emission reductions. In addition, this group is engaged in monitoring and evaluation of forestry and watershed development related activities. Besides, studies on biodiversity and payment for ecosystem services are undertaken. Capacity

building activities, particularly for state forest departments, are an important activity for this group.

Carbon Forestry

With possibilities of accessing carbon-based financing for forestry activities, under compliance and various voluntary mechanisms, TERI provides technical services towards project development to forest departments of various states.



- Calculation of biomass for estimating carbon as a part of the carbon-based financing project for forestry activities

The key areas of expertise are assessment of biomass, socio-economic/institutional assessment, and preparation of project design documents (PDDs) for CDM projects. During 2016/17, under the auspices of the Division, ten PDDs were successfully registered with the United Nations Framework Convention on Climate Change (UNFCCC) for A/R CDM projects and these were validated by the external validating agency. Once the projects are validated, the Certified Emission Reduction or CERs can be sold either in the compliance market or the voluntary market.

Monitoring and Evaluation

Assessment of impacts in the area of forestry and natural resource management is a continuing area of interest in the Division. A major long-term study on Monitoring, Evaluation, Learning, and Documentation (MEL&D) of projects under the Integrated Watershed Management Programme (IWMP) for batch II, III, and IV projects in Uttarakhand is underway. Currently, the Division has completed various reports—baseline, thematic, preparatory phase, indicator-wise monthly process monitoring, and case studies, etc. The duration of the consultancy awarded by the Watershed Directorate (WD), Government of Uttarakhand, is for five years starting from 2015 to 2020. The assignment is being implemented by a multidisciplinary team, comprising of professionals specializing in forestry, agriculture, hydrology, watershed management, GIS, biodiversity, livestock, economics, and sociology.

The Division has also successfully carried out monitoring and evaluation of advance soil work and plantations undertaken by the Uttar Pradesh Forest Department in 2016/17. The study report aimed at assessing the quantitative and qualitative progress of plantation activities (50 million saplings planted around 6,000 sites across different districts of the state) and their role in carbon sequestration. This massive afforestation drive by the Uttar Pradesh Forest Department, recorded in *The Guinness Book of World Records*, has won many accolades.

Biodiversity

The Division works on several aspects of biodiversity, including assessment of flora and fauna, management of protected areas, community conserved areas (CCAs) and sacred natural sites, landscape level planning, sustainable use of NTFPs, and various policy issues, including access and benefit-sharing (ABS), out of the commercial use of biodiversity resources.

In the current year, the Division is engaged in carrying out the GEF Satoyama Project in Nagaland. This proposal stems from inventory and documentation of CCAs in Nagaland and work with the Sema people of Sukhai village of Zunheboto district. The study titled 'Mainstreaming Community—Conserved Areas for Biodiversity Conservation in Nagaland' aims at supporting community-based conservation by mobilizing support for the formation of CCAs, including larger networks of contiguous forest patches in Zunheboto district of Nagaland and developing community-based ecotourism initiatives. This will help to protect biodiversity and reduce widespread hunting and habitat destruction by helping to revive traditional conservation practices (e.g. hunting bans during the breeding season) and carrying out community-assisted ecological assessments of these CCAs, including status of the Vulnerable Blyth's Tragopan and other globally threatened species. Upscaling of project activities will involve formalization and mainstreaming of a network of CCAs in the state in conjunction with the Government of Nagaland and the state forest department. The Division has also proposed a policy on behalf of the state to formalize and mainstream CCAs and currently, the draft is pending with the Ministry of Environment, Forest & Climate Change, Government of India.

The Division has also initiated a project with the Tribal Cooperative Marketing Development Federation of India Ltd (TRIFED) on enhancing income of forest dependent communities through establishing minimum support prices (MSPs) to assess 12 minor forest produce (MFPs) namely Tendu, Bamboo, Karanj seed, *Madhuca longifolia* (Mahua) Seed, *Shorea robusta* (Sal) leaves and seeds, lac, *Buchnanian lanzan* (Chironjee), wild honey, *Terminalia chebula* (Myrobalan), *Tamarindus indicus* (Imli), *Sterculia urens* gum (Gum Karaya) in nine states, including Madhya Pradesh, Chhattisgarh,

Odisha, Jharkhand, Andhra Pradesh, Telangana, Maharashtra, Rajasthan, and Gujarat, and its impact on conservation of forests. The current status is that out of 12 MFPs, a detailed study on 4 MFPs, including *Madhuca longifolia* (Mahua), *Buchnanian lanzan* (Chironjee), *Tamarindus indicus* (Imli), and *Pongamia pinnata* (Karanj seed) has been completed and submitted to TRIFED.

Further, the Division is preparing an updated version of state biodiversity strategy and action plan for Uttarakhand. The objectives of the study are to align the SBSAP with National Biodiversity Action Plan (NBAP), Aichi Targets, and National Biodiversity Targets (NBTs). We are also preparing a robust financial plan for the strategies and actionable points identified for the state. The other two deliverables include identifying and listing public and private (scientific) research institutions that require access to the biological and genetic resources and their capacity building on ABS provisions.

Participatory Forest Management

The group works on various institutional issues relating to participatory forest management, and has major interests in the study of forest-based livelihoods and benefit-sharing at the community level. At present, the group is implementing a programme on Agriculture, Greening, Training, Capacity Building, and Income Generation Activities supported by Coal India Ltd. The project aims at improving the socio-economic conditions of 1,250 farmers covering 10 villages in the Neturia Block of Purulia District of West Bengal. The project is spread over 3 years from 2015 to 2017.

Also, the Division has recently finished developing and facilitating Community Development Plans (CDPs) in Mizoram and Tripura under the North East Rural Livelihood Project. In this project, one of the important components is facilitation of Community Development Groups (CDGs) to develop holistic CDPs with location-specific activities, such as land development, water management, forest management, and small need-based village infrastructure, that directly enhance local livelihood activities (storage, grading facilities, and collection centers).

Outreach and Training

The Division, in partnership with Ministry of Mines, Government of India, and the Indian Bureau of Mines organized a one-day workshop on 'Remediation of Mined-Out Areas and Abandoned Mines—Status & Strategies' at the national level. The outcome of the workshop was a high-level dialogue involving the mining industry, the government, restoration experts, and practitioners to address the growing need for effective reclamation of mining areas and help reduce the economic costs of mining-induced land degradation.

The Division is also focussing on dissemination of information and is active in using print and social media effectively. Various popular articles, touching a wide range of topics, such as forestry, NRM, and biodiversity, were published in newspapers and social sites in 2016/17.

In addition, the Division is at present engaged in capacity development for forest management and training of personnel in Arunachal Pradesh and Assam. The main services provided by the group are finalizing the state training improvement plan, reviewing and preparing state joint forest management (JFM) Guidelines, and the plan for state training of trainers programme.

The group for last several years has also been working with Ministry of Environment, Forest and Climate Change, Government of India, to conduct the one week refresher training course for IFS officers. The topics covered under the training course are carbon forestry, green GDP, environmental economics, forests and climate change, etc.

Other Research Avenues

The Division is diversifying and is engaged in projects that study long-term effects of climate change on various landscapes. One such study is to assess the scale of land degradation with the economic impacts in India. The other objective of the study is also to assess the quantum, along with the sources of investment required for undertaking preventive and restorative measures that can help achieve the aspirational goal of land degradation-neutral India by 2030. The study has been completed recently, and the major scientific findings have been submitted to Ministry of Environment, Forest and Climate Change.

In addition to climate change, the group has also initiated a study with Coal India Ltd to conduct a baseline study and assess the ground realities in order to measure impact and changes in the privately managed 285 schools of ECL, BCCL, and CCL (subsidiaries of Coal India Ltd). Recently, a detailed report eliciting information through appropriate research methodologies and providing a baseline for comparison with future monitoring and evaluation has been submitted to the client.



Human Resources

The objective of the Human Resource Division is to provide the organization with a pool of satisfied employees who diligently work towards the realization of the vision and mission of TERI and, in turn, serve society. Its role is not only to identify and acquire the desired 'talent' for TERI, but it also takes initiatives for talent management and retention.

Apart from facilitating the learning and development activities for the staff as per their roles and requirements, the Division endeavours to facilitate smooth induction of new employees besides mentoring and enhancing the engagement levels of existing employees through various employee-engagement activities. Colleagues at all levels, across the Institute, are exposed to training programmes on a variety of behavioural and technical skills. These programmes aim at refining leadership skills, enhancing personal effectiveness, sharpening interpersonal skills, improving time management, and building people management skills. The outbound learning activities focus on promoting team dynamics at work and building a proactive approach for generating new research ideas.

TERI's cross-functional research activities provide opportunities to professionals to contribute to areas other than their primary research area, thereby enhancing interdisciplinary work. The Division organizes sports and cultural activities for TERI's employees and their families to strengthen employer–employee bonding. A system of rewards and recognitions, over and above the annual appraisal system, recognizes colleagues for their significant contributions at work. Town Hall Meetings and the Annual Vision Retreat provide a platform for employees to share ideas and participate in decision making. Some of the HR initiatives taken during the year were introduction of flexi-timings, revision in TA/DA rules, introduction of Disciplinary Action Policy, new Retirement Policy, and online appraisals for all the staff members.

The Internal Complaints Committee (ICC) for TERI had been constituted as per the New Act 2013 on 'Sexual Harassment of Women at Workplace: Prevention, Prohibition and Redressal'. Its objective is to look after the welfare of the female employees, to facilitate redressal of their grievances, to help maintain a harmonious atmosphere at office, and to enable women to pursue their work with dignity and reassurance.

The Division caters to the ever-changing needs of the organization to develop new strategies to keep employees motivated and engaged.



Administrative Services

The Administrative Services Division provides the necessary administrative support for all research projects and technology dissemination activities of the Institute. It is also responsible for the maintenance and upkeep of 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.

It is the custodian of all the assets of the Institute. The strength of the Division lies in its well-motivated, dedicated, and qualified personnel.

TERI has a certified ISO 9001:2008 standard for its Quality Management System (QMS) and a certified BS OHSAS 18001:2007 standard for its Health and Safety Management System, and ISO 14001:2004 certification for its Environment Management System.

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 continue to receive appreciation from the heads of missions in New Delhi. The World Sustainable Development Summit, TERI's annual flagship event, and other conferences, events, and workshops that attract worldwide participation are also supported by the Division.



○ Energy audit at Indorama Europort, Rotterdam, The Netherlands

Industrial Energy Efficiency

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 of India's ambitious 'Make in India' campaign is dependent upon prosperity of this sector. The challenge, however, is to grow in resource-efficient manner and address sustainability considerations from all perspectives—social, economic, and environmental. In this context, TERI's

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.

The pool of engineers in the Division, many of who are accredited and certified energy auditors with Bureau of Energy Efficiency, Government of India, regularly conduct energy audits in industries to identify options for energy conservation at the plant level. With expertise and deep knowledge of applicable technologies, TERI is able to offer the corporate sector 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 over the past two decades.

During the year, the Division undertook energy audits in different industries in India, such as refineries, oil and gas, cement, textiles, chemicals, heavy engineering, plywood as well as in commercial buildings and hotels. TERI continued providing support under the Perform Achieve and Trade scheme of Bureau of Energy Efficiency for large consumers of energy. In addition, TERI also undertook energy conservation studies in plants located in Bhutan, UAE, Tanzania, and Indonesia. Other highlights of work undertaken included providing knowledge and technical assistance to MSMEs located in different industrial clusters in India. The work in MSME sector was primarily supported by SIDBI/World Bank, UNIDO, IFC, SDC, and the Shakti Sustainable Energy Foundation.



Information Technology and Services

The Information Technology and Services Division is responsible for installing and maintaining state-of-the-art IT infrastructure and platforms as well as developing software applications for enhancing productivity, increasing efficiency, and enabling collaboration. It also provides IT support to

other Divisions for knowledge sharing, capacity building, and outreach activities.

This year, the Division has designed and developed several web portals/sites for our external clients as well as to support various activities and events conducted by TERI. Notable among these are the portals developed for smart city projects at Surat and Ahmedabad; Renewable Purchase Obligation (RPO) portal for MNRE; event websites for WSDS, ICDL, GRIHA Summit, TERI-Deakin Nano-Biotechnology Centre (TDNBC) Inauguration, Green Heroes event; and project websites for LEADearthSHIP Program, Mahindra-TERI Centre of Excellence, UCHAI, etc. Exploiting its expertise in mobile applications, the Division developed internal mobile applications on timesheets, business opportunities, and several apps in support of events such as WSDS 2016, ICDL 2016, GRIHA Summit 2017, etc.

The Division also continued on its video graphic work by creating infographics, 3D animations, and motion graphics for disseminating research project outcomes, promoting events, and creating awareness on different topics. In the area of customized applications, the Division developed a Web App for Daily Timesheets, online performance appraisal system for administrative and secretarial staff, and a work breakdown structure in the PMS. It also implemented "FLOW", a tool to create a collaborated environment for managing projects and communicating with team members. There has also been an extended usage of video and web conferencing platforms for interactions with various stakeholders and outreach activities in the form of meetings, consultations, and webinars. The Division has set up the entire IT infrastructure and web presence for the newly constructed TDNBC building. For the GRIHA Council, an online exam portal and a set of evaluators' e-learning modules were developed.

Throughout 2016/17, the Division continued in its dedicated effort at optimizing IT support to nearly 1,000 research and support staff in TERI.



Knowledge Management

TERI emphasizes on knowledge generation, creation and global dissemination of its research, and innovation on energy, environment, and sustainable development. Its objectives are fulfilled through innovative library and knowledge services, documentation, managing TERI's vast knowledge, research data, and publication services. The Knowledge Management Division supports TERI's research activities through a well-designed, state-of-the-art intranet-based knowledge management system.

- Inauguration of ICDL 2016 Exhibition by Ms Donna Scheeder, IFLA President, Deputy Chief Information Officer, Library of Congress US and Professor Micheal Seadle, Dean, Faculty of Arts, and Director, Berlin School of Library and Information Science and Editor, *Library Hi-Tech*, Germany

The Library and Information Centre (LIC) caters to the knowledge needs of both TERI researchers and external users visiting LIC by collecting, collating, and disseminating knowledge-based products and services using subscribed and free resources, which include books, reports, periodicals, and e-resources. Besides providing research and project assistance to TERI researchers and external users, the core competency of LIC professionals also includes catering to innovative services, capacity-building programmes for research and information professionals, web content and database development, contributions to publications, and setting up specialized information centres on contemporary themes, such as transport, renewable energy and environment, mycorrhiza, and climate change. The LIC developed value-added sectoral knowledge products, such as industry trend reports on topics of national importance including smart cities, Indian steel sector, and many more. The LIC also executed a few projects consisting of Database on R&D Equipment from the Department of Science & Technology, Mycorrhiza Information Centre from Department of Biotechnology, and ENVIS Centre on Renewable Energy and Environment from Ministry of Environment, Forest and Climate Change, Government of India.

As part of its capacity-building initiative, the LIC organized the International Conference on Digital Libraries (ICDL 2016), one of TERI's flagship programmes, during December 13–16, 2016, at New Delhi. Based on the theme “Smart Future: Knowledge Trends that will Change the World”, the Conference was attended by 652 participants and 160 speakers from across the world. LIC also organized several workshops in the north-eastern region; some of these were on topics such as, “Preservation and Conservation of Traditional Knowledge and Practices of North East for Sanitation, Cleanliness and related Medical Issues” on February 27, 2017, in New Delhi in collaboration with Ministry of Development of North Eastern Region (MDoNER). As a knowledge partner, LIC was also associated with the competency-development workshop on the Role of ICT in Preservation of Indigenous Knowledge in North-Eastern Region during March 15–17, 2017.

TERI Press, the publishing arm of TERI, is one of the India's leading publishers in the areas of environment, energy, and sustainable development. TERI Press publishes books, journals, and magazines on these topics at all levels—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 children's books, produced under the imprint of Terrapin, not only engage and sensitize young minds with nature-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 environment 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 beneficiaries. This includes undertaking environment-related projects to encourage an active social connect with the environment. In fact, TERI Press is the most preferred publication partner for leading corporates and ministries, such as the Ministry of New and Renewable Energy, Oil and Natural Gas Corporation, GAIL, and the Ministry of Environment, Forest and Climate Change, Government of India.

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.



- Release of the thirtieth edition of *TERI Energy and Environment Data Diary and Yearbook 2015/16 (TEDDY)*—TERI's annual publication on energy and environment



Sustainable Development Outreach & Youth Education

During 2016/17, the Sustainable Development Outreach & Youth Education Division (now renamed as the Communication Outreach and Advocacy Unit), continued to work on its mandate of spreading TERI's message to varied audiences, including governments, media, youth, and the public at large. TERI's flagship event, the World

- Dignitaries at WSDS 2016 with the President of India, Shri Pranab Mukherjee

Sustainable Development Summit, WSDS 2016 was held in New Delhi from October 5–8, 2016, under the theme 'Beyond 2015: People, Planet & Progress'. The Summit was inaugurated by the President of India, Shri Pranab Mukherjee and witnessed the participation of nearly 2,000 people to deliberate on the accelerated implementation of the Sustainable Development Goals (SDGs) and Nationally Determined Contributions (NDCs) agreed under the Paris Agreement. Besides the plenary sessions, the Summit organized 25 parallel thematic tracks to facilitate in-depth discussions on key topics by experts and practitioners.

During the Summit, President Pranab Mukherjee conferred the 2016 'Sustainable Development Leadership Award' to Sikkim Chief Minister Pawan Chamling for his vision and leadership in environment and sustainable development.

The key messages from the Summit were disseminated through wide media coverage in the national press. On social media, the summit hashtag # Act4Earth gathered 1,451 followers; the hashtag was picked up in 20 different countries. Under the Media Colloquium organized on the sidelines of the Summit, TERI brought together 19 young



- The #ACT4EARTH initiative, flagged off as part of WSDS 2016, brought people together on the goal of energy efficiency

journalists from Ghana, India, Bangladesh, France, Sri Lanka, and Nepal, to train them on reporting of global climate action. This effort led to wide coverage of the Summit deliberations in vernacular press in India in regions like Jammu & Kashmir and the north-eastern states. Two top-ranking journalists from the Media Colloquium were given the opportunity to travel to Marrakech to cover COP22. TERI's work in air pollution monitoring and analysis, particularly its caution against regularizing the Odd-Even scheme in Delhi NCR, dominated headlines in print and electronic media.

A key report by TERI on 'Transitions in the Indian Energy Sector' was picked up widely by both national and global media. The report stated that India may not need any new investments in coal-based power generation till 2026, if renewables continue to fall in cost at their current rate.

In the domain of audio-visual communication, TERI steered an innovative outreach project known as the 'Green Heroes Film Workshop and Festival'. TERI identified unsung Green Heroes from India's western region and trained journalism and mass media students in 5 cities to produce short films on selected Green Heroes. The project resulted in 20 short films that showcase pioneering efforts of individuals and communities working at the grassroots to protect the environment. TERI also produced films to showcase successful approaches towards climate-compatible development. This included a film on climate smart agriculture in Nepal and another film on Heat Action Plan in India.



- Sikkim Chief Minister Pawan Chamling was conferred the prestigious 2016 'Sustainable Development Leadership Award' by President Pranab Mukherjee during WSDS 2016

At the grassroots, TERI's community radio, Kumaon Vani in Nainital district, produced and broadcast a daily series of 365 episodes to promote women's health and nutrition. The series directly connected women listeners in over 300 villages to doctors and health workers in Nainital and Almora and gave them the opportunity to share their health concerns without inhibition. As part of its efforts to connect with the youth, TERI leveraged its network of over 50,000 schools and 10,000 colleges in India to promote environmental education and awareness. Under its school outreach efforts, TERI designed effective pedagogy to promote sustainability practices around water, sanitation, and hygiene. This was demonstrated in approximately 100 schools across the country. The Green Olympiad, an environment examination, conducted by TERI since 2000, continued to grow in numbers and received participation from nearly 2.3 lakh students from India and 9 other countries that included Indonesia, Kingdom of Saudi Arabia, Kingdom of Bahrain, Kuwait, Nepal, Russia, State of Qatar, Sultanate of Oman, and the United Arab Emirates.



- Demonstration of solar home system and improved cook stove in Banmankhi block, district Purnia, Bihar

Social Transformation

The Social Transformation Division, the action-research arm of TERI in the rural development space, works primarily through a combination of grassroots interventions and action-research based policy design. It brings together the latest in techno-socio-institutional knowledge, to deliver locally appropriate solutions that address basic needs of underserved communities. Over the last few years, the Division has worked extensively in the field of 'energy access' to accomplish TERI's commitment towards enabling affordable and

sustainable energy services through interventions that address consumptive and productive energy requirements at the household and micro enterprise levels, specifically in rural, remote, and peri-urban areas.

In this realm, with 'energy access' as a pivotal theme for the Division's activities, effort has been to address two key aspects for effective and sustainable energy provisioning. The first is to ensure that affordable and reliable clean energy solutions (for lighting and cooking) reach rural households. This has been driven through the development and implementation of innovative, responsive, and replicable technologies and delivery models; the creation of new partnerships and collaborations at the grassroots; and the adoption of a bottom-up approach; and engaging members of the community to create inclusive energy provisioning supply chains.

Lighting a Billion Lives (LaBL), TERI's flagship initiative for clean energy access, is a major programme being led by the Division that implements localized village-level interventions to provide lighting and clean cooking solutions, fosters the creation of partners and networks at the village, block, and state levels; and enables the provision of a bouquet of customizable and reliable technology solutions for households and small enterprises. As of March 2017, LaBL has completed 9 years of operations, impacting 5.3 million lives, across 23 states in India and 12 countries in Africa and South Asia. In the case of clean cooking solutions, the Division has worked towards customizing forced-draft cooking technology to improve quality, to suit consumer preferences, and contextual cooking conditions. More than 11 variants of forced-draft cooking technologies, varying in complexity and cost, have been developed by the Division over the past five years. A forced-draft cook stove designed specifically for households in coal mining areas

was developed and optimized for burning coal as a cooking fuel. As of March 2017, more than 65,000+ improved cook stoves have been disseminated through various interventions by the Division.

The second key aspect that has underlined the Division's work in 2016/17 takes interventions in energy access beyond the conventional scope of addressing only basic lighting and cooking requirements directly and attempts to weave 'energy' as a contributor towards other associated aspects of development, such as health, education, livelihoods, empowerment, and mitigating climate change. In this context, the nature of some key projects undertaken by the Division include installation of clean and reliable power infrastructures to improve the operational reliability and service quality of primary health centers in rural India; enabling the maintenance of vaccines in identified community health centres and clinics through the installation of smart monitoring solutions that help technicians to monitor optimal freshness and quality of vaccines more efficiently and effectively; enabling the creation of improved and prolonged study environments for children in rural India through the provision of stand-alone clean lighting solutions; fostering the creation of community centers and knowledge hubs through development of green and sustainable community libraries in villages; assessing household and village energy needs to recommend and design integrated energy plans for the development of smart villages; installation of solar street lights; incentivizing the adoption of improved cooking solutions through a simulated carbon credit market.

Effort has also been made to bring focus to gender-related perspectives in energy access and energy service delivery. A key project in this context is working to build a better understanding of the implications of electrification on women's empowerment by building evidence on such opportunities created through electrification and how these opportunities are further affected by several variables, such as technological design, management of systems, prevalent socio-cultural factors and practices (e.g., gender ideologies, roles and relations, household finances, poverty, etc.), policy regulations, and financing schemes.

The Division also conducted a detailed study on electricity pricing and consumers' willingness to pay for electricity services in India, the findings of which form the basis of a larger power sector reforms programme being undertaken by the Ministry of Power, Government of India, with support from the DFID, UK, and have garnered keen interest from stakeholders in the government and those involved in electricity supply.

Going forward, the Social Transformation Division will continue to expand its scope in developing and delivering innovative and integrated solutions, focussing on clean energy and resource-use efficiency with an emphasis on replicable interventions that support rural livelihoods and sustainable management of natural resources with better resilience to climate change. Building on its past experience in the areas of integrated rural development, natural resource management, and energy access, the Division also aims to work towards expanding its activities in these areas.



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 land utilization hold the key. Through advanced research, education, societal engagement, small farmer entrepreneurship, and transfer of finished products and technologies to industries and stakeholders for

- The TERI-Deakin Nano Biotechnology Centre (TDNBC) aims to support and nurture innovative ideas for existing problems of Indian agriculture

wider reach, the Sustainable Agriculture Division 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; mitigate environment-related problems, such as toxic chemicals and wastes; innovate solutions for cleaner and greener energy; safe natural products to ensure human health; and policy research and cross-cutting research that bridges all areas (water, energy, soil, and alternative farming systems).

The Division comprises five areas, each one specializing in different but related fields with the mission to create

innovative and green solutions for the challenges 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, Mycorrhiza will, in the future, play a key role owing to its contribution to the plant apropos to phosphorus nutrition in agriculture. 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 Micropropagation Technology Park (MTP) focusses on large-scale production of tissue-cultured plants of various economically important species with an annual capacity of over two million. This facility is ISO 9001 certified and is also accredited under the National Certification System for Tissue Culture Raised Plants (NCS-TCP) by the Department of Biotechnology, Ministry of Science and Technology, Government of India, for the production of quality planting material through tissue culture.

The Plant Tissue Culture and Molecular Biology (PTCMB) area has been working on the themes of genetic improvement of crops to achieve food and energy security under changing environments with a wide array of crops with high economic value; bioprospecting and production of valuable compounds for agriculture and health; and livelihood augmentation through dissemination of agritechologies amongst the farming community. The research in Plant Biotechnology area focusses on bioprospecting of plant and microbial biodiversity for biopesticide, biofuel, and medicinal value; develop value-added products from industrial by-products/waste; develop analytical methods for quality control and metabolomics; quality improvement of oilseeds; and promote practices for sustainable agriculture, food security, and climate change.

The TERI Deakin Nanobiotechnology Centre (TDNBC) 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 nanonutrients, nanopesticides, and nanoformulations. Keeping in mind the deteriorating soil health, growing demand of food, and water safety as the biggest challenges, the Centre is uniquely poised to develop path-breaking technologies using biologicals interwoven with nanotechnologies and biocompatible materials.



- SPARSH#GRIHA4all: A life-size green building model. This building integrates all energy and resource-efficient features under one roof and uses 40%–50% less energy than a conventional building.

Proposal (SCP). Dharamshala emerged as one of the top three cities among the list of winner cities selected in the Fast Track Round Challenge of Government of India's Smart Cities Mission in May 2016. As a National Partner and Policy Advisor to the Asian Cities Climate Change Resilience Network (ACCCRN), TERI has conducted state-level engagement and capacity building to come up with a Roadmap for Urban Climate Change Resilience Policy in the states of Goa and

Sustainable Habitat

The Sustainable Habitat Division continues to focus on cities, transport, and buildings with its activities ranging from city- to building-level interventions.

In the area of urban development, the Centre for Research on Sustainable Urban Development & Transport Systems (CRSUD&TS) carries out research to help create sustainable, resilient, and 'smarter' cities, through policy analysis, sustainable urban planning, capacity building, and knowledge creation. TERI has been recognized as a Centre of Excellence (CoE) in this field by the Ministry of Urban Development, Government of India, and has been empanelled as a consultant for the Smart Cities Mission of the Government of India. In this capacity, TERI provided technical assistance to Dharamshala in preparation of its Smart City

Uttarakhand, India. TERI is committed to capacity building and policy advocacy emerging from its research activities. To this end, TERI organized a session focussing on disaster risk reduction and climate change adaptation for the Children and Youth Assembly of Habitat III Conference in Quito in partnership with the United Nations Major Group for Children and Youth and the Water Youth Network. With the key objectives of promoting low-carbon and sustainable transportation, the focus of TERI's work in the domain of transport research has been on policy analysis, energy and environment analysis, capacity building, and knowledge creation. TERI, with support from Shakti Foundation, is working towards identifying strategies for increasing the share of the Indian Railways' total national freight mobility. In another collaborative research with the National Rural Roads Development Agency (NRRDA), TERI is evaluating the impacts on safety and health of construction workers with an aim to promote green technologies in the rural roads sector. TERI has also been commissioned by the Ministry of Road Transport and Highways (MoRTH), Government of India, to identify carbon reduction potential of the highways sector and identify interventions to enhance climate resilience of the highways sector in India. In its endeavour to promote sustainable and inclusive mobility options in Indian cities, TERI is conducting a study as part of the Switch Asia Programme funded by the European Union. The Centre for Research on Sustainable Building Science (CRSBS) Group under the Sustainable Habitat Division has been set up to facilitate development and mainstreaming of sustainable buildings in order to facilitate efficient design of new buildings and to improve performance of existing buildings. The Centre has been offering sustainable design solutions for buildings of various complexities and functions for nearly two decades.

The Centre has undertaken several research and development activities and has set up a CoE with the support of Mahindra Life-spaces Developers Ltd (MLDL) to carry out research on energy efficient building envelopes and sustainable water use in habitats. Another CoE, set up in collaboration with UTC, works towards the development of an energy-use reporting framework for existing buildings, real time reporting of consumption, and identification and cost-benefit analysis of energy conservation measures.

A project on "Mainstreaming Sustainable Social Housing in India (MaS-SHIP) was sanctioned by UNEP, consisting of four consortium partners (TERI, Oxford Brookes University (OBU), Development Alternatives, and UN-Habitat). The project is aiming to develop a 'Sustainability Index' for the building materials and construction technologies for affordable housing sector. Another ongoing research activity comprises visual and thermal comfort monitoring of Somfy Roller Blinds in the Indian context.

TERI is also actively involved in implementing Energy Conservation Building Code (ECBC) at state levels and has set up a Project Management Unit (PMU) at Odisha State Designated Agency (SDA) and two ECBC Cells in Haryana and Punjab.

A study was conducted for the development of Nationally Appropriate Mitigation Actions (NAMAs) for the buildings sector with United Nations Environment Programme (UNEP). The CRSBS Group has also provided India-specific inputs to support the diffusion of both energy-efficient technologies and policy packages that overcome barriers for implementing these technologies as part of BigEE project funded by Wuppertal Institute. The outcome of the partnership is to create an international web-based knowledge platform for energy efficiency policies in buildings, building-related technologies, and appliances in the world's main climatic zones.

The Centre for Research in Sustainable Building Science (CESB) Group, TERI Southern Regional Centre, is currently working with corporates, developers, and public sector units to provide consultancy services for design of energy-efficient buildings. The Centre has been working with industry partners on Sustainable Affordable and Climate Resilient Construction Technologies. Besides, the Centre is carrying out research on performance monitoring of the indoor and outdoor environment. The Group has developed a policy framework for Government of Tamil Nadu where economic benefits of green buildings, for the government, consumers, and developers can be simultaneously calculated.

During 2016/17, the Centre initiated research on Sustainable Consumption and Production of Building Materials wherein a tool has been devised to calculate the Sustainability Index of Building Materials used in the climate vulnerable Himalayan region.

Institutional engagements to disseminate research work have been carried out in partnership with educational institutes, such as Manipal University, NIT Trichy, and the EMPRI.

The GRIHA Council under the Sustainable Habitat Division is actively working towards implementation of the GRIHA Rating System. The GRIHA Rating System, conceived by TERI and supported by the Ministry of New and Renewable Energy, Government of India, is a key guideline for construction of sustainable buildings across the country. India in the "Intended Nationally Determined Contributions (INDCs) submitted to the United Nations Framework Convention on Climate Change (UNFCCC), has highlighted GRIHA, as the country's own green building rating for combating global warming and climate change. The key strength of this unique rating system lies in the rigorous implementation through due diligence visits and proven performance of rated projects. The GRIHA Council organized its annual national conference in March 2017 with the theme 'Transforming Habitats'. The most recent addition to the GRIHA rating systems—the GRIHA Existing Building (EB) rating was also launched. A distinctive feature of the Summit was a mock-up



○ Release of *GRIHA for Existing Building Rating System (GRIHA EB) Manual*

GAIL (India) Ltd Office Building & Regional Gas, Mumbai, and IIT Delhi Lecture Hall Complex, New Delhi. In addition, South Asian University and Office Building of Design Associates Inc., Noida, achieved 5 Star GRIHA LD Masterplan Rating and SVAGRIHA rating, respectively. This year, Government of Haryana, and Uttar Pradesh Housing & Urban Planning Department have also rolled out incentives linked with GRIHA. This is in addition to the existing incentives provided by Delhi, Goa, Maharashtra, Punjab, Government of Sikkim, Pune Municipal Corporation, Government of West Bengal, Government of Rajasthan. The fourth GRIHA Trophy was conducted at the 69th Annual Convention of National Association of Students of Architecture (NASA) held at Jaipur wherein Sinhgad College of Architecture, Pune, won the first prize.

With a negligible impact on initial investment, the payback period for any GRIHA rated building is not more than 2–3 years. In March 2016, GRIHA had over 900 registered projects, covering a built-up area of over 36 million sq. m.

of a green building “Sparsh#GRIHA4all”, which was displayed in the central courtyard of the India Habitat Centre. It was an integrated life size model incorporating all elements that constitute a green building, including acoustic and thermal insulation, reuse of material, state-of-the-art lighting and air-conditioning, water efficient fixtures, and solar PV power generation.

Some of the key projects that received GRIHA rating in 2016/17 include the New Integrated Passenger Terminal at Chandigarh Airport, Chandigarh;



○ Group Photograph of training workshop on Best Practices for Solid Waste Management in Indian Cities

bioreactors, forward osmosis process, resource recovery, and development of composite membranes containing metal organic frameworks. In distillery wastewater treatment, the focus has been on resource recovery (melanoidins and polyphenol recovery) using fractionation with mixed matrix membranes (MMM) and adsorption using modified activated carbons and commercial resins. The antioxidant properties of the recovered fractions have been studied and optimum recovery methods have been identified. Forward osmosis using biomimetic membrane is also being studied for melanoidins concentration and water recovery in distillery wastewater. Polyamide thin-film composite membranes containing metal organic frameworks (MOFs) were prepared and tested for separation of common analgesic acetaminophen; up to 55% retention was obtained.

Biodegradable polymers for packaging, biomedical electromagnetic interference (EMI) shielding, and fire resistant applications are being developed by the Division’s team in Bengaluru. High-performance nano-composites using recycled comingled plastics for fire retardant applications were developed along with different superabsorbent

Environment and Waste Management

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

During 2016/17, the activity in water/wastewater treatment focused on membrane



- Visit to the South Delhi's Compost Plant in the Okhla during workshop on 'Best Practices for Solid Waste Management in Indian Cities', 20-21 March 2017

bionano-composite by microwave-assisted method for removal of toxic dyes and heavy metals from water bodies. The Division also has a well-furnished laboratory for polymer materials, which is fully equipped with all the necessary instruments and equipment needed for processing and to carry out various tests.

During the said period, resource savings have been obtained from implementation of resource-efficient cleaner production (RECP) measures and demonstration of acid/rinse water recovery systems in Indian metal finishing SMEs. This RECP work was extended to 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. In the first year of the project, around 32 pioneering companies were assessed and 50 showcases of implemented RECP measures are being prepared. In addition, TERI is working with select auto component manufacturers and electroplating units in Pune to implement RECP and promote use of secondary raw materials. Savings from implementation are being quantified.

The Division also collaborated with the Climate and Clean Air Coalition's Municipal Solid Waste Initiative (CCAC MSWI) in a project working with network cities in India to improve their solid waste management practices to address black carbon and methane emission. In the project, the Division organized a two-day training workshop on 'Best Practices for Solid Waste Management in Indian Cities' during March 20-21, 2017, at TERI RETREAT that included municipal officials from different Indian cities, domestic and international experts in waste management, and the Ministry of Urban Development (MoUD), Government of India.

In addition, the Division is also working on USAID-funded project on strengthening water and sanitation in urban settings. The project involved working with slum clusters in Chennai and Kolkata for baseline sanitation survey and implement participatory sanitation interventions in the two cities that are sustained beyond the project period and help reducing burden of water-borne diseases in the selected clusters.



- 3rd India Water Forum (IWF) 2016: 'International Water Convention' on 'Water for Sustainability: Towards Development and Prosperity'

Water Resources and Forestry

The Water Resources and Forestry Division strives to develop and implement integrated solutions for sustainable water management and thus, provide sustainable solutions for the existing challenges in the sector. The Division has core competencies in quantitative and qualitative assessment of water resources, water audit and water foot-printing, watershed management, urban water demand management, glacier research, hydrological

assessments, rural water supply and sanitation sector, water quality and pollution studies, and policy analysis.

Over the years, the Division has built expertise in carrying out water audits and water foot-printing studies and has helped various industries and clients in enhancing water use efficiency. A number of water audits have been conducted by TERI for various entities such as Indian Railways (Various Railway Stations & Rail Coach Factory), Thermal Power Plants, Textile Industry, Tobacco industry (ITC) etc., across the nation and strategic recommendations such as recycle/reuse of wastewater, reduction in process water consumption, leakage/losses control, integrated automation of the water supply network, rainwater harvesting etc., were designed and suggested to enhance their water use efficiency

and reduce their Specific Water Consumption. The Division also works on important and emerging issues of water–energy–food and climate change nexus and has analysed the intricate nexus at various spatial scales with a focus on various power generating plants. The Division actively works in the Water and Sanitation Hygiene (WASH) sector and has undertaken both implementation and awareness generation related activities. 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 the downstream community.

The Division successfully organized the Third India Water Forum during 2016, in association with the Ministry of Water Resources, SasiWATERS, Hindustan Unilever Foundation and Israel Embassy, which witnessed experts from across the globe deliberating on the theme, “Water for Sustainability: Towards Development and Prosperity”. The Division is also a resource centre on Water Use Efficiency, jointly hosted by TERI and Jain Irrigation Systems Ltd. It has been endorsed as the Regional Knowledge Hub for Water and Climate Change Adaptation by the Asia-Pacific Water Forum. It has also been recognized as the National Key Resource Centre for rural drinking water and sanitation by the Ministry of Rural Development, Government of India.



Earth Science and Climate Change

The Earth Science and Climate Change Division has core competencies in environmental monitoring and modelling, impacts assessment, and policy analysis. State-of-the-art air quality models have been used in the Division for suggesting measures to improve air quality at urban and regional scales. The group has also been active in advocating policies for clean and sustainable transport in the country.

- Engaging with different stakeholders to raise awareness on extreme event attribution science

Energy–environment relationships in urban,

industrial, and rural settings have received continued interest in a number of research studies that involve both quantitative modelling as well as the use of participatory field-based methods. Over the years, the Division has built expertise in establishing and assessing the linkages between environment and health, which have been instrumental in driving national-level policies. In the context of climate change research, the Division focuses on climate modelling; impacts, vulnerability, and adaptation assessment; policy analysis; climate change mitigation and GHG (greenhouse gas) inventorization as its key thrust areas. Capacity building and outreach forms the core of each of these thrust areas.

The Climate Modelling work focusses on understanding climate risks at different spatial and temporal scales, both in the context of current climate variability and change and future climate change. For this purpose, the Division uses state-of-the-art global and regional climate models, such as CCSM 3.0, CESM 1.0, GFS and Met Office Unified Model (GCMs) and PRECIS, WRF and COAWST (regional coupled) (RCMs). These outputs are then linked to various Impact Assessment Models, such as ADCIRC (for storm surge and coastal circulation), SWAT (for water resources), DSSAT (for agriculture), IBIS (for forestry), and DIVA (for coastal zones) for the Impacts Assessments. TERI has a 5.5 TFLOP high-performance computing infrastructure which helps in performing these model simulations.

The work on impacts and vulnerability assessments focusses on key sectors, such as water, agriculture, and health, through engagement with multi-stakeholders, including policy makers as well as local communities. The research also focusses on various aspects of adaptation, such as identification, prioritization, monitoring and evaluation, and capacity building for policymakers and other stakeholders on different issues related to impacts, vulnerability assessment, and adaptation. The Division also focusses on policy analysis and recommendations on climate change and sustainable development at national and international levels.

These include analysis and innovation for global climate policy negotiations thus, providing a developing country perspective on issues of mitigation, adaptation, technology and finance; analysis, recommendation and consultancy on market mechanisms and emerging new market mechanisms; generation and analysis of data on GHG emissions, including carbon foot-printing and focussed analysis, innovation and consultancy on negotiating, designing and informing Nationally Determined Contributions (NDCs).

The Division has been regularly carrying out capacity-building programmes for various stakeholders on different subjects pertaining to climate change science and policy. Recently, the Division has started extending its research and capacity-building activities to other developing countries and emerging economies, including a major e-learning programme on the science and policy of climate change. 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 Division.



Growth, Diversification and Commercialization Unit (GDCU)

The GDCU is primarily responsible for creating interest and promoting TERI solutions and services and in exploring potential opportunities for collaboration with major funders in the OECD countries, central government agencies, state government agencies, large corporates, and CSR funds. The Division nurtures long-term partnerships through credible relationships with a diverse set of clients. The GDCU identifies successful solutions

- The inaugural session of Business Day at the World Sustainable Development Summit 2016 focussed on businesses taking the lead in climate change

that need to be scaled up and evolves appropriate strategies for successful market entry and implementation. The Unit strategizes scaling up cooperation activities for TERI in the global South, especially Africa.

Broadly, the mandate of GDCU is operationalized by the Technology Dissemination (TD) group and the Council for Business Sustainability (CBS). As a part of the Unit, TERI CBS leads all engagements with the Indian corporates to frame and implement their sustainability agenda. TERI CBS is an independent and credible platform for corporate leaders to address issues related to sustainable development and promote leadership in environmental management, social responsibility, and economic performance. Presently, the network has corporate members across India representing a varied section of Indian industry. Guided by an industry-led executive committee, the Council includes PSUs, MNCs, and private companies from across India.

The Council empowers its members with the know-how to identify sustainability issues material to their organization, decipher the approach to address the issues, guides them to operationalize the approach, and assists to report their achievements. The Council connects companies, partners, stakeholders, and government organizations to address issues and opportunities among sectors and in supply chains.

The TD group aims at securing Intellectual Property for TERI innovations and to enable the flow of technologies from lab to industry. Over the past few years, TERI has developed a rich portfolio of Intellectual Property (IP) related to renewable energy technologies and biotechnology solutions. In 2016/17, TERI was granted patent in India for developing a process to produce novel biopesticide. Patents were also granted in Australia and South Africa for this product. TERI also filed a patent for novel work being undertaken for treatment of recalcitrant pollutants in wastewater streams.

In addition, TERI has made advancements and improvements in its existing technologies and the TD group has facilitated the securing of IP for the same. These include:

- » Resource efficient technology – ‘Novel modified/grafter multi-walled carbon nanotube material and method of production’
- » Waste-water treatment technology - ‘Novel hybrid working-mode based photocatalytic reactor for treatment of nonbiodegradable and/or recalcitrant pollutants in wastewater streams and/or discharged effluents and its method of working’

Another key activity of the group is to develop strategic alliances and partnerships for the dissemination of technologies. The Group actively facilitates framing and signing of commercial agreements for effective dissemination of technology. TERI has entered into several technology license agreements with suitable industry partners in the past. In the last year, TERI concluded technology licensing agreements for its technologies with:

- Department of Renewable Energy, Ministry of Economic Affairs (DRE), Royal Government of Bhutan and College of Science and Technology (CST), Bhutan, for TERI’s TEAM (Enhanced Acidification and Methanation) Process

b. M/s Harith Avni Technologies, Bangalore, for TERI's TEAM (Enhanced Acidification and Methanation) Process. TERI also entered into agreements with Bioproperty Strategy Group, Inc., New York, and with M/s Croft IP, Australia, to explore and develop technology licensing opportunities in foreign markets.

The TD group coordinated the participation of TERI at the WasTe And SaniTech India, 2016, event organized by the Ministry of Urban Development (MoUD), Swachh Bharat Mission (SBM), and Central Pollution Control Board (CPCB), and also at the first WSDS (World Sustainable Development Summit) event. Technologies available for licensing and technology transfer were showcased at these events. Infographics and animation films were developed, which were utilized for promoting TERI's technologies on various social media platforms.

Going forward, the Group is looking to identify and exploit opportunities wherein TERI's technologies and technical capabilities can be utilized for the benefit of industry and society. The Group will be actively engaged in strengthening TERI's IP portfolio and in the development and implementation of sustainable business models for existing and emerging TERI technologies.



Integrated Policy Analysis

The Centre for Integrated Assessment (CIAM) provides energy-economy- and environment-related inputs to researchers, industry, and policy makers at the global, national, and sub-national levels. Towards this end, the Division is continuously involved in 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

- Exploring synergies across a wide range of energy-economy-environment issues forms the core competency of the Division

linkages as well as undertaking economic and statistical analysis of energy and climate-change related data.

The MARKAL (Market Allocation) model set up at the national level for India has provided useful inputs to the Government of India by examining alternative energy demand and supply scenarios to analyse prospects for India's sustainable development and to identify as well as prioritize options among various fuel and technology choices across the energy sectors. Over the years, this model has also provided inputs for India's climate change negotiations and more recently served to provide inputs to the Ministry of Environment, Forest and Climate Change, Government of India, for delineating India's Intended Nationally Determined Contributions (INDCs).

The CIAM maintains a dynamic profile to align its analysis and modelling capabilities to address key issues that are of emerging importance at global, national, and sub-national scales. Accordingly, while the group is involved in global modelling studies to delineate India's role in moving the world towards a low carbon pathway consistent with a 1.5°C world; at the national level, the modelling is oriented towards examining ways and means by which India could simultaneously achieve its NDC targets and development objectives. Inputs from this group have played a key role in assisting the Government in international negotiations in terms of providing inputs for India's country presentations at the COP, SBSTA, and other dialogue meetings, and organizing side events and exhibits that showcase India's position on climate change.

The national-level energy models are also linked with sector-specific models, behavioural models, computational general equilibrium model, air pollution model, and other resource use models to find solutions that maximize synergies and benefits amongst the multiple objectives of sustainable development. The integrated modelling frameworks facilitate analysis across several dimensions linked with energy production and consumption, such as the implications on air pollution and human health, estimates of water requirements, and assessment of the infrastructure and financial needs of various development futures.

The team is also involved in conducting short-term and long-term energy demand forecasts to help estimate the long-term energy sector needs for better planning and decision making as the country enhances access to cleaner energy forms and improved efficiency of energy generation and supply.

With the wide range of energy–economy–environment issues that the group studies, the team is constantly engaged with national and international networks and contributes to several peer-reviewed publications, conferences and seminars, panel discussions, and talks.

Through the use of a variety of geospatial tools, such as satellite-based remote sensing and geographical information systems (GIS), the Division also undertakes assessment of spatially downscaled data to help decision making at various levels. Based on monitoring and analysis of natural resources and changes in energy and environment parameters, spatially and temporally, the Division undertakes downscaled assessments of resource availabilities and examines vulnerability and needs of communities and other actors at localized levels.



TERI University

With 'Knowledge for Sustainable Development' as its tag line, the TERI University's academic programmes are focussed around the challenges of providing for a rising global population with a limited and degraded natural resource base. Set up as a research university, it started its Masters programmes in 2003 and has around 1,500 alumni working in various institutions across the globe—a cadre of professionals with a deep understanding of the nuances of sustainable development. Developing such an understanding among its students is best achieved through exposure to a variety of subjects, tools, and methodologies offered in the interdisciplinary mode. This has been the guiding philosophy behind the programmes offered by the TERI University and is practiced by

- The TERI University campus, Vasant Kunj, New Delhi

building a theoretical understanding in courses covering a variety of traditional disciplines, such as ecology, natural and social sciences, governance, policy, law, and engineering.

At the TERI University, students are exposed to a new way of thinking from the perspective of one who recognizes the complex linkages between man and his environment. The TERI University's programmes are unique not only in terms of the degrees but in terms of the fact that they equip the graduates to lead in a resource-sensitive world. The programmes leverage TERI's knowledge capital in sustainable development to deepen the social and ethical consciousness of higher education in India. Being a research university, its doctoral programmes cut across disciplinary boundaries and integrate a holistic view with more traditional fields. Its research activities focus on natural resource management, policy and governance, environment and development, business sustainability, biotechnology, and renewable energy.

A variety of MSc programmes are offered in the fields of Environmental Studies and Resource Management, Climate Science and Policy, Geoinformatics, Water Science and Governance, Plant Biotechnology, and Environmental and Resource Economics. The University also offers programmes leading to the award of MA (Public Policy and Sustainable Development), MA (Sustainable Development Practice), MTech (Renewable Energy Engineering and Management), MTech (Urban Development and Management), and MTech (Water Science and Governance). MBA programmes are offered in Infrastructure and Business Sustainability. The University also offers LLM programmes in Environment and Natural Resources Law and in Infrastructure and Business Law.

Accredited with an 'A' Grade by the National Assessment and Accreditation Council of India (NAAC), the University has received accolades for incorporating new and innovative elements in education. In keeping with its global outlook, the TERI University has academic collaborations with select foreign universities, which provides for joint research and curriculum development as well as faculty and student exchanges. The top performers in the Masters programmes acquire an opportunity to carry out their major projects abroad. The University attracts students from all over the country and also a fair number of international students.



3

Domestic and Global Operations

- ❁ TERI North Eastern Regional Centre, Guwahati
- ❁ TRISHA, Mukteshwar
- ❁ TERI Western Regional Centre, Mumbai
- ❁ TERI Southern Regional Centre, Bengaluru & Goa
- ❁ TERI Europe, Utrecht
- ❁ TERI Japan, Tokyo
- ❁ TERI-Africa

Domestic Operations

Creating a broad network for continued and sustained research and analysis of the various facets of environment conservation requires dedicated work across several sectors from partners. TERI has been engaged in forging long-term linkages and partnerships with agencies and organizations, including the government, so that the effort towards a green tomorrow never ceases. In keeping with this agenda, TERI has established regional presence in various nerve centres of the country, supported by the headquarters in New Delhi. TERI's regional centres continued to generate interest in the field of energy, environment, and sustainable development in the year of reporting.

TERI North Eastern Regional Centre, Guwahati

TERI North Eastern (TERI-NE) Regional Centre has been working for sustainable development in the region through innovative research in the fields of agriculture and biotechnology and is also implementing projects related to rural extension of research activities. The Centre as a whole works on a wide range of thematic areas, such as natural resource management, livelihood enhancement, sanitation, biodiversity conservation, algal biofuel, mycological research, etc. Over the years, TERI-NE has formed collaborative partnerships with government agencies, civil bodies, and private players, and built strong community partnerships. It has found a niche for itself in the northeastern region

as a premier institute for issues related to sustainable development.

Several projects of the Centre are currently related to different facets of a degrading environment. In one such project, the Government of Assam has entrusted the responsibility to TERI-NE as an MELD (monitoring, evaluation, learning and documentation) agency for monitoring, evaluation, learning, and documentation of IWMPs (integrated watershed management programmes) in five districts of Assam. In another project, the Centre has been providing consultancy services to FREMAA (Flood and River Erosion Management Agency of Assam), Government of Assam, for executing projects on livelihood enhancement of the river erosion victims in the Kamrup (Rural) District of Assam through improved Eri silk spinning and weaving and vegetable cultivation.



○ Production of budded Khasi Mandarin plants



Over the years, TERI-NE has formed collaborative partnerships with government agencies, civil bodies, and private players, and built strong community partnerships.



In its efforts to promote horticulture in the region and improve productivity, the Centre continues to produce quality planting materials of horticultural crops, such as black pepper, Assam lemon, and Khasi mandarin, that have significant economic values for the region.

Biotechnological research of the regional centre engaged in exploration of economically important germplasm of northeast, such as *Hippophae salicifolia*, bacteria, and algae, and evaluation of their intended properties. Application

of molecular genetics for taxonomic identification of germplasm, cDNA AFLP tools for transcriptome analysis of *Hippophae salicifolia* fruit ripening process through nextgen sequencing tools, transcriptome driven formulation culture technique for uncultivable microbes are adopted. Abiotic stress management of tea ecosystem through plant microbe interaction is in progress. Waste water management through robust phototrophic biofilm development and human waste management through anaerobic digestion in school hostels are being evaluated. Microbial formulation have been developed using indigenous entomopathogenic fungal consortia for Mustard aphid management. Downstream processing of Muga silk through microbial enzyme treatment has also been developed.

In the capacity building initiative of the Centre, TERI-NE with the support of North Eastern Council (NEC), Government of India, organized a training programme for government officials to equip them with skills in designing sustainable livelihood interventions pertaining to the north eastern region.

TRISHA, Mukteshwar

TERI's Research Initiative at Supi for Himalayan Advancement (TRISHA), situated at a height of 7,500 ft in Supi village of Nainital district, Uttarakhand, is a distinct endeavour towards sustainable development. Since agriculture is the main occupation, research and extension has 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 along with complete package of practices using diverse and dynamic cropping patterns.
- » Optimally enhancing resource-use efficiency.
- » Increasing marginal farmers' capacities through training and demonstration.
- » Development of market linkages guaranteeing economic returns to the farmer by establishing value chains.

There are various facilities at Supi, including a soil-testing lab for farmer fields, vermicomposting unit, polyhouses and glasshouses, oil distillation unit, herbal garden, air quality



- Skill development of women farmers for achieving better incomes by growing high value crops



TERI, through this research initiative, has touched the lives of around 1,500 farmers in 25 villages in Ramgarh and Dhari blocks of the district to provide them end-to-end solutions for increasing their farm incomes.



monitoring unit, knowledge-cum-training centre, the Kumaon Vani facility (a community radio service for the local populace), and rainwater-harvesting systems. There is also a passive solar greenhouse which can facilitate vegetable production all round the year, even under unfavourable climatic conditions. TERI, through this research initiative, has touched the lives of around 1,500 farmers in 25 villages in Ramgarh and Dhari blocks of the district to provide them end-to-end solutions for increasing their farm incomes. Hence, TERI has created a platform for enhancing livelihood security by eliminating intermediaries and thus, created a win-win situation for all stakeholders.



- Construction of a low-cost poly-lined rainwater harvesting tank providing critical irrigation

TERI Western Regional Centre, Mumbai

TERI's Western Regional Centre (WRC) has focussed its activities in the areas of nutritional security, environmental resource management, wetland restoration, and Eco city project. The highlights of the various activities undertaken by the Centre during 2016/17 have been presented below.

Nutritional Security

Realizing the fact that malnourishment is one of the major concerns in tribal as well as urban areas, the Centre initiated

various programmes to address concerns of teenage malnourishment as well as early childhood malnourishment. In 2014, the Centre launched a multi-pronged programme titled PROTEIN (Programme to Revitalize the Overall health of Tribals by Ensuring the Intake of Nutritious food products). Research, implementation of technologies, documentation of ethnic knowledge, and training on cultivation and consumption of nutritive food varieties are the major components undertaken under this programme to facilitate availability of sufficient, safe, and nutritious food while sustainably addressing the local issues with innovative approaches.

The highlights of 2016/17 include the following:

» TERI-WRC received the Department of Biotechnology (DBT), Government of India, sponsored project 'Developing a Mushroom Germplasm Bank for Western Coast of India with Special Emphasis on Maharashtra and Goa to commercialize their Neutraceutical and Pharmaceutical potential'. To establish a Macrofungal Germplasm par excellence at TERI-WRC, 11 different forest ecosystems of coastal regions of Maharashtra were explored for collection of mushrooms. A total of 200 mushrooms collected were studied and assigned to 61 species in 41 genera belonging to 27 families and eight orders. All the samples were properly dried and herbaria were prepared. Forty mushrooms were brought in to axenic cultures, and all the cultures were analysed for pharmaceutical and neutraceutical analysis. Of these, two strains (V5-T3 and V5-T12) were identified as potential cellulose producers and two strains (V1-T1 and V3-T8) were laccase producers, which can further be exploited in the paper and pulp industries.



- *Tricholoma sp*, a fragrant mushroom spotted and collected from Amboli forest in the Western Ghats of Maharashtra
- » TERI-WRC implemented a project called 'Health and Energy Facilities' in a small tribal village Pathardi located in the Mikhada block of Palghar District in Maharashtra. In order to reduce their dependence on forest-based fuelwood, the project introduced the alternate plantation of fast-growing species based on their energy yield and promotion of improved cook stove in the village. Along with this, fruit tree plantation and promotion of vegetable



In 2014, the Centre launched a multi-pronged programme titled PROTEIN (Programme to Revitalize the Overall health of Tribals by Ensuring the Intake of Nutritious food products).



- Trained tribal women preparing Khakhras at the resource centre established at Wada Block, Palghar District, Maharashtra

cultivation in the backyard through establishment of Nutri-gardens has been successfully implemented.

» In another initiative, a dual-pronged approach of food fortification and creating livelihood options for women was successfully implemented in Wada block of Palghar district in Maharashtra. A resource centre was established to prepare nutritious food products (*Khakhras*) through fortification to fulfill the micro-nutrient demand. The recipe of fortified *khakhra* with mushroom and spinach powder was standardized and the sample products were tested for its nutritional content. The results showed that the fortified *khakhras* were rich in Vitamins D and A, and Iron. Moreover, TERI formed a self-help group under the programme and built their capacities on packaging and marketing of the product.

Environmental Studies and Resource Management

The Centre works on advocating recommendations based on analysis of secondary data for environmental and resource-related parameters to various state agencies, such as urban local bodies, Maharashtra Pollution Control Board (MPCB), planning authorities, and so on. The reports published in the year 2016/17 included the following

- » The report titled 'Air Quality Status of Maharashtra 2015–16' developed by TERI WRC was released on June 7, 2016, at the hands of Shri Devendra Fadnavis, Hon'ble Chief Minister, Government of Maharashtra (GoM). This was the fifth consecutive annual report developed by TERI-WRC for the MPCB. The report provides decadal overview and



The Centre works on advocating recommendations based on analysis of secondary data for environmental and resource-related parameters to various state agencies, such as urban local bodies, Maharashtra Pollution Control Board (MPCB), planning authorities, and so on.



analysis of the quality of air recorded across all the AAQMS (Ambient Air Quality Monitoring Stations) in Maharashtra. The report documents the daily, seasonal, and annual trend in concentrations of air pollutants such as SO₂, NO_x, RSPM, CO, CH₄, and ozone in Maharashtra for the past 10 years through illustrations and graphical representations and is uploaded on the website of the pollution control board.¹

- » The Centre also successfully worked and completed Environmental Status Reports of three cities located in Maharashtra—Navi Mumbai, Kolhapur, and Nanded city.

Navi Mumbai—An Eco-City Programme

The WRC is also actively involved in its ambitious project titled 'Navi Mumbai: An Eco-City'. The project is being implemented through a unique programme-based approach focussing on low carbon growth through impact-oriented and quantifiable initiatives across the societal sectors—residential, industrial, and governmental. This year, TERI-WRC launched the 'Navi Mumbai Eco-city Forum' on July 29, 2016, in Navi Mumbai as a platform to engage diverse stakeholders and bridge the gap between technology providers and consumers through seminars, conferences, exhibitions, expert talks, hands-on training workshops, demonstrations workshops, and so on. To begin with, the core themes have been identified as green buildings, urban farming, energy efficiency & renewable energy, and water conservation. On the occasion of the launch, TERI-WRC also released *Handbook on Water Conservation* that presents illustrations of easy to practice water conservation techniques that could be practiced by the citizens of Navi Mumbai. TERI WRC organized two demonstration workshops through lectures, interspersed with practical demonstrations, involving volunteers from the audience on 'Growing organic vegetables in windows & balconies' and a hands-on training



The Centre also initiated a project on waste to energy where in the project aspires to commission a 20kWe capacity biomass gasifier using the waste woody biomass from the city and generate electricity.



1 http://mpcb.gov.in/ereports/env_qualityReport_air.php

on 'Cultivation of Oyster mushrooms', which recorded a participation of more than 250 city enthusiasts. The Centre also initiated a project on waste to energy, where in the project aspires to commission a 20 kWe capacity biomass gasifier using the waste woody biomass from the city and generate electricity. This would reduce the load on the landfill site and help demonstrate a pilot project on responsible disposal of woody biomass through renewable technology.

Jaltarang 2017

On account of World Wetlands Day on February 2, the WRC celebrated its annual event 'Jaltarang', 2017, for the tenth consecutive year, under the flagship programme WeMaP (Wetland Management Programme). A nature trail and interactive session to create awareness about the importance of wetlands in disaster risk reduction was organized for around 50 people; this was followed by a nature trail where 39 avi-fauna species, including several important migratory ones, were spotted. The participants included students and residents from Navi Mumbai.



- (L to R) Dr Ajay Mathur, Director General, TERI; Shri Tukaram Mundhe, IAS, Municipal Commissioner, NMMC; Shri Mohan Dagaonkar, City Engineer, NMMC; and Shri G S Gill (IAS), Distinguished Advisor TERI-WRC, launching the book titled *Handbook on Water Conservation*

TERI Southern Regional Centre, Bengaluru & 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), the Centre for Impact Evaluation and Energy Access, Bengaluru (CIEEAB), and Coastal Ecology & Marine Research Centre (CE&MRC).

IEG has been providing 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 has been carrying out verification audits of new designated consumers

under the PAT schemes II & III, phase III of HAL CSR initiatives with HAL and BESCOM, energy efficiency studies of utilities in the Gulf region, and entering into a strategic partnership with EESL for the implementation of energy efficiency and renewable energy projects outside India.

CIEEAB, Bengaluru, is primarily engaged with rural communities and works closely with various government departments on issues, such as energy, livelihoods, empowerment of women and effective utilization of natural resources. During the period under review, the CIEEAB worked with the Forest Department of Karnataka for evaluating their work during 2009/10 to 2014/15, with the Sales Force Foundation for dissemination of solar lanterns in remote tribal areas and with Karnataka Evaluation Authority for the evaluation of micro-credit scheme aimed at empowerment of self-help groups for women.

CESB, Bengaluru, is working with corporates, developers, and public sector units to provide consultancy services for design of energy-efficient buildings. During the year under review, the Group has worked with several industrial partners, builders, etc., and developed policy frameworks for Tamil Nadu as an aid to decision making to several stakeholders, including the government, carried out performance evaluation of energy-consuming equipments, within buildings, with a view to optimize an energy-efficient thermal comfort levels, and spread its services within the country and outside.

CE&MRC, 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; bio-diversity mapping; and various activities in areas of environmental awareness, education, and outreach projects. During the year under review, the Group, supported by the Toyota Foundation,



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has worked in areas, such as capacity building of artisanal fishery; demonstration of mussel and crab farming under a NABARD-assisted project to encourage the local fishing communities to undertake mariculture; a Goa State Pollution Control Board (GSPCB)-assisted project to determine the persistence of pesticides in different coastal ecosystems of Goa; Goa State Biodiversity Board and GIZ-assisted projects to map the coastal biodiversity in several coastal villages; a project to better understand the health, changes in water use, and economic impacts of providing access to river water treated by using Riverbank Filtration Technology (RBF), through the National Health Medical Research Council (NHMRC) of the Government of Australia; and a similar project on RBF supported by Rambol-Environ Foundation, USA. A DSTE-supported by the Government of Goa involving the climate change impacts on Zuari river sub-basin has also been completed. In addition, the Group has also conducted numerous seminars and educational tours to different coastal habitats.

Global Operations

TERI, with a vision to address the universal nature of the problems that human society faces today, continues to make efforts, on a global scale, to create a sustainable future for society. Over the years, TERI's global affiliates and centres have developed strong linkages with like-minded institutions and important organizations to further the cause of sustainable development.

TERI Europe, Utrecht

Since its establishment, TERI Europe has been implementing projects in the following key areas: supporting climate change policies in developing countries, including carbon trading and sustainable building design; promoting trade in sustainably produced goods; analysing corporate responsibility trends and practices; analysing sustainable investing trends in emerging markets; and building capabilities for sustainability reporting amongst small and medium enterprises. During 2016/17, TERI Europe continued to build on the expertise and insights gained on sustainable investing and sustainability reporting.

TERI Japan, Tokyo

Established in 1998, TERI Japan continues to promote relationships with Japanese institutions, universities, governmental agencies, and 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 undergone a significant and qualitative shift. The Japan-India comprehensive economic partnership agreement has opened up new opportunities in the bilateral economic engagement. This includes collaboration and technology transfer in the areas of energy conservation and renewable energy sectors, which are areas of direct interest to TERI.

TERI has a close working relationship with the Institute of Global Environmental Strategies (IGES), where the office of TERI Japan is located. IGES has the office of its representative in India located in TERI, New Delhi.

A team from IGES participates on a regular basis in the Delhi Sustainable Development Summit (WSDS since 2016) organized by TERI. TERI supports and participates in the International Forum for Sustainable Asia and the Pacific (ISAP), organized annually by IGES. This collaboration is



○ India-Japan Energy Forum-2017



TERI has a close working relationship with the Institute of Global Environmental Strategies (IGES), where the office of TERI Japan is located.



strengthened further through occasional visits to Japan by the Director General of TERI and through projects that are undertaken by TERI jointly with IGES and other institutions in Japan. TERI's collaboration with the Kansai Research Centre of IGES continued to focus on low-carbon technology transfer aspects and the two institutes successfully organized three workshops in India during the year (at Chennai, Pune, and Mumbai).

In addition, TERI and NEDO jointly organized the 7th India-Japan Energy Forum at New Delhi in January 2017. The Forum focussed on enhancing technology cooperation and business opportunities between the two countries in the energy sector with a focus on renewable energy, grid stability, and energy efficiency. Mr Hiroshige Seko, Minister of Economy, Trade and Industry (METI), Government of Japan, and Shri Piyush Goyal, Minister of State (I/C) for Power, Coal, New and Renewable Energy and Mines, Government of India, addressed the participants at the event that attracted over 200 delegates from the two countries.

TERI-Africa

TERI continued its partnership with Horn of Africa Regional Environment Centre and Network (HOAREC&N) in Ethiopia. TERI has undertaken various projects and studies in Africa in the past decade and continues its close collaboration with various institutions, such as UNIDO, African Centre for Technology Studies (ACTS), Kenya, among others. Since its empanelment in 2007 under the Indian Technical and Economic Cooperation (ITEC), Ministry of External Affairs, Government of India, and TERI have welcomed more than 500 participants from Africa.



4

Thematic Overviews

- ✿ Agriculture
- ✿ Climate Change
- ✿ Energy
- ✿ Environment
- ✿ Forestry and Biodiversity
- ✿ Integrated Policy Analysis
- ✿ Urbanization and Transport
- ✿ Water

Agriculture

Agriculture holds the key to overall growth of a country's economy. TERI is uniquely poised to develop pioneering technologies and solutions using microbial systems, bio-fertilizers, bio-pesticides, genetic improvements, crop diversification, bioinformatics, nanotechnologies, and biocompatible materials. It offers cross-sectoral, technology-based solutions, implemented in an integrated manner, for achieving equitable and sustainable results.

Set-up of World's Biggest Facility for Mycorrhiza Production

TERI's mycorrhiza has already shown to be a valid option for sustainable high-quality crop production in low-input and marginal areas, promising to improve the nutritional status and health of the rural Indian population. In 2016/17, TERI set up the world's biggest facility for producing mycorrhizae. The TERI facility, with a production capacity of over 600 billion propagules/annum, expandable to 1000 billion propagules/annum in next two years, can potentially benefit 1.2 million hectare or more of farmland. The facility is equipped with best in class systems, equipment, and hardware based on next generation technology. The facility is spread over 414 m² of floor area fully dedicated for production activities and covers class 10000 and 1000 cleanroom areas with temperature and relative humidity controlled environment.

Nanobiotechnological Interventions for Agriculture

The TERI-Deakin Nanobiotechnology Centre has been making significant strides in developing nanonutrients and nanofertilizers, nanopesticide nanoformulations, and nanosensors. Keeping in mind the deteriorating soil health, growing demand of food, and water safety as the biggest challenges, the Centre is striving to develop path-breaking technologies using biologicals interwoven with nanotechnologies and biocompatible materials. The Centre has developed a series of nanonutrients-based products, which are biologically synthesized and can reduce the burden of excessive use of fertilizers. These are prospective supplements to existing fertilization practices by cutting down consumption of the standard chemical fertilizers while increasing the crop productivity and soil health.

In the search for an effective nanopesticide for controlling soil-borne pathogens, eight stable nanoformulations of



○ Potato trial treated with mycorrhiza

nalidixic acid sulphonyl acyl hydrazine were synthesized and evaluated for their toxicity against a variety of pathogens. Two of these displayed remarkable insecticidal potential. Markers and methods for sensing and detecting various soil microbes and toxic materials are also being developed actively. Along with this, functional characterization of agriculturally important microbes and naturally existing microbiota are keenly being pursued for development of next generation bioformulations for agriculture.

The Centre is also actively devising innovative solutions for application in the food industry, specifically to replace the currently used synthetic colours with natural colours. Coupled with these activities is the development of plants to supplement human health and this is being approached through plant-made pharmaceuticals.

High-quality Tissue Culture Plants

During 2016/17, using tissue culture technology, the Sustainable Agriculture Division had distributed more than 3.5 million disease-free plants of banana, strawberry, citrus, potato, bamboo, and ornamentals to farmers and agro-based companies, either directly or through state horticulture departments. This facility has served large number of farmers in Uttar Pradesh, Bihar, Punjab, and Gujarat towards better crop production and has thereby improved the socio-economic status of farmers.

Biopesticides and integrated pest management for controlling plant diseases and pests

TERI's biopesticide product 'Bollcure' has been tested effectively for its usefulness against *Helicoverpa armigera* in Cotton and Chickpea in India and abroad. The product is





○ Typical symptoms of dead larva after Bollicure spray

CIBRC registered and has also been registered for use as an input in organic agriculture. This makes Bollicure suitable for use in conventional/IPM/ organic farming systems.

Enhancing Livelihoods of Marginal Farmers Using Bio-innovations

TERI is working in Uttarakhand to strengthen farmers by providing them with need-based technologies, technical know-how, as well as market linkages and motivating them to become entrepreneurs from producers. TERI had initiated a project supported by the Louis Dreyfus Foundation with the objective of promoting traditional crops that have high nutritive value using traditional knowledge coupled with modern technology. This work is currently in the second phase with enhanced number of beneficiary households in far spread villages.

Technological Interventions for Genetic Improvement of Crops

A breeding population was generated in chilli by cross-breeding pungent (*Bhut Jolokia*) and non-pungent varieties. This mapping population was used to identify molecular markers linked to pungency. Attempts are being made to increase its yield. Molecular breeding approach is being used to develop resistance against major diseases, such as Pepper leaf curl and anthracnose in vegetables, such as chilli and tomato. TERI is also working on developing a genetically enhanced rice plant that is able to synthesize its own nitrogen fertilizer; thus, freeing the farmers from the



○ Various Bhut Jolokia accessions collected from North East

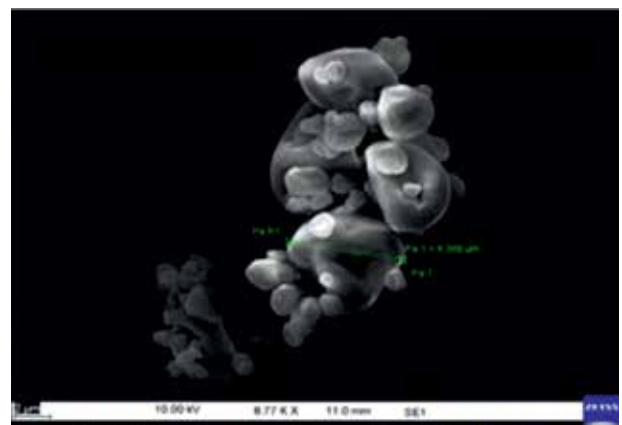
burden of supplementing the crop with expensive synthetic fertilizers derived from non-renewable petroleum resources. In addition, attempts are also underway to enhance the photosynthetic ability of rice plant to boost rice production.

Development of Nutritionally Improved Varieties of Mustard

In 2016/17, TERI has developed nutritionally improved double low (00) mustard variety having low erucic acid and low glucosinolate content through a collaborative project with Nirmal Seeds Pvt. Ltd, supported by DBT-BIRAC.

Microencapsulation for Increased Shelf Life of Bacteria

Farmers are dissuaded from using non-sporulating plant growth promoting bacteria (PGPR) due to their low shelf life and requirement of high dosage application. In 2016/17, the optimization of microencapsulation process at low outlet temperature for *Bradyrhizobium japonicum* has led to viability, product consistency, and functionally active formation of nodulation and nitrogen fixation.



○ Microencapsulated non sporulating bacteria (*Bradyrhizobium japonicum*)

research projects have been conducted, however, long-term and sustained collaboration between Indian and European researchers, continuation of research, building up of expertise and knowledge of the Indian economy remains a gap. This project, supported by IDRC and Climate Adaptation and Services Community (CASCO) initiative of the EU, brought together more than 40 young researchers from Asia, Africa, and Europe and provided them training/exposure on the various economic tools available for conducting adaptation research. The five-day training-cum-workshop also provided a platform for sharing ongoing research and build further collaborations within the CARIAA (Collaborative Adaptation Research Initiative in Africa and Asia) consortia that includes the HI-AWARE Research on Glacier and Snowpack Dependent River Basins for Improving Livelihoods, Pathways to Resilience in Semi-Arid Economies (PRISE), Deltas, Vulnerability & Climate Change- Migration & Adaptation (DECCMA), and Adaptation at Scale in Semi-Arid Regions (ASSAR).

TERI, in collaboration with the Norwegian Institute of Urban and Regional Research (NIBR), Norwegian Institute for Water Research (NIVA), University of Oslo (UiO), is conducting a three-year study (2015–17) on Governance of Climate Services (GovClimServices), supported by the Research Council of Norway, that aims to study the conditions for effective multi-level governance of climate services in India, with a focus on the state of Maharashtra. The project is studying Indian climate service systems, both public and private, and is comparing diverse systems and outcomes for different types of farmers and user groups (provider–user interface). In this way, focus is on the important aspect of how India operationalizes its climate adaptation policy. India's public climate service system is fairly well established and has been in operation for many years.

Maharashtra is a pioneer in testing innovative solutions (including 'open access' systems). Interesting research and policy lessons can be drawn for other developing and developed countries from this system. The analysis will help overcome some of the barriers identified in earlier climate research related to various disconnects in knowledge, action, and policy amongst public, private, and civil society actors involved in provision and use of climate services. Towards this cause, the team conducted a workshop in Pune at the inception stage of the project to understand the evolving governance structure of climate services in Maharashtra and to learn how service providers translate climate knowledge to farmers. The workshop was attended by over 50 relevant stakeholders comprising a good mix of representatives from government (IMD, IITM, KVKs, NABARD, ICAR) and private sector service (RML, CABI, TCS, IFFCO IKSL), research organizations (MPKV, IWMI, and NGOs (WOTR), and farmers. The team also visited villages of Pune and Ahmednagar district multiple times to interact with farmers and climate service providers to understand how climate services in Maharashtra are evolving.

The Raising Risk Awareness (RRA) project (2016/17) is assessing whether climate change has contributed to extreme weather events, such as floods and heat waves, in India and other countries in Africa and to identify how such scientific evidence could help to bridge the science–communications–policy gap, and enable these countries and communities to become more resilient in a warming world.

TERI, along with 'World Weather Attribution' initiative, including Environmental Change Institute–University of Oxford, the Royal Netherlands Meteorological Institute, the University of Melbourne, the Red Cross Red Crescent Climate Centre with support from Climate Central and Climate Development and Knowledge Network (CDKN) conducted





workshops in this project that aimed to build local attribution capacity, address knowledge gaps, and ensure that climate information is communicated effectively to key audiences. The events combined a host of expertise spanning climate science, development, policy, planning, and communications to discuss extreme weather event attribution and facilitate in co-learning on the need for attribution science in informed decision making. Using examples from the RRA project (on Chennai floods and North Indian Heat Wave), the workshops attempted to initiate a learning sphere around the usefulness of attribution to enable adaptation decisions that takes in to account changing risks, vulnerability, and exposure of communities.

The participants in the workshops explored how climate change attribution—the science of how climate change affects the magnitude or frequency of an extreme event—can create a better informed public debate around climate change, vulnerability, and exposure, and lead to better decisions. The focus of the meeting was on the interface between policy, science, and communication and aimed to identify ways to strengthen the linkages between these different communities around climate change attribution so as to provide easily understandable information while respecting the scientific integrity of the information.

Significantly, the Plant Biotechnology Area is working on role of endophytic fungi in conferring resistance to biotic and abiotic stress in crop plant to combat challenge of climate change along with demonstration and technology for adaptation to climate change at farmers' level.

TERI also has an ongoing project focussing on impact of floods on urban transport in the cities of Bengaluru, Mumbai, and Delhi. The objective of this study is to assess the impacts of urban floods on traffic congestions by using geospatial and hydrodynamic model to identify the flood hotspots on road network and assess potential need for interventions. The study is focussing on the potential impact of flooding on the performance of urban transport.

TERI also has an ongoing study on heat island in Jharsuguda, Odisha, which is funded by Oxford Policy Management with support from the Odisha State Pollution Control Board. The Jharsuguda lb-valley region is a coal mining and industrial cluster and frequently records temperatures in excess of 45°C during the summer. The study has identified temperature hotspots in the region through GIS-based spatial analysis and field monitoring using temperature data loggers, infrared

camera, and heat stress meters. The study has provided an action plan outlining mitigation strategies for various heat sources, such as coal mining, heavy industries such as iron and steel, aluminium refining, refractories, thermal power plants, brick kilns, and rice mills; and adaptation strategies through heat sinks, such as vegetation, forests, and water bodies. The study included various phases of monitoring in 2016 wherein 12 data loggers were installed in the different regions of the district to record the ambient air temperature. Stakeholder consultation workshops were conducted to seek inputs from municipal officials and ward members, OSPCB officials and industry representatives, health specialists, researchers and civil society organizations on the heat stress situation and ways to mitigate and adapt to it. Thermal hotspots have been identified using approaches, such as remote sensing based land surface temperature (LST) modelling and field survey-based ambient temperature and humidity monitoring. Mitigation measures in the areas of coal mining, industries, agriculture, transport, and urban planning have also been evaluated and recommended in a consolidated Action Plan for policy makers.

A study on Climate Change Risks and Preparedness for Oil and Gas Sector is being undertaken. This is supported by the seven public sector oil and gas companies in India, namely, the IOCL, ONGC, BPCL, HPCL, Petronet LNG Ltd, and GAIL and is being jointly carried out by TERI and Federation of Indian Petroleum Industry (FIPI). First of its kind, the study is a comprehensive examination of the implications of climate change from the perspective of oil and gas industry. It examines (a) incremental risks to infrastructure and operations that change in climatic variability may pose for the sector and possible adaptation options, (b) changes in the international and national market for the India's oil and gas industry due to climate policies, and (c) technological options for mitigation in the sector.

Inventorization and Mitigation

The India GHG Program jointly run by TERI, CII, and World Resources Institute (WRI), India, is an industry-led voluntary framework to measure and manage greenhouse gas (GHG) emissions. The programme builds comprehensive measurement and management strategies to reduce emissions and drive more profitable, competitive, and sustainable businesses and organizations in India. The India GHG Program also acts as an exchange platform for sharing best practices, creating a pool of trained practitioners, and encouraging businesses to have focus on managing GHG risks and opportunities. Experts from WRI, TERI, and CII conduct various capacity building programmes and have, till date, trained close to 100 practitioners, helping businesses develop and customize tools and guidance policies. The Program currently has a registered membership of over 40 leading corporates and recognition from all relevant ministries in India. In fact, the Program has been listed in India's Intended Nationally Determined Contributions (INDCs) as one of the key initiatives by the corporate sector for GHG mitigation. This year, TERI conducted several engagements with the industrial



groups on GHG accounting and measurement in the sectors. During the year, TERI has provided support to set up working groups on air, road, and rail transport emissions through its technical inputs and through facilitating participation of relevant companies in the Program. On the policy front, till date, several formal/informal interactions with government stakeholders have been undertaken. Besides engaging with the policy makers for their presence in the policy workshop, such interactions proved beneficial in terms of introducing them to the objectives of the Program and disseminating the work being done under the Program. The engagement with policy makers involved specific discussion looking at opportunities for private sector in the National Clean Energy Fund, Green Climate Fund, and the overall impacts of the much anticipated Paris Deal on corporate actions. TERI organized a roundtable to enable dialogue between policy makers, businesses, and financial institutions/agencies on the 'Emerging Opportunities for Indian Business in the Evolving Climate Finance Scenario' on January 29, 2016, at the India International Center, New Delhi. Nearly 35 participants joined in the programme. Presentations from ministries as well as the private sector together led the discussions around the key issues related to climate finance, reflecting on the post-Paris outcomes, consequences, and the business expectations. As an outreach, TERI has provided blurbs, newsfeed for content for wider dissemination through the Program website as well. In the coming year, TERI aims to deepen its engagements with the companies through the Program and expand Program activities to areas aligning with the national priorities on climate finance, GHG accounting for companies, and transparency framework.

International Negotiations and Domestic Policy

On the domestic policy front, TERI is undertaking preparatory work with a view to assist the Government of India in two

areas—(1) National Inventory Management System (NIMS); (2) Tracking the progress on mitigation actions, plans, and policies. This study is being conducted using a participatory approach combining rigorous consultations with technical aspects of international guidelines on MRV with the needs and capabilities of various actors, including national and state governments, private sector, and subject experts. A stakeholder workshop was organized in March 2016 focussing on the strategies to implement INDCs with particular reference to selection of mitigation actions and MRV challenges. The project aims to propose an institutional strategy to facilitate mitigation actions in India along with mitigation ideas that could be considered for further development into projects. TERI has initiated a new project dealing with various aspects related to implementing India's NDCs in both international and domestic context. The activities include: Review of nationally determined contributions and tracking of implementation of mitigation actions; leveraging climate finance: lessons from international and domestic best practices; India's technology transfer needs for implementing ambitious NDCs; and approaches for mainstreaming gender dimension into mitigation projects.

The 22nd Session of the Conference of Parties to the United Nations Framework Convention on Climate Change (CoP22) was held in Marrakech from November 7 to 18, 2016. The Paris Agreement, adopted on December 12, 2015, in Paris, came into force on November 4, 2016, making CoP 22 the first CMA wherein most discussions would focus on operationalizing the Paris Agreement.

The discussions took place around transparency mechanisms; the global stock take; issues related to technology transfer; ratcheting up the ambition of countries through their INDCs; mobilization of finance, including the future of carbon markets; and scaling up of adaptation actions.

Just like all the previous CoPs, TERI was engaged in active constructive dialogue on climate policy and action. The formal platforms included the exhibit booth of TERI and various other side events organized by TERI and other organizations, in which TERI colleagues shared their research and insights on climate policy and sustainable development practices with the audience. TERI also participated in the six upcoming India Pavilion events. More information on this can be found at <http://www.teriin.org/index.php?option=com_events&task=details&sid=898&Itemid=110>.

Prior to this, TERI had also organized a policy workshop in Delhi in collaboration with IGES. Views from a variety of stakeholders were taken on many issues linked with international climate negotiations. TERI experts had also participated in international forums, such as OECD's global climate change exchange to elaborate on various facets of transparency in international regime. This included organizing a joint session on modalities of Article 13 and speaking on adaptation MRV.

In order to enhance the transparency and comparability of climate actions and ultimately facilitate 'networking' of carbon markets, TERI is trying to devise a methodology to form the

basis with support from the World Bank. This methodology tries to unbundle the climate change mitigation benefits from other energy and domestic policy benefits and services, thereby assessing the mitigation value in order to standardize comparisons across climate actions. TERI also helped the Government of India draft India's Market Readiness Proposal in consultation with Ministry of Environment, Forest and Climate Change (MoEF&CC). This helped India secure a funding of 8 million USD from the PMR Secretariat.

TERI also undertook policy analysis to inform India's position on an HFC phase down agreement and secure the future of clean energy in India by aiding design and implementation of policies that encourage energy efficiency and renewable resources. The TERI delegation participated in the Meeting of Parties (MOP 28) held at Kigali in October 2016, where the discussions focussed on deciding the freeze years, that is, the period when HFC phase down begins. Keeping in mind the overriding concerns of poverty alleviation and economic growth, it is indeed important to assess the implications of such a phase down and the level of ambition that India must showcase and prepare an informed position on this particular issue. The policy analysis served as a proposal from India to the MOP 28.

TERI with support from Department of Personnel and Training has been organizing an annual six-day training programme for All India Service officials, since 2011, on varied topics encompassing science and policy of climate change. The programme is structured in a manner that it is inclusive of the ongoing international, national, and local debates on climate change. Speakers and faculty for the programme are renowned experts in the field of climate policy, climate adaptation, and climate mitigation. The programme is infused with a number of examples, good practices, case studies, and also includes a visit to the sustainable live demonstration at Gual Pahari Campus of TERI. The training programme is aimed at building capacity of government officials from different

states of India for facilitating integration of climate concerns into development planning.

TERI CBS Annual Leadership Summit for Sustainable Development 2016

Leaders of corporate India at TERI CBS's 'Leadership Summit for Sustainable Development 2016' (LSSD 2016) agreed that India is very well placed to be at the forefront to build the world's low-carbon economy. It was emphasized that more ambition and innovative collaboration among businesses, policy makers, and financing institutions is required for bringing low-carbon propositions to scale. LSSD 2016 brought together corporate leaders and multiple stakeholder groups to debate and discuss the need for corporate organizations to usher in urgent commitments to the ongoing collaborative movement on climate change via a combination of interventions at the policy, financing, and technology levels.

Themed as 'Translating India's NDCs to Business Actions', the Summit received an overwhelming response with participation from 100+ delegates, including CBS member companies. LSSD 2016 commenced with a special video message by Shri Prakash Javadekar, Former Minister of State (IC) for Environment, Forest and Climate Change with his inaugural address on India's commitment to NDCs and the critical role that corporates could play in technology innovation and investments in order to achieve the set targets. Commending TERI's efforts Shri Prakash Javadekar, said, "The government has started walking the talk by initiating actions such as coal cess which has contributed to the Clean Energy Fund. Businesses will now have to do the same. They need to invest and innovate in India, instead of importing expensive technology. There is a need to attract our technology manpower to capitalise on innovation opportunities in India. Working on improving energy, water and emission efficiencies today present a huge business opportunity."



○ TERI CBS Annual Leadership Summit for Sustainable Development 2016

Energy

TERI is committed to contributing towards global energy access targets through clean energy interventions. In this endeavour, divisions working on energy have undertaken diverse activities in different scales of outreach.

Introduction

The Social Transformation Division seeks to make long-lasting impact on rural lives in developing nations through transformative development technology, collaboration with local partners, and sustainable service delivery models. The Division has a team of researchers who take action-oriented research approach, testing innovative technologies and service delivery models in the field, and proving its efficacy and feasibility for large-scale dissemination. The division has worked on rural energy access, livelihood generation, sustainable natural resource management, and capacity building related projects in the recent past.

Providing clean, affordable, and reliable clean energy solutions to rural households is one of the focal activities of the Social Transformation Division. Under the umbrella theme of energy access, the Division specifically focuses on four areas, namely, technology customization, entrepreneurship development, developing efficient service delivery models, and capacity building of value chain stakeholders. 'Lighting a Billion Lives' (LaBL) campaign of TERI, which is managed by the Social Transformation Division, is a pioneering initiative in the country to provide clean lighting solutions to rural households, having impacted more than 1 million households by March 2017. The campaign provides the Division with an arena to innovate on technology and service delivery models in clean energy access. Other than clean domestic lighting solutions, the division also works on energy for productive activities in rural areas and clean cooking solutions.

Rural Cooking Energy

The Division has worked towards customizing forced draft cooking technology to improve quality and to suit consumer preferences and contextual cooking conditions. More than 11 variants of forced-draft cooking technologies, varying in complexity and cost, have been developed over the last five years. The most recent addition is a forced-draft cookstove optimized for burning coal as a cooking fuel, specifically meant for households in coal mining areas. The division proposes to continue working on clean cooking solutions, encompassing a wider range of technology options and fuel types. Providing 'last-mile' delivery of services through a mix of market-based and non-market approaches is a cornerstone of TERI's rural development projects. In the case of improved cookstoves, a vast network of energy entrepreneurs, numbering 300+ (as on March 2017) has been created to provide household-level services to users of clean energy technology. In many cases, self-help groups have been village-level functionaries responsible for providing post-deployment user service and collection of user payments. Energy enterprises also maintain

an inventory of spare parts for prompt repair and maintenance of systems. Through this network of entrepreneurs, NGOs, and financial institutions, the division has disseminated more than 65,000 improved biomass (forced draft) cookstoves till March 2017.

This approach has been utilized in varied contexts, from energy access to livelihood creation—where a group of village level entrepreneurs have been instrumental for providing access to products and services to poor households. In the coming years, TERI envisages a wider network for service delivery, involving myriad entities, including individual entrepreneurs, micro-finance institutions, NGOs, village cooperatives, and most importantly, self-help groups.

Lighting a Billion Lives

Access to clean energy for basic and productive use has been prioritized at national, regional, and international levels. TERI's LaBL initiative has evolved as a pioneer and has immensely contributed to rural energy access for the poor through actual implementation, technology and skills development, institution building innovation, and knowledge sharing. In India, LaBL has set its footprints in 23 states, and at international levels, it has presence in more than 12 countries. While on innovation front it moved from state-of-the art LED lighting devices to DC micro-grids and integrated domestic systems, a lot of emphasis has been put on developing enterprises and value chains at local levels. Moving away from subsidy and distribution driven models, LaBL focussed on sustainability of the endeavour, and by extension, on capacities. This is the main reason behind whole lot of efforts being placed on developing capacities of technicians, entrepreneurs, and even users, to absorb these new technologies. Creation of local-level energy entrepreneurs to roll out and maintain rural lighting and mini-grid solutions for sustainable community-based management has been one of the most innovative features of LaBL. Hand-in-hand with these efforts, equally important has been sensitization of financing community and policy makers. In order to draw maximum benefits for the community, the programme has also been continuously working on designing its interventions such that they complement government's development schemes such as rural livelihood programmes. This has helped LaBL not only in increasing its reach, but also in leveraging resources multifold, in a manner that facilitates greater ownership of devices among rural households. And now, as LaBL enters in its decadal year, the knowledge gained from extensive field work over the years contributes to SDG 7 attainment not only in India but over Global South. With the programme being designed around clean and renewable energy, LaBL encompasses all the critical dimensions of SDG 7. Efforts of LaBL's village-level entrepreneur, Shrimati Noorjahan

(Uttar Pradesh) were recognized by Hon'ble Prime Minister of India Shri Narendra Modi during one of his "Mann Ki Baat" radio sessions. Another female entrepreneur from Kanpur, Shrimati Priti Kushwaha, received several awards for her tireless efforts in the area of rural energy access. Projects executed by LaBL in 2016 have facilitated integration of energy access in the areas of education, health, entrepreneurship, and integrated rural development. With support and confidence entrusted by patrons, partners, volunteers, and supporters on the overall commitments of the campaign, the initiative has so far impacted over 5.3 million lives globally.

Based on this learning, LaBL will continue to focus strongly on providing a growth path to energy entrepreneurs for Panchayat and Block level service provision. LaBL will also further promote community participation through Panchayats, self help groups (SHGs) and local- and state-level NGOs, in particular by building long-term strategic partnerships with the latter. LaBL will also endeavour to mainstream this activity through the livelihoods programme of the State Rural Livelihoods Missions (SRLM) and align it more closely with activities related to achieving the SDGs.



Productive Uses of Energy

The Division has been able to bring transformative impact to various spheres of human development through the provision of clean and reliable energy systems. In the area of public health, the Division completed the project funded by a major public sector unit for provision of solar power plants to primary health centres in three Indian states. The solar power plants were designed to meet energy requirements of health equipment in these centres, based on present availability and future patient needs.

Solar power plants have also been designed for several primary schools in eastern India to operate lights, fans, and computers in villages not connected by the grid and having erratic power supply. The Division has also been making interventions focussing productive uses of energy. In the past, solar-powered small business units were set up in Uttar Pradesh, Madhya Pradesh, and Odisha to provide livelihood opportunities to (SHGs). With support from HCL Technologies,

the Division carried out an assessment of the energy needs in a cluster of villages for both productive and consumptive uses.

Promoting Access to Sustainable Energy

With the aim to improve sustainable energy access among SC/ST households in Chamarajanagar district in Karnataka, TERI is implementing a project with the support of the Department of Science and Technology in five villages in Bhogapura Panchayat. A baseline socio-economic survey was completed to select 475 beneficiary households to disseminate solar home lighting systems and improved cook stoves. Awareness programmes were conducted in all the villages to orient the target community on renewable energy and the purpose of the project. Local youth and masons were trained on constructing low-cost improved cook stoves, thus investing in building skills of the local human resource. From the scientific viewpoint, performance testing of the traditional cook stoves comprising water boiling test, kitchen performance test, and indoor air quality testing were carried out to establish baselines, so that the impact of the project interventions could be studied in future.

Policy Support to the Government and Promoting Sustainable Energy Access

During this fiscal, the Division has worked on a range of projects. A study on understanding the willingness to pay and on the business models for energy access in India, funded by the DFID, UK, sought to understand the viability of on and off-grid energy solutions and potential uptake for energy solutions in India by assessing the 'willingness to pay/invest' for energy services and the commercial viability of business models for both on- and off-grid energy service provisioning. In particular, the study examined the potential for distributed generation to contribute to energy supply.

Another project is exploring factors that enhance and restrict women's empowerment through electrification, supported by the ENERGIA Gender and Energy Network. The project examines the electricity systems in East Africa and South Asia and their social effects. Through empirical investigation, comparison between gender dimension of emerging centralized (grid) and decentralized systems is being done, and also, study how such systems work in parallel and/or complement each other is being carried. The overall objective is to account for the factors that enhance and restrict women's opportunities and empowerment through electrification.

In partnership with the Salesforce Foundation solar lanterns were distributed in Moleyur haadi, a tribal hamlet in D.B. Kuppe Forest Range, Nagarhole Forest Division, Karnataka. This was a modest but meaningful initiative that brought light to the unelectrified hamlet. In addition, a similar initiative was taken up in Hulkund village, Ramdurga taluk,



Belgaum district suffering from erratic power supply, where the households benefitted from a sustainable source of light—solar lantern.

With the support of the Department of Science and Technology, the area is aiming to improve sustainable energy access among SC/ST households in Chamarajanagar district in Karnataka. The project is being implemented in five villages in Bhogapura Panchayat, where a preliminary socio-economic survey was completed to select more than 400 beneficiary households to disseminate solar home lighting systems and improved cook stoves. The activities completed during the year included awareness creation on renewable energy, training to youth, and performance testing of traditional cook stoves.

Capacity Building

TERI is recognized as a capacity-building hub of the United Nation's Sustainable Energy for All initiative (SE4All). Since the division adopts a rural enterprise-building approach for implementing its energy access initiatives, building technical and business capacities of entrepreneurs is an integral part of the Division's energy access programmes. In the past year, the Division developed video-based training modules for users and entrepreneurs in English, Hindi, and some regional languages to introduce them to improved cooking and clean lighting technology. Various state-level civil society organizations have also partnered with TERI for providing training programmes in states. To enhance financial capacities of entrepreneurs, the division has partnered with micro-finance institutions and regional rural banks that provide capital support to entrepreneurs and consumer finance to rural buyers of clean energy technology.

With a goal to further the mandate of knowledge sharing, the Division has been conducting the TERI-ITEC programmes supported by the Ministry of External Affairs, Government of India. Programmes ranging from integrated approach towards sustainable development, decentralized energy solutions, solar energy for rural livelihoods, trade and sustainable development to renewable energy, and energy efficiency are being hosted.

In the recent past, the Division has been engaged in building capacities of Panchayati Raj institutions for sustainable natural resource management at the village level.

It has also conducted detailed stakeholder workshops for senior and middle-level government officials undertaking energy access and rural development projects at the state level. Currently, the Division is building partnerships to engage with self-help groups and federations, and producer companies to build their capacities in entrepreneurship, livelihood generation activities and clean energy technology.

Monitoring and Evaluation

Particulate matter, including short-lived climate pollutants, such as black carbon, is a significant pollutant resulting from the use of solid biomass cookstoves. In partnership with the University of California, San Diego, and Nexleaf Analytics, USA, the Division led the activities of Project Surya in India. The objective of the project was to carefully monitor black carbon emission from biomass cookstoves and work towards reducing emissions of short-lived climate pollutants through dissemination and encouraging use of 'truly' improved cookstoves. In a pilot project in Odisha and Uttar Pradesh (Climate Credit Pilot Project), TERI monitored black carbon emissions and usage of forced-draft cookstoves in rural kitchens, using mobile-based wireless sensors developed by Nexleaf Analytics and Qualcomm Technologies Ltd. Based on this data, the Project Surya team created a dummy carbon fund to provide monthly usage-based incentives to nearly 4,000 rural women directly to their bank accounts. As a follow-up of this project, TERI compared exposure to particulate matter in households using improved and traditional cookstoves, further linking it to health outcomes. Using similar wireless sensor technology, the division monitored the temperature in cold chain facilities in health centers. Installation and commissioning of around 15,000 Cold Trace monitors were done in Uttar Pradesh, Madhya Pradesh, and Rajasthan.

The Electricity and Fuels Division has recently completed a first of its kind project that required development of roadmap for implementation of solar rooftop system scheme in Surat Smart City, for the Surat Municipal Corporation. We believe that for successful implementation of any project, engagement of citizens as stakeholders is a must and in this project we made sure that the citizens are well informed and are made aware of the benefits of solar rooftop systems. Activities that were undertaken included solar rooftop potential estimation for the city of Surat, preparation of city-specific guidebook, and information manual, development of online portal, that is website and mobile application for information dissemination and consolidation of solar rooftop installation interest from the citizens of the city. Publicity through national/regional newspapers, social media (Facebook, Twitter), FM radio, public hoardings, was carried out at a large scale. We recognized 22 brand ambassadors (Mayor, Commissioner, Committee Heads, Member of Parliament, Member of Legislative Assembly of Surat City, etc.) who have been engaged to spread the message among the citizens for the installation of solar systems. This effort has resulted in achieving a total installation of more than 4 MW in residential and various other consumer category segments in a period of 3 months.

The activity in water/wastewater treatment focussed on membrane bioreactors, forward osmosis process, resource recovery, and development of composite membranes containing metal organic frameworks. In distillery wastewater treatment, the focus has been on melanoidins and polyphenol recovery using fractionation with mixed matrix membranes (MMM) and adsorption using modified activated carbons and commercial resins. The antioxidant properties of the recovered fractions have been studied and optimum recovery methods have been identified. Forward osmosis using biomimetic membrane is also being studied for melanoidins concentration and water recovery in distillery wastewater. Polyamide thin film composite membranes containing metal organic frameworks (MOFs) were prepared and tested for separation of common analgesic acetaminophen; up to 55% retention was obtained.

Biodegradable polymers for packaging, biomedical, EMI shielding, and fire-resistant applications are being developed at TERI Bengaluru. High-performance nanocomposites using recycled comingled plastics for fire-retardant applications were developed. We have also developed different superabsorbent bionanocomposite by microwave-assisted method for removal of toxic dyes and heavy metals from water bodies. 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.

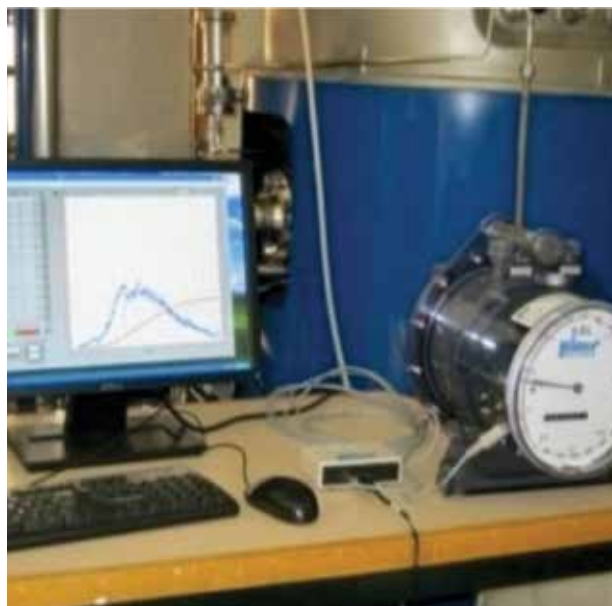
Resource savings have been obtained from implementation of resource-efficient cleaner production (RECP) measures and demonstration of acid/rinse waster recovery systems in Indian metal finishing SMEs. This RECP work was extended to metal sector in Bangladesh, Nepal, and Sri Lanka as part of the METABUILD project supported by the

European Commission under the SWITCH Asia programme. In the first year of the project, around 32 pioneering companies were assessed and 50 showcases of implemented RECP measures are being prepared. In addition, TERI is working with select auto component manufacturers and electroplating units in Pune to implement RECP and promote use of secondary raw materials. Savings from implementation are being quantified.

Technologies Developed for Advanced Biofuel Production

*Development of a Pilot Scale Process for Dark Fermentative Hydrogen Production by *Enterobacter cloacae* DT-1 from Lignocellulosic Biomass, a Second Generation Feed Stock*

Large-scale consumption of fossil fuels resulted in rapid depletion of fossil oil reserves along with accelerated release of CO₂. Hence in recent years, much attention has been paid by scientists worldwide to search for alternative sustainable energy sources. In this context, microbial hydrogen production from renewable sources offers a promising way to produce H₂ through biological route. The Environmental and Industrial Biotechnology Division (EIBD) is at the forefront of fermentative biohydrogen production research and has been extensively working on hydrogen production majorly via dark fermentation, photo fermentation process including integration of dark and photo fermentative hydrogen production process (with the financial assistance provided by Department of Biotechnology, Hindustan Petroleum Corporation Ltd (HPCL), Center for High Technology (CHT), Ministry of Petroleum and Natural Gas (MoP&NG), Ministry



- Fermentative biohydrogen production by C5 sugar utilizing *Enterobacter cloacae* DT-1 strain (isolated by TERI) from lignocellulosic (woody) biomass sugar (second generation feedstock) in 150 litre pilot scale bioreactor (100 litre working volume), through dark fermentation route.

of New and Renewable Energy (MNRE). With the assistance of these financial grants, EIBD developed a 1000 L scale fermentative hydrogen production process from sugar cane industry waste.

Considering the food security issues, this division explored on advance biofuel production and developed recently a process for fermentative hydrogen production from lignocellulosic biomass/aquatic macrophytes, the second-generation non-feed competitive feedstock with a goal to generate energy in a sustainable manner from agri-waste (woody) biomass. This process was successfully scaled up in 100 L scale fermenter at TERI's state-of-art Fermentation Technology Research Centre (FTRC).

Technologies Developed for Enhanced Energy Production

Prevention of Paraffin Deposition in Oil Well Tubing/Oil Pipeline by the Application of Paraffin/Wax Degrading Microbes

In the prevailing context, a major concern is decline of new oil reservoirs. This has raised global concern for petroleum industries to explore processes for enhanced oil recovery from existing oil wells. Production of waxy crude oil poses a serious constraint in oil production as it leads to blocking of oil well tubing/oil pipelines. Oil industries spend enormously in implementing the conventional techniques for removal of paraffin/wax deposition from the oil well tubing/oil pipelines. With in-depth research explorations, TERI and IRS (Institute of Reservoir Studies) ONGC, have developed a cost effective microbial process for prevention of paraffin/wax deposition in oil well tubing/oil pipelines. This microbial process helped in increasing the oil production and thus eventually got commercialized. Since last seven years, this technology has been playing pivotal role in enhancing the oil production and has been successfully implemented in 257 oil wells of Oil India and ONGC.



○ Large-scale injection of paraffin degrading microbial culture at the oil well reserve sites

Microbial Enhanced Oil Recovery from Heavy Oil Well Reserves

With a goal to cater to the rising oil demand, the EIBD continued its research explorations to develop new technologies/ to upgrade developed technologies and got the lead over years to upgrade the MEOR (Microbial Enhanced Oil Recovery) technology through employment of specific unique indigenous heavy oil-degrading thermophilic microflora 'B-90' (isolated from indigenous samples collected from heavy oil reserve). This technology has significance in terms of its oil recovery from heavy oil reserve. Following the process optimization in laboratory scale, recently this technology was successfully implemented in field scale in five heavy oil well reserves of ONGC, through injection of large-scale (2,00,000 litre) heavy oil-degrading thermophilic microbial culture prepared in large industrial scale 13,000 L fermenter at TERI's state-of-art FTRC. This culture was then transferred to the site of injection in desired condition with an aim to not reduce the functional attributes of the microbes. Following injection, the wells were closed for certain time period. Subsequently, oil production from heavy oil reserves enhanced by 5%–7%.



○ Large-scale (200,000 litre) preparation of heavy oil degrading themophilic 'B-90' microbial culture in anaerobic condition, at TERI's state-of-art Fermentation Technology Research Centre



○ Field-scale injection of 'B-90' microbial culture into heavy oil well reserve of ONGC



- Scale up of microbial production of 2,3-Butane Diol by *Enterobacter cloacae*, in 1500 liter pilot scale

Development of Microbial Process for *in situ* Generation/Enhancement of Methane from Underground Coal Seams

With a goal to enhance energy recovery from coal bed, this division with the financial assistance from Oil & Natural Gas Corporation Energy Center (OEC) explored on Coal Bed Methane generation from un-minable coal reserves through the implication of thermophilic methane-producing microflora (isolated at TERI from indigenous samples collected from Coal Bed Methane [CBM] wells, situated in Jharkhand, India). Following the successful leads of this process in laboratory scale in terms of process optimization and formulation of cost-effective nutrient solution for enhancing the performance of this methane-producing microbial consortium, this process was implemented in field scale. Field-scale execution was achieved through injection of 200 KL of the newly formulated nutrient solution (prepared in 13,000 L industrial scale fermenter prior to injection at TERI's state-of-art FTTC). The nutrient solution enhanced the methane production performance of indigenous microflora from coal in the coal bed methane well, as confirmed, that resulted in multi-fold stimulation of *in-situ* biological gas production.

Sustainable Production of Green Chemicals

Microbial Production of 2,3 Butane Diol, a Green Industry Platform Chemical

Chemical industry is critical for the economic development of a nation. Indian chemical industry accounts for ~3% of the global chemical industry. Among all, the specialty chemical



- Downstream purification of 2,3-Butane Diol and its precursor, 'Acetoin' from fermentation broth

segment in India has been growing at a rapid pace owing to the growing key end use markets. 2,3-Butane Diol (23BD) is an industry platform specialty chemical that has profound application as a precursor molecule for synthesis of range of important downstream chemicals: 1,3-butadiene; butenes; methyl ethyl ketone (MEK); gamma butyrolactone; diacetyl; esters, and for use in fuel additives, textiles, polymers, synthetic rubbers and plastics, printing ink. 2,3-BD also has valuable fuel property with burning value of 27,198 J/g, comparable to other liquid fuels as ethanol (29,055 J/g) and methanol (22,081 J/g) and acquired importance as a fuel additive.

Current demand of 2,3-BD is catered through production from petroleum-based feedstock. With a goal for sustainable production, a green process was developed for production of '2, 3-BD' from non-petroleum based feedstock; commercial grade glucose, waste glycerol, agri-waste biomass, by using *Enterobacter cloacae* (non-pathogenic strain, isolated by TERI). Eventually this process was scaled up in pilot scale (in 150 L and 1500 L scale bioreactor) at TERI's state-of-art fermentation research facility and has good potential for further scale up in large industrial scale. Further, strategies were developed for downstream purification of 2,3-BD from the fermentation broth. Currently, explorations are carried out to bridge the transition gap for moving this technology to demonstration scale.

Microbial Production of Xanthan Gum for Implication in Drilling Mud Formulation

Drilling the wellbore is one of the most expensive steps in the oil and gas industry that requires the use of drill in fluids/muds. Drill in fluid/muds play a key role in oil exploration jobs as the success or failure of a geothermal drilling mainly depend on employment of appropriate drilling fluids. Drilling expenses represent 25% of total oil field exploration cost, out of which drilling muds account for around 15%–18%.

Currently, the demand for drilling mud chemicals by Indian oil industries are fulfilled by importing from overseas, countries. Majority of these chemicals, especially, XC polymers

(drilling mud prepared from xanthan gum) are imported from China, Indonesia, and USA. As on date, no Indian manufacturer has got the lead on formulation of drilling mud chemical.

With a goal to formulate an indigenous product, the researchers at the Environmental and Industrial Biotechnology Division (EIBD) explored on microbial production of xanthan gum and currently engaged with formulation of an indigenous drilling mud chemical, that would significantly benefit the oil industries for their explorations and production tasks.

Industrial Energy Efficiency

TERI works closely with the corporate sector and provides services to the industrial and commercial clients in the field of energy conservation. During 2016/17, TERI provided energy audit services to many large industries in India in various end-use sectors. Under the BEE-promoted Perform Achieve and Trade (PAT) Scheme, TERI was involved in studies in nearly 50 designated consumers falling in sectors such as cement, iron & steel, chlor-alkali, and thermal power plants. All these studies under PAT scheme were undertaken as per requirements stipulated by BEE. During the year, TERI also completed BPCL Kochi refinery mandatory energy audit, which was initiated in 2015/16. This was the first major refinery audit undertaken by TERI. Subsequently, TERI started working on a similar study for another large private sector refinery in India. A one-day workshop was also organized on energy conservation in refinery sector in collaboration with BEE and GIZ at New Delhi. The Ministry of Defence organizations, such as MIDHANI & DRDO, as well as various commercial buildings and factories also involved TERI in their energy reduction initiatives. TERI, in association with HAL and BESCOM, is presently engaged in an assignment for installation of 178 kWp solar rooftop PV systems across 22 public schools and colleges in and around Bengaluru.

Apart from serving clients in India, TERI undertook studies in the energy efficiency domain in other parts of the world. TERI auditors were engaged in conducting energy efficiency studies of utilities (power and water) in the Gulf region. The group is providing implementation assistance to the Water Utility in Sharjah. In addition, TERI undertook studies on energy efficiency for municipal water pumping of Dar Es Salaam Water Utility, Tanzania (supported by World Bank) during the year. UNEP also supported TERI to undertake studies in seven plants in Indonesia and Bhutan in the iron & steel, calcium carbide, and ferro silicon sectors. TERI entered into a strategic partnership with EESL for the implementation of energy efficiency and renewable energy projects outside India. Under this initiative, the first stakeholder workshop was organized during the third quarter of the year in Georgetown, Guyana.

TERI continued its extensive efforts for improving energy efficiency in the Micro, Small and Medium Enterprises (MSME) sector. With support from SDC, TERI extended energy audit and implementation services in Rajkot foundry cluster and helped a host of other foundry industries in Howrah cluster

to improve their energy performance by adoption of best operating practices. TERI also expanded its knowledge collation and dissemination activities under its prestigious SAMEEESHKA (Small and Medium Enterprises Energy Efficiency Knowledge Sharing) platform. During the year, TERI conducted field-level surveys and developed cluster level profiles for several energy-intensive MSME clusters. The Shakti Sustainable Energy Foundation also supported TERI in its efforts in the MSME sector in terms of developing various cluster profiles. TERI also continued its activities under the extended World Bank–SIDBI–GEF project and conducted studies in SMEs in Varanasi and Mumbai–Thane mixed industries clusters. Additionally, a new project was initiated this year with support from IFC that focussed on identifying energy-intensive SME clusters in five cities across India where it would make sense to initiate larger programmes on energy efficiency.

In addition, TERI expanded its cooperation with expert institutes from Japan, such as Institute for Global Environmental Strategies (IGES), Energy Conservation Centre Japan (ECCJ), Mitsubishi Research Institute (MRI), and New Energy and Industrial Technology Development Organisation (NEDO). India–Japan Energy Forum 2017 was organized in New Delhi jointly by TERI and NEDO, which attracted participation from a large number of Indian and Japanese experts. Three capacity building workshops were organized in India jointly with IGES on energy efficient technologies in industry sector.

Sustainable Agriculture

Algal Biofuels and Commodities

An indigenous algal photobioreactor design based on sunlight distribution has been found to yield 1.5–3 times higher areal productivity compared to standard system. After testing at 600 and 1,800 L scale, a 10,000 L system was set up in 2016/17. This also includes a simultaneous growth–harvest system that has been tested for consistent daily harvest of algae.

Developing value-added products from microalgae (mainly EPA, DHA, and carotenoids) with antioxidant property and application in food and health industry is another approach being followed for achieving sustainable development.

Outreach

» Two-day workshop on 'Metabolomics for Plant, Human, and Animal Health' was organized on November 17–18, 2016. The key objective of the workshop was to sensitize the scientific community on emerging areas of metabolomics and to discuss the challenges and opportunities related to metabolomics study for plant, human, and animal health. More than 40 national and international delegates from various organizations, such as research institutes, universities, attended the workshop.

Environment

TERI, over the years, has been working vigorously on assessing and improving the quality of the environment. While efforts have been made to analyse and report the status of environmental quality, several initiatives were undertaken in 2016/17 to mitigate pollution and sensitize the stakeholders. All this has yielded considerable benefits and in certain cases, has significantly helped policy formation and implementation.

Air Pollution

Air pollution is a critical concern in a city such as Delhi, where more than 16 million people are exposed to severely high pollutant concentrations on an annual average basis. In 2016/17, the Centre for Environmental Studies (CES) carried out urban/regional air quality management studies, involving monitoring of air pollutants, inventorization of source emissions, state-of-the-art simulations and modelling of air quality, and development of air quality management plans. The Group was involved in the pioneering source apportionment study for the city of Bengaluru and is presently working on a similar study for the Delhi-NCR region. CES, for many years, has also been working on the use of state-of-the-art air quality models (ISCST3, AERMOD, WRF, CMAQ, etc.), to predict urban/regional-scale pollution of criteria as well as emerging pollutants, such as ozone. The Group has also been monitoring aerosols and their properties, particularly in the Himalayas, to assess regional-scale pollution.

Based on air quality modelling work, TERI along with UCSD (and also with author contributions from 13 other institutes internationally) has come out with a report that suggests ten scalable solutions for improvement of air quality in India. The report, widely recognized, suggested a Clean Air Mission for India on the lines of Swachh Bharat Mission.



To encourage Delhi's residents to use public transport and reduce pollution and traffic congestion, the Delhi government observed 'Car-Free Day' on specific road stretches on a particular day of a month. CES carried out a study to ascertain the impact of these "Car-free Days" on the ambient air quality in the area surrounding the route.

In the light of air pollution being a huge issue in the capital city, the Government of Delhi introduced the Odd-Even scheme in which plying of privately owned cars was restricted on alternate days based on the last digit (odd/even) of the registration number. The first phase of the scheme was launched in January 2016 and thereafter it was re-introduced from 15-30 April 2016. CES analysed the effectiveness of the scheme in reducing air pollution and congestion in Delhi and also released its assessment report on the odd/even assessment and submitted an emergency response plan to both the state and central government for tackling high air pollution episodes.

While India has made significant progress in tightening the emission norms of new vehicles, the inspection and maintenance (I&M) programme for vehicles running on-road still needs to be strengthened. CES carried out a project aimed at identifying technological and institutional bottlenecks in the current I&M programme of India and accordingly suggested suitable recommendations. In addition, special focus was laid on Bengaluru and Mysore, as case studies, to understand the situation of I&M programme at the city level. A perception survey was also conducted to gauge the understanding of vehicle owners regarding the role of vehicles in air pollution and importance of regular maintenance of vehicles. The findings of the project were presented to the policy makers at the central and state levels in two conferences held in Delhi and Bengaluru.

The Group is also working on assessing the co-benefits of low-carbon pathways, presently being followed by India, on air quality, human health, and agriculture.

Indoor Air Pollution and Health

CES has also conducted several studies to assess indoor air quality at both regional and urban scales, especially in rural households, where biomass is used predominantly for cooking purposes. CES carried out indoor air quality assessment studies at different office buildings (WHO, UNDP, and Accenture) and suggested various measures to improve the indoor air quality. In association with the University of California, San Diego (UCSD), TERI has initiated an indoor air quality (IAQ) monitoring and exposure assessment study in Odisha, where improved cook stoves were implemented. The main objective of the study was to measure the impact of

the use of improved cook stoves on Indoor Air Pollution (in terms of CO, PM_{2.5}, and BC) and also to measure the impact of interventions on the cardio-pulmonary health of non-smoking women in rural households of Odisha.

CES carried out a collaborative research project with Child in Need (CiNE) with a research grant from Ministry of Health, Government of India, to assess adverse health outcomes of exposure to household-level air pollutants in rural community. The study assessed maternal exposure of different pollutants in cooking environment of rural homes using different cooking fuels or improved cooking stoves. The study also helped in assessing the association of pollutants during different stages of fetal growth (intra-uterine growth), and pregnancy outcome (pre-maturity and birth weight of the newborn), and also to see the association of pollutants on fetal biometry and pregnancy outcome for different cooking technologies. Finally, a report was prepared to review the feasibility and efficacy of interventions aimed at reducing household-level air pollution.

With the research funding support from DFID, United Kingdom, CES has conducted a study in one of the pristine rural areas of the Indian Sunderbans (Baikunthapur, 24 Parganas (S), West Bengal) to estimate the pollutant concentrations in the rural households due to the burning of solid biomass fuel and ignition of kerosene wick-lamp and to estimate the pulmonary health status of women and children. As an intervention study, the conventional cook stove and the kerosene wick-lamp in ten random households were replaced with a specific improved cook stove and solar lantern, respectively, to study their effects in reducing the pollutant levels inside the households during day time and evening cooking periods.

Workshops/Training Programmes

TERI continues to strengthen, 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.

CES has carried out a training programme for Government officials on the impact of various environmental contaminants on human health with support from the Central Pollution Control Board (CPCB). The proposed training programme aimed to bridge the gap and build the capacity of state pollution control boards (SPCBs), pollution control committees (PCCs), etc., in the field of environmental pollution and associated health effects. Twenty participants from different state and central pollution control boards across the country participated in the training programme. The basic objective of the training programme was to make the participants understand the basic concepts of environmental pollution and its impact on human health and provide ready-to-use course materials on the subject. CES has also organized a training programme on Emission Testing and Monitoring for the Bhutan Government officials.

In the backdrop of the current challenge of air pollution in Indian cities and the significant role of the transport sector in the problem, TERI organized two workshops, one in Delhi in October 2016 and the other in Bengaluru in November 2016 and released a position paper on 'Improving Inspection and Maintenance System in India'.



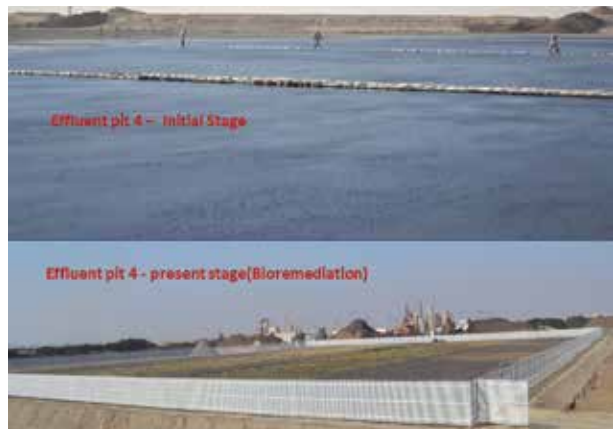
The objective of the workshop was to initiate a discussion on the current I&M system for in-use vehicles in India and its limitations and to contemplate on the possible solutions to improve I&M system in India. The workshop witnessed representation from the government, industry, research institutes, and regulatory authorities.

During 2016/17, TERI also carried out maintenance of a green belt covering an area of 20 acres at Tata Chemicals Ltd, Gujarat, earlier developed by TERI on chlor-alkali waste.

Continual application of biomethanated spentwash for a period of over 10–15 years has made the land highly saline for the sugar industry (Ugar Sugar). As part of the Indo-EU Water4Crops project, the Sustainable Agriculture Division has the objective to remediate this land. The selected consortium (4 bacteria and 3 mycorrhiza species) are applied in field trials of sugarcane with assistance of University of Agricultural Sciences, Dharwad, at the Ugar Sugar Works Ltd, Karnataka. The field trial is aimed to investigate the possible impact of microbial consortia on crop yield as well as soil quality of the experimental field.

'KT-Oilzapper', A Green Technology for Sustainable Remediation of Oil-Contaminated Site at Kuwait oil field

Considering the eco-friendly and cost-effective approach of Oilzapper technology, developed by the Environmental and Industrial Biotechnology Division, for bioremediation of total petroleum hydrocarbon (TPH) contaminated sites, this technology has been widely used by almost all the oil industries in India over the last decade (since 2007). Successful field-



- TERI's Oilzapper technology is instrumental in restoration of oil-contaminated soils in Southeast Kuwait

scale implementation of TERI's Oilzapper technology over the years, for bioremediation of oil-contaminated sites across the nation as well as in overseas countries, enabled the research team at TERI to develop core competency for upgrading this technology further for ease of application of this product in different environments, such as at high temperature zone areas or in high saline conditions. To accomplish the mega task of remediation of an oil-contaminated site in Kuwait South East oilfield (under a mega project sanctioned by Kuwait Oil Company, KOC), this division upgraded the Oilzapper product, through the use of indigenous oil-degrading microbes (isolated from Kuwait oil field sample), designated as 'KT-Oilzapper'. This product enabled TERI to successfully complete bioremediation of 220,000 m³ of TPH-contaminated soil at South East oilfield of Kuwait. The performance evaluation of 'KT-Oilzapper' for bioremediation was found to be most sustainable, eco-friendly, and cost-effective among all the remediation approaches, such as soil washing, 'Indirect Thermal Desorption Unit', Direct Thermal Desorption (TDU).

Considering the significance and performance of bioremediation approach (carried out by TERI through implication of KT-Oilzapper product), the Kuwait Oil Company only considered the bioremediation approach for remediation of large oil spill affected area at the Kuwait South East oilfield.

Sustainability 4.0 Awards

Frost & Sullivan has joined hands with TERI for the Sustainability 4.0 Awards 2016/17. TERI's continuous engagement with the corporate sector through its Council for Business Sustainability (CBS), a CEO-led industry body with membership of over 100 leading corporates from diverse sectors and geographies, provides an independent and credible platform for corporate leaders to address issues related to sustainable development and promote leadership in environmental management, social responsibility, and economic performance.

Through this initiative, Frost & Sullivan and TERI aspire to have larger number of companies in the country moving to a structured sustainability programme. The assessment process has been designed to enhance the knowledge of sustainability, highlight the best practices in the industry, and create a roadmap for sustainable businesses.

Sustainability 4.0 Awards are designed to accelerate adoption of sustainable development practices through a benchmarking and recognition process, and recognize leaders of the sector by highlighting their best practices and creating a roadmap for sustainable businesses.

Forestry and Biodiversity

Forests cover approximately 30% of the Earth's land surface and provide critical ecosystem goods and services, including food, fodder, water, shelter, nutrient cycling, and cultural and recreational value. Forests also store carbon, provide habitat for a wide range of species, and help alleviate land degradation and desertification.

Currently the forestry sector is at the centre stage of global climate change negotiations as it is a low-cost carbon mitigation option. The ongoing paradigm change in the sector necessitates fundamental orientation and attitudinal changes of the personnel in line with multifarious roles of forests, corresponding variety of externalities and for coping with traditional forestry management practices. The focus has shifted considerably to environmental stability, biodiversity monitoring and management, restoration of ecological balance of the disturbed areas, protective functions of the forest resources, and other socio-economic benefits based on non-timber forest products (NTFPs). The concept of sustainability in forest management thus implies not only sustainability of productive functions but also environmental functions (soil and water conservation, carbon sequestration, etc.) and socio-economic benefits (meeting livelihood and basic needs) to forest dwellers and other forest-dependent communities.

Understanding the importance of the sector, TERI has a dedicated Forestry and Biodiversity Division that has developed a major research interest in technical forestry, participatory forestry approaches, governance and rehabilitation of degraded areas, clean development mechanisms, and emission reductions. In addition, the Division is engaged in monitoring and evaluation of forestry and watershed development-related activities. Besides, studies on biodiversity and payment for ecosystem services are undertaken. Capacity-building activities, particularly for state forest departments, is an important activity for the Division.

In the year 2016/17, the major focal area for TERI was Carbon Forestry and Biomass Estimation, wherein TERI undertook a detailed study of Clean Development Mechanism (CDM) project assisting the state forest department of Uttar Pradesh to successfully register 10 small afforestation/reforestation CDM projects with the United Nations Framework Convention on Climate Change (UNFCCC). There are around 20 registered projects in the country, of which 10 registered projects are located in Uttar Pradesh. Once validated by the external validating agency, Certified Emission Reduction or CERs can be sold either in the compliance market or voluntary market. In addition, TERI has also successfully carried out Monitoring and Evaluation of Advance Soil Work and Plantations undertaken by the Uttar Pradesh Forest Department in the year under review.



Web Application-Based Evaluation of Forestry Works in Tiger Reserves

During the year, the CIEEA (Bengaluru) area conducted an intensive evaluation study for the Karnataka Forest in two forest circles, namely Field Director Project Tiger (FDPT) Mysuru and Chamarajanagar Wildlife Circles in Karnataka. These circles comprise core tiger reserves such as Nagarahole, Bandipura, BRT Tiger reserve, Cauvery Wildlife Sanctuary, Male Mahadeshwara and Chamarajanagar social forestry. This study covered the works carried out by the department on wildlife and forest protection, plantations, soil and water conservation, eco-tourism, infrastructure works, seedlings distributed to public, and beneficiary oriented schemes, such as disseminating solar lanterns, LPG, and solar water heaters for the period 2009/10 to 2014/15. For the first time in Karnataka, a web-based application was developed solely for the purpose of this study called 'KFD External Evaluation Survey'. The application comprises digitized forms of questionnaires with instant upload of data to the department server, along with photos, including GPS coordinates. This method reduced the time taken for data entry and ensured accuracy, integrity, and standardized data. The study was challenging, given the variety of terrains and diversity of works.

Another thrust area for TERI is Biodiversity and Conservation wherein a variety of national and international projects are currently underway. These include Uttarakhand State Biodiversity Board and UNDP-funded 'Preparing an Updated State Biodiversity and Action Plan for Uttarakhand' and the GEF Satoyama-funded 'Mainstreaming Community Conservation Areas for Biodiversity Conservation in Nagaland'. The Division has also initiated a project with Tribal Cooperative Marketing Development Federation of India Ltd (TRIFED) on enhancing income of forest dependent communities through establishing minimum support prices (MSPs) to assess 12 minor forest produce (MFPs) in 9 states with predominant tribal communities also known as PESA states, that fall under the Panchayats (Extension to the Scheduled Areas) Act.

In addition, TERI is also involved in monitoring and evaluation of projects and is performing consultancy for impact assessment of Pradhan Mantri Krishi Sinchai Yojana (PMKSY) Watershed Development Project in Uttarakhand and



web application-based evaluation of forestry works in tiger reserves in two forest circles, namely Field Director Project Tiger (FDPT) Mysuru and Chamarajanagar Wildlife Circles in Karnataka. Recently, TERI has completed a study on assessing scale of land degradation with the economic impacts in India. The other objective of the study was also to assess the quantum, along with the sources, of investment required for undertaking preventive and restorative measures that can help achieve the aspirational goal of land degradation-neutral India by 2030.

Besides, TERI has also been active in training and capacity building of state forest departments and has regularly conducted training programmes, including the one-week refresher training programme for IFS officers, and capacity development for forest management and training of personnel in Arunachal Pradesh and Assam. TERI works actively in the field of natural resource management and has recently completed developing and facilitating community development plans in Mizoram and Tripura under the North East Rural Livelihoods Project. TERI also works on various institutional issues relating to participatory forest management and has major interests in the study of forest-based livelihoods and benefit-sharing at the community level. At present, the Division is implementing a programme on 'Agriculture, Greening, Training, Capacity Building and Income-generation Activities' supported by Coal India Ltd.

Another important area of TERI is conservation of Mycorrhizal biodiversity by means of collection, isolation, propagation, characterization, and maintenance of cultures under *in-situ* conditions. The Centre for Mycorrhizal Culture Collection (CMCC) is a Mycorrhizal Bioresources Centre that manages a next-generation germplasm bank, which now houses over 1,500 trap cultures, obtained from various sources, and from these trap cultures we have been able to raise more than 4,248 monosporal cultures, representing a total of 816 different monosporal lines being maintained. Apart from these, there are around 250 different isolates of

ectomycorrhizal fungi (EMF) obtained from different hosts all over the world. These mycorrhizal isolates are also being characterized for their functionality and uniqueness in improving plant growth, ameliorating biotic and abiotic stress under greenhouse conditions. Several other research studies are ongoing in search for novel molecules of biological importance as well as technologies that would benefit the local farmers in their practice of agriculture.

TERI, thus, endeavours to facilitate creation and development of models, systems, and concepts for conservation and sustainable utilization of natural resources. The organization has not only put considerable effort into documenting the research findings but has also stressed on outreach and training component by sensitizing the policy makers, government officials, educational institutes, and common people through various outreach activities.

The People's Biodiversity Register (PBR) and City Biodiversity Index (CBI) of the City of Panaji, Goa, is a project that is supported by the Goa State Infrastructure Development Corporation. The PBR of Panaji City involves the recording and inventorization, in consultation with the local people, the occurrence of various species of flora and fauna and resources present in the region, which may be of local significance. It is also an attempt at recording rapidly eroding knowledge of the medicinal uses of local plants, and the occurrence and management practices of land races of cultivated crops. Thus, the PBR provides a platform through which members of a community may initiate steps towards better management of their biodiversity resources. The CBI aims at chronicling the status and trends of biodiversity and ecosystem services in urban settings. The CBI of Panaji is



important in that it will provide an overview of the degree of sustainable development in the city.

The development of the PBR is also being facilitated in the coastal villages of Velim and Chorao, Goa, under the support of Goa State Biodiversity Board and GIZ-India.

Mainstreaming Biodiversity for Responsible Business

Realizing the fact that business is an important mechanism through which biodiversity conservation and enhancement of ecosystem services could be achieved, a thematic track was organized on 'Mainstreaming Biodiversity for Responsible Business' as part of WSDS 2016. The Aichi Targets by Convention on Biological Diversity (CBD) and the SDGs have largely focused on this theme through its various goals such as Target 6 and 15 of UN's Sustainable Development Goals and Target 3, 4, 6, 7, 13, 16, and 18 of CBD's Aichi Biodiversity Targets. Similarly, India has also developed its National Targets (5, 7, 9, 10, 11) focussing on biodiversity conservation.

Prominent programmes, such as TERI Council for Business Sustainability and Leaders for Nature programme of IUCN, work towards building the capacity of businesses and towards on-ground solutions. All of these initiatives are oriented at educating, advising, and providing solutions to the industries to mainstream sustainability in their operations and reduce as well as mitigate impacts on ecosystems. These efforts need to be consolidated nationally, thus forming a synergetic impact. To build this synergy, this session brought stakeholders together and deliberated upon the issues of sustainability that vary with respect to the type of business, and hence, defining the sustainability and developing solutions to mitigate impacts are needed. The panelists also discussed that investing in biodiversity and ecosystem services is futuristic and ensures multiple benefit flow in favour of business and local livelihoods. The deliberations brought out the challenges and opportunities for responsible business to mainstream biodiversity conservation in India.

Thus to bring out the challenges and opportunities for responsible business, the following pointers were discussed upon: The issues of sustainability vary with respect to the type of business and hence defining the sustainability and developing solutions to mitigate the impact are needed. Investing in biodiversity and ecosystem services is futuristic and ensures multiple benefits flow in favour of business and local livelihoods. Documentation, safeguarding, and strengthening traditional knowledge needs standardization,

partnerships and innovative models of equitable sharing benefits from commercialization of biological resources.

The discussion and the presentations prioritised three main approaches to undertake with respect to business and biodiversity, such as:

- » Species-level conservation by developing the *ex-situ* methods of multiplication for commercial use
- » Livelihood options for local communities to reduce their impact on the natural ecosystems, and
- » Restoration of degraded landscapes by developing suitable habitats

These three approaches would be important for industry to contribute substantially in attaining the National Biodiversity Targets and hence also contribute to the global efforts of biodiversity conservation and sustainable use of the biological resources.

As part of the World Sustainable Development Summit 2016, the Business Day event provided timely responses for the next global meet in Marrakech in November 2016 in the form of taking concrete steps towards international co-operation to limit the rise of global temperatures to well below 2 °C. The Business Day underscored the need for businesses and the private sector to take the lead in poverty reduction and to ensure rapid and sustained adoption of SDGs.

To explore the biodiversity and bio-prospecting of endophytic microorganisms isolated from different microhabitats in search for novel molecules of biological importance is another important area of research presently under investigation in the Plant Biotechnology (PBT) Division. More than 1,500 endophytes have been isolated from different medicinal plants growing in India and screened against a plethora of plant pathogenic fungi for antagonistic activity, phytotoxicity studies, nematicide activity, and antifeedancy activity against plant pests of economically important crops. A significant number of endophytes have shown promising results and bioactive metabolites produced by these endophytes have been characterized. These endophytes are currently under various stages of evaluation and subsequent development and in near future may become a part of Integrated Pest Management programme. In a DBT sponsored project, PBT area isolated 840 fungal and bacteria isolates from stem, leaf and surrounding soil of Agarwood (*Aquilaria* sp.), a valuable tree of North-Eastern India, and developed technology to induce artificial infection in agarwood by using these microbes. After validation, the technology would benefit the local farmers.



○ The Mainstreaming Biodiversity for Responsible Business session at WSDS 2016

Integrated Policy Analysis

India faces a number of development challenges that are essential to be kept in mind while formulating potential strategies and solutions. With a population of 1.2 billion and the aspiration to maintain a high rate of economic growth that could provide a future with better lifestyles and access to improved level of services, infrastructure, and modern energy forms, India's energy needs could rise phenomenally over the next few decades.

Considering India's present stage of development, while she needs to cater to the growing aspirations of society and address the issue of provisioning for adequate and affordable energy requirements on the one hand, it is also important to ensure that the development is sustainable from a resource efficiency and environment perspective, given the growing concerns related to climate change at the global level. Accordingly, the work at the Centre for Integrated Assessment (CIAM) is focussed around several thematic areas in development, energy, and environment space. The Centre is involved in data analysis across different socio-economic categories and regions to understand variations in consumption patterns, lifestyles, and behavioural patterns across income categories

and regions. Such analysis is undertaken at the national level to understand transitions over time and across specific user groups or regions to identify preferences towards specific commodities, fuels, or technological choices. Based on the understanding of preferences and choices, as well as a detailed techno-economic assessment of alternatives, the Group strives to identify barriers to the uptake of efficient and clean alternatives, and identify ways by which access to and use of cleaner and more efficient alternatives can be enhanced. The Centre also focusses on forecasting future energy needs at various levels and across different sectors based on past data and using a variety of statistical and econometric tools and techniques.

Studying the implications of energy use on carbon dioxide (CO₂) emissions and other air pollutants through the application of various scenario-based optimization models and air quality models, conducting inventorization of GHG emissions as a result of the activities undertaken across various sectors of the economy, and assessing the levels of water withdrawal and consumption across various sectors and technologies are a few of the key thematic areas that the Centre has been consistently working on for several years. Using results of such assessments, the Centre is able to provide useful insights into alternative technology and policy options that could enable a more sustainable future.

Integrated modelling of energy demand and supply is undertaken at the national level through the use of the MARKAL (MARKet Allocation) model, which the Centre modifies and updates regularly. The MARKAL model is a dynamic, linear programming model with overall objective of cost minimization of the entire energy system, subject to user-defined constraints. Scenario-based analysis and results from this model and other linked modules are used to provide inputs to policy makers towards identifying and prioritizing mitigation options, delineating a roadmap towards low-carbon pathways at the national level, and providing useful inputs for climate change negotiations.

Through its integrated modelling assessments, the Centre largely analyses climate change mitigation, energy security, energy efficiency potential, and choices towards a more sustainable economy and environment.



Urbanization and Transport

Cities play a central role in generating economic growth and prosperity. Sustainable development of cities largely depends upon their physical, social, and institutional infrastructure. In this context, the importance of transport infrastructure is paramount. Although circumstances differ considerably across cities in India, certain basic trends that determine transport demand are the same. These changes have placed heavy demands on urban transport systems. There is a huge need for a holistic urban transport policy to promote a better quality of life.

Sustainable Urban Development and Smart Cities

TERI has been recognized as a Centre of Excellence by the Ministry of Urban Development, Government of India, and has also been empanelled as a consulting firm under the Smart Cities Mission of Government of India. In this capacity, TERI provided technical assistance to Dharamshala in the preparation of its Smart City Proposal (SCP). The project involved preparation of a city vision along with an area-based development proposal and a pan-city proposal. Dharamshala found its place among the top three cities, among the list of winner cities, selected in the Fast Track Round Challenge of Government of India's Smart Cities Mission in May 2016. TERI is also contributing to capacity building of urban local bodies in the country in the areas of urban planning and development of sustainable infrastructure services under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) Mission.

Urban Climate Resilience

As a National Partner and Policy Advisor to the Asian Cities Climate Change Resilience Network (ACCCRN) since 2009, TERI has been engaged in both city-level resilience planning exercises as well policy assessment for mainstreaming climate

resilience in urban planning and development processes. In its recent engagement under ACCCRN, TERI has conducted state-level engagement and capacity building in order to come up with a Roadmap for Urban Climate Change Resilience Policy in the states of Goa and Uttarakhand, India.

TERI is committed to capacity building and policy advocacy emerging from its research activities. To this end, TERI organized a session focussing on disaster risk reduction and climate change adaptation for the Children and Youth Assembly of Habitat III Conference in Quito in partnership with the United Nations Major Group for Children and Youth and the Water Youth Network. This session focussed on highlighting synergies amongst urbanization, climate change adaptation, and disaster risk reduction and showcase examples of youth and experts engaged in leveraging science and technology and innovation to support urban resilience.

Sustainable Mobility

With the key objective of promoting sustainable urban and inter-city mobility, TERI carries out research focussing on policy analysis, energy and environment analysis, capacity building, and knowledge creation. In an ongoing project with the Shakti Sustainable Energy Foundation, TERI is helping Indian Railways in identifying factors driving the movement





of non-bulk traffic and developing strategies for increasing its share in the movement of total national freight. TERI is also assisting the National Rural Roads Development Agency in evaluating hot and cold mix technologies on account of their life cycle cost, energy consumption, greenhouse gases (GHGs) and criteria pollutants, material consumption, and impacts on safety and health of construction workers, with an aim to promote green technologies in the rural roads sector.

TERI undertakes studies to understand the nexus of transport–energy–climate change and is supporting implementation of nationally determined contributions (NDCs) by conducting an inter-model comparison of various transport sector policies in India. TERI is also conducting a study to assist the Ministry of Road Transport and Highways (MoRTH), Government of India, in drafting policy guidelines for reducing the carbon footprint and enhancing climate change resilience of the National Highways sector in India.

In its endeavour towards promoting sustainable and inclusive mobility options in Indian cities, TERI is conducting a study as part of the Switch Asia Programme funded by the European Union. The study aims to understand the role of various informal transport modes (like auto rickshaws, mini buses, cycle rickshaws, etc.) in meeting the mobility demand in our cities with the objective of bridging the existing knowledge gap in this field and influence policies.

Buildings

India's demographic trends indicate a consistent rise in urbanization. It is estimated that by 2030, over 33% of the total Indian population would reside in urban areas and, by 2050, building-related emissions are expected to double or even triple without action. The rising population and rapid urbanization would push the demand for housing and

commercial spaces, providing a further impetus to the rising growth of the construction sector in the country.

In order to ensure sustainable development, as part of the environment, TERI has set up a Centre of Excellence (CoE) with the support of Mahindra Life-Spaces Developers Ltd (MLDL) as well as UTC to carry out research on energy-efficient building envelopes, sustainable water use, development of an energy-use reporting framework for existing buildings, real-time reporting of consumption, and identification and cost-benefit analysis of energy conservation measures. TERI's research has been focussed on low energy architecture and electro-mechanical system, water and waste management, and renewable energy systems. A project on "Mainstreaming Sustainable Social Housing in India (MaS-SHIP) was sanctioned by United Nations Environment Programme (UNEP), consisting of four consortium partners (TERI, Oxford Brookes University (OBU), Development Alternatives, and UN-Habitat). The project aims to develop a 'Sustainability Index' for the building materials and construction technologies for the affordable housing sector. Another ongoing research activity comprises visual and thermal comfort monitoring of Somfy Roller Blinds in the Indian context.

TERI is also actively involved in implementing the Energy Conservation Building Code (ECBC) at state levels and has set up a Project Management Unit (PMU) at Odisha State Designated Agency (SDA) and two ECBC Cells have also been established in Haryana and Punjab.

A study was conducted for development of Nationally Appropriate Mitigation Actions (NAMAs) for the buildings sector in collaboration with UNEP. The CRSBS Group has also provided India-specific inputs to support the diffusion of both energy-efficient technologies and policy packages that overcome barriers for implementing these technologies as part of BigEE project funded by The Wuppertal Institute.

The TERI Southern Regional Centre is working on projects, both at the domestic and international levels. In domestic operation, the group worked with Power grid, NBCC (National Buildings Construction Corporation Ltd), Karekar Associates, Salarpuria Properties, Zuari Infracore, ITC, and Bharat Electronics Ltd, thus, helping them in green building consultancy and GRIHA certification. TERI has been providing green building consultancy for office spaces in countries of the Middle East as well. Under financial support from UNEP, start-up research was carried out in formulating a framework of Sustainable Construction and Production of Building Materials in the Himalayan Regions of India, Nepal, and Bhutan. Along with industry partner SHARP, TERI carried out a performance evaluation of air purifiers through research on its effect on reducing indoor pollutants, such as particulate matter and obnoxious gases, in tropical cities such as Delhi and Bengaluru.

At city level, TERI is carrying out research on establishing relationship between urban planning and its impact on the Urban Heat Island Effect. At present, this work is being carried out for the city of Bengaluru, with financial support from EMPRI, Government of Karnataka.

Assuming that the buildings sector belongs to a complex industrial chain, involving a wide range of actors, a variety of instruments imbued by the political agenda are used to achieve certain degree of sustainability. The most commonly used instruments are economic incentives, rating systems, and energy audit programmes. To provide a framework to ensure design, construction, and implementation of regionally relevant and resource-efficient buildings, TERI developed the Green Rating for Integrated Habitat Assessment (GRIHA). GRIHA enhances energy-use optimization by promotion of bi-climatic passive architectural practices; facilitates enhanced energy efficiency by ensuring mandatory compliance with the Energy Conservation Building Code of India, the National Building Code, and other relevant codes and standards for efficiency and comfort; and mandates renewable energy integration.

GRIHA has been adopted by the Government of India and various state governments to ensure design and implementation of sustainable habitat. With measured impact on resource efficiency, GRIHA rating for buildings and developments has also been linked to incentives in the form of additional Floor Area Ratio (FAR), property tax rebates, and cheaper loans for developers across the country. Recently, the

Government of Haryana revised their building bye-laws, in 2016, to encourage and recognize green building measures by projects and award benefits of additional FAR by getting the building/site/project certified from the GRIHA Council.

GRIHA has been embraced by organizations, including the NBCC and Central Public Works Department (CPWD), wherein the building standards and specifications have been revised to meet minimum 3-Star GRIHA requirements.

Sustainability Report for DMRC

TERI CBS has been engaging with DMRC to develop its Sustainability Report conforming to GRI G4. DMRC's second Sustainability Report was launched on March 31, 2016. Urbanization is increasing, rural populations are declining and these trends are set to continue, driven by demographic, economic, and environmental changes. India's future cities will pose new challenges for how we live, work, and travel. Reaffirming DMRC's leadership position, the Third Sustainability Report illustrates how urban travel can be made sustainable, and contribute to the local communities and economies that it connects and creates. The Report helps DMRC with increased understanding of risks and opportunities, emphasizing the link between financial and non-financial performance; influencing long-term management strategy and policy, and business plans; streamlining processes, reducing costs and improving efficiency; comparing performance internally, and between organizations and sectors.



Water

The prospective water availability scenario is set to be the greatest challenge of the 21st century amongst all the users or sectors due to continual rising and competing demand, inefficient use, pollution, and added risks due to climate change.

Enhancing Water Use Efficiency

To support the National Water Mission's goal of enhancing water use efficiency, TERI is actively involved in studies that help to improve water use efficiency through water audits and assessment of water footprint along the entire value chain and by providing inputs for benchmarking water use in specific sectors. Through water audits, TERI has helped sectors, such as thermal power plants, heavy engineering, pulp and paper, food and beverages, IT companies, railways, etc., in reducing losses and specific water consumption, implementing recycle/reuse of water/wastewater, and improving their overall water use efficiency. TERI, in association with Jain Irrigation, has also established a Resource Center for Water Use Efficiency in the agriculture sector.



Water-Energy Nexus

TERI is progressively working in the field of water-energy nexus and has established linkages at various spatial scales. TERI has undertaken a study to assess the water-energy nexus linkages in various power generating plants in India and, relying on a watershed-based assessment, has evaluated the situation of water availability for a selected power plant and provided recommendations to reduce the water footprint of power plants in general.



Glacial Research

TERI is conducting research to quantify the impacts of climate change on the Himalayan cryosphere and estimated the differentiated contributions to snow and ice melt, attributable to changes in temperature, precipitation, and black carbon. The team monitors glacier dynamics that regulates the flow pattern of the river regimes with the help of the 'Glacier Monitoring Observatories'/field laboratories established at Kolahoi Glacier, Jammu and Kashmir, Sunderdhunga Valley, Uttarakhand, and East Rathong Glacier, Sikkim, at altitudes of > 4000 masl.

From Polluted Rivers to Clean Irrigation Water is an ongoing project funded by Ramboll-Environ Foundation, USA. This project's objective is to demonstrate how a river bank filtration (RBF) system can turn heavily polluted surface water into clean irrigation water under conditions typical for rural India. RBF technology offers an inexpensive and widely applicable means to remove a large amount of contaminants (including pathogens) without the use of chemicals. First, access to clean and reliable irrigation water will directly benefit small-scale farmers in producing high value crops, such as lettuce or tomatoes, for which farmers can demand higher prices in the market, compared to those farmers who use polluted river water for irrigation. Second, clean water improves the health of farmers, therefore permitting farmers to practise agriculture more efficiently and for longer periods of time. Finally, the utilization of RBF technology also aids in job creation, that is, to operate and maintain a RBF system along with hiring technicians and water quality controllers. This diversifies job opportunities in primarily agricultural communities of our study area.

Strengthening Water and Sanitation in Urban Settings

Supported by USAID, the Strengthening Water and Sanitation in Urban Settings Project also includes TERI University, Coca Cola, and TERI as partner institutions. The project involved working with slum clusters in Chennai and Kolkata for a



baseline sanitation survey and to implement participatory sanitation interventions in the two cities, sustained beyond the project period, and to reduce the burden of water-borne diseases in the selected clusters.

CC Impact on River Basin

Assessing the impact of climate change on water availability in Zuari river sub-basin using high-resolution climate and hydrological modelling is a recently completed research project supported by DSTE, Government of Goa. The overall objective is to develop a modelling protocol that couples future climate data with hydrological model simulating the river discharge. Uguem sub-basin in Goa has been selected as the study area. The future climate projections using PRECIS model has been completed. Future model prediction of 2030s shows increasing trend in both precipitation and temperature compared to model baseline period. To examine the impact of this future climate on surface runoff/water availability, a hydrological model known as SWAT is being used.

Integrating Bio-treated Wastewater Reuse with Enhanced Water Use Efficiency to Support the Green Economy in EU and India (Water4crops)

This Indo-EU collaborative project aims at treatment of wastewater for its reuse in agriculture and to improve the water use efficiency in agriculture. Treatment/recovery of components in distillery wastewater using modified adsorbents and filters have been carried out. The focus has been on melanoidins and polyphenol recovery, using fractionation with mixed matrix membranes (MMM), and adsorption using modified activated carbons and commercial resins. Unburnt carbon in sugarcane bagasse ash after deashing and steam activation could recover up to 78% melanoidins. In general, the antioxidant activity of different distillery wastewater fractions rose with higher content of phenols and melanoidins.





5

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 academic institutions to promote sustainable interventions. Our research collaborations, MoUs, and partnerships, along with their areas of interest, through the year 2016/17, are listed in the following section.

Governments/PSUs

Partner	Profile	Focus Area	Type of Association
Arunachal Forest Department	State Government	Capacity building for assisting the state project management unit in the implementation of JICA project	Capacity building
Assam Forest Department	State Government	Capacity building for assisting the state project management unit in the implementation of JICA project	Capacity building
Assam State Council for Science and Technology	State Government—Assam	Downstream processing of muga silk	Funding support
Biotechnology Industry Research Assistance Council	Public Sector Enterprise, Government of India	Advanced sanitation through biodigester in schools	Funding support
Bureau of Energy Efficiency	Government Agency	Energy efficiency	Funding
Center for High Technology, Ministry of Petroleum and Natural Gas	Government of India	Microbial biotechnology	Funding support
Central Glass and Ceramic Research Institute, Khurja	Government Organization	Research on ceramic filters for wastewater treatment	Collaborative research
Central Power Research Institute	Government Organization	Research and developmental studies EMI shielding nano-composites for power sector	Collaborative research
Climate & Clean Air Coalition (CCAC)	Intergovernmental Coalition	SLCP reduction from MSW management	Implementing partner in India
Department of Atomic Energy (DAE)	Government Agency	Risk analysis and energy security	Knowledge partner
Department of Biotechnology	Government of India	Biodiversity exploration for <i>Hippophae salicifolia</i> , orchids	Funding support
Department of Biotechnology	Government of India	Bioremediation of wastewater through phototrophic biofilm	Funding support
Department of Biotechnology	Government of India	Ericulture for upliftment of socioeconomic conditions of rural women in tribal villages of Assam	Funding support
Department of Biotechnology	Government of India	Ethnobotanical survey of indigenous plants and their pharmacological screening for anti-ulcer potential	Funding support
Department of Biotechnology	Government of India	Policy formulation, research and innovation, and funding in biotechnology sectors	Mycorrhiza Network project funded
Department of Biotechnology, Ministry of Science and Technology	Government of India	Microbial biotechnology	Funding support

Partner	Profile	Focus Area	Type of Association
Department of Energy and Environment, Government of Maldives	Government of Maldives	Biofuel feasibility study	Collaborative research
Department of Horticulture, Bihar	Government of Bihar	Micropropagation of banana	Supply of plants
Department of Horticulture, Punjab	Government of Punjab	Micropropagation of citrus	Supply of plants
Department of Horticulture, Uttar Pradesh	Government of Uttar Pradesh	Micropropagation of banana	Supply of plants
Department of Science and Technology	Government of India	Policy formulation, research and innovation, and funding in science and technology sectors	» Extramural R&D equipment projects funded » Digitization of DST resources funded
Department of Science and Technology	Government of India	Meta transcriptomics driven isolation of tea root associated bacteria for abiotic stress management	Funding support
Department of Science and Technology, Ministry of Science and Technology, India	Government of India	Microbial biotechnology	Funding support
Embassy of Israel	Government	Water use efficiency	Funding support
Embassy of Norway	Government	Climate change research	Funding support
Energy Efficiency Services Ltd	Government Agency	Energy efficiency, load research	Funding support
Flood and River Management Agency of Assam (FREMAA)	State Government— Assam	Livelihood enhancement for river erosion victims	Funding support
Global Green Growth Institute	Intergovernmental Organization	Integrated techno-economic modelling at national and state level	Knowledge and consortium partner
Goa State Pollution Control Board	Government Agency	Pollution	Funding agency/ collaborative research
Government of Maharashtra	State Government	Climate change impacts and adaptation	Preparation of state adaptation action plan on climate change
GSBB	Government	Biodiversity	Support for projects
GSIDC	Government	Smart city and biodiversity	Support for projects
ICIMOD	Intergovernmental Organization	One day events on REDD+ and carbon financing	Partnership
Indian Oil Corporation Ltd	Public Sector Undertaking, Government of India	Bioremediation of oily and acidic sludge	Funding support
International Network for Bamboo and Rattan (INBAR)	Intergovernmental Organization	Feasibility study on livelihood and market potential of bamboo in north-east of India	Knowledge partner
Karnataka Electricity Regulatory Commission (KERC)	Electricity Regulator	Research studies	Funding support
Maharashtra Forest Department	State Government	Preliminary study on implementation of FRA and vulnerability of forests and forest-dwelling communities in Maharashtra	Knowledge partner

Partner	Profile	Focus Area	Type of Association
MCIT	Government of India	Information and communication technology, digital India, eGovernance	Funding support
MDoNER	Government of India	Policy formulation for north eastern region	Event organized jointly to sensitize issues related to traditional health, cleanliness, and sanitation in north eastern states
Ministry of Environment, Forest and Climate Change	Government of India	GHG mitigation options for the energy and non-energy sectors in India	Knowledge partner
Ministry of Environment, Forest and Climate Change	Government of India	Funding	Funding support
Ministry of Environment, Forest and Climate Change	Government of India	GHG mitigation options for the energy and non-energy sectors in India	Knowledge partner
Ministry of Environment, Forest and Climate Change (MoEFCC)	Government of India	Policy formulation, research and innovation, and funding in renewable energy and environment	ENVIS center project funded
Ministry of Environment, Japan	Government	Climate change	Funding support
Ministry of External Affairs	Government of India	Energy efficiency	Funding support and partnership
Ministry of Micro, Small and Medium Enterprises	Government of India	Energy efficiency in MSME sector	Knowledge partner
Ministry of Mines and Indian Bureau of Mines	Government Institutions	Conducted national workshop titled 'Remediation of Mined-Out Areas and Abandoned Mines—Status & Strategies'	Knowledge partner
Ministry of New and Renewable Energy	Government of India	Microbial biotechnology	Funding support
Ministry of New and Renewable Energy	Government of India	Preparation and distribution of Ministry's flagship magazine	Funding support
Ministry of Water, Irrigation & Energy, Federal Democratic Republic of Ethiopia	Republic of Ethiopia	Environment (general), climate change	Funding support
MPEDA	Government	Aquaculture: Capacity building of fishing community	Support for projects
Nagaland Forest Department	State Government	Assess the biodiversity status of CCAs in Nagaland; carrying out GEF Satoyama project titled 'Mainstreaming Community-Conserved Areas for Biodiversity Conservation in Nagaland'	Knowledge partner

Partner	Profile	Focus Area	Type of Association
National & State Biodiversity Board	Government Agency	Consultancy services for monitoring and evaluation of NMPB schemes, state biodiversity strategy, and action plan under BIOFIN project	Consultancy support
National Health Medical Research Council (NHMRC)	Government of Australia	Expert body supporting health and medical research	Support for projects
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	Government Agency	Lignocellulosic residue hydrolysate assimilation using microalgae	Collaborative research
National Renewable Energy Laboratory (NREL) and RTI International, USA	Government of USA	Algal thermochemical processing	Collaborative research
National Thermal Power Corporation Ltd	Public Sector Unit	Water audit, water use efficiency	Funding support
National Water Mission, Ministry of Water Resources	Government of India	Water use efficiency	Funding support
NITI Aayog	Government of India	Water energy	Funding support
NITI Aayog	Government of India	Policy analysis and development of the energy system tools	Capacity building and knowledge partner
North Eastern Council (NEC)	An Autonomous Body	Policy formulation and development of north eastern region	Event organized jointly to sensitize issues related to traditional health, cleanliness, and sanitation in north eastern states
North Eastern Council	Government of India	Capacity building programme for assisting state government officials in designing sustainable livelihood programmes	Funding support
Northern Railways	Government of India	Water audit	Funding support
Norwegian Ministry of Foreign Affairs	Government Agency	Designing a REDD+ pilot project in India	Knowledge support
Norwegian Water Resources and Energy Directorate	Government Organization	Water resources, energy	Partner
NTPC Energy Technology Research Alliance (NETRA)	PSU	Water use optimization	Collaborative research
PETROFED	Government	Impacts of structural adjustments and distributional effects of energy policy, fossil fuel prices	Knowledge partner and consortium member
Punjab Forest Department	State Government	Status of biodiversity and conservation in Punjab and preparation of Biodiversity Management Plan	Knowledge support
State Council for Science, Technology and Environment, Shimla, HP	State Council	Renewable energy for sustainable future	Seminar partner

Partner	Profile	Focus Area	Type of Association
State Forest Departments, MoEFCC and MNRE	Government of India	Conduct 8-week training programme for Indian Forest Service Officers (with 16–18 yrs of service) in association with IGNFA, Dehradun Project titled “REDD + at Madhya Pradesh, Uttarakhand, Odisha and Uttar Pradesh” Assessing scale of land degradation with the economic impacts in India	Knowledge partner
State Level Nodal Agency (SLNA), Soil Conservation Department	State Government— 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	State Government	Watershed management programme	Knowledge partner
TRIFED	Government Agency	<ul style="list-style-type: none"> » Minimum support price for 12 minor forest produce in 9 states » Identification of medicinal and aromatic plants suitable for cultivation and inclusion in afforestation and income generation programmes in the state of Uttarakhand » Feasibility study on carbon sequestration benefits from growing tree species of medicinal value » National Green Highways Mission, NHAI—Conducted joint workshop on role of plantations along national highways in sequestering carbon 	Knowledge partner
TRIFED, New Delhi	Government Agency	Micropropagation of chironji	Collaborative research
USAID	Government	Water and sanitation, gender equality, agriculture	Funding support
Uttar Haryana Bijli Vitran Nigam Limited (UHBVNL)	State-Level Electricity Distribution Company	Load research studies	Partnership
Uttar Pradesh Forest Department (UPFD)	State Government	Biodiversity and socio-economic assessment of protected areas in Uttar Pradesh; monitoring and evaluation of advance soil work and plantations undertaken by Uttar Pradesh Forest Department	Knowledge partner
Uttar Pradesh Forest Department (UPFD)	State Government	Preparation of afforestation and reforestation CDM PDD, facilitation of validation, registration and verification. Monitoring and capacity building of UPFD staff on monitoring	Knowledge partner
Water Resources Department, Government of Goa	Government Agency	Water resource management	Funding support

Research and Academic Institutions

Partner	Profile	Focus Area	Type of Association
Assam Agricultural University, Jorhat	Indian Institution	Rice biotechnology	Collaborative research
Africa Climate Policy Centre	Policy Think Tank	Climate Policy	Collaborative research
ALTERAA, WU	Wageningen University Research Institute, The Netherlands	Independent research to the realization of a high-quality and sustainable green living environment	Collaborative research
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
Bangladesh Centre for Applied Sciences	Think Tank	Resource management, environment and development (RMED) issues by use of existing intellectual, technology and manpower	Collaborative research
Bangladesh Centre for Advanced Studies	Research Institution	Climate-resilient housing in coastal Bangladesh	Implementing partner in Bangladesh
Birla Institute of Technology & Science	Indian Institution	Water remediation	Collaborative research
BITS, Pilani	Indian Institution	Education	Collaborative research
Bjerknes Centre for Climate Research, University of Bergen	Research Organization	Climate modelling	Collaborative research
University of Calcutta Kolkata	Academic Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
University of Calcutta, Kolkata	Academic Institute	Virtual joint centre: India–UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
Center for Tropical Crops and Bio-commodities, Queensland University of Technology, Brisbane, Australia	Government of Australia	Microbial biotechnology	Collaborative project partners
Central Institute of Medicinal and Aromatic Plants (Lucknow)	Research Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
Centre for Ecology Development and Research	Research Organization	Biodiversity conservation, Western Himalayas	Collaborative research
Centre for Fly Ash Research and Management	Not-for-Profit Research Institute	Commercialization of fly ash-based flame retardant nano-composites	Collaborative research
Centre for International Climate and Environmental Research—Oslo (CICERO)	International Research Organization	Climate change research	Collaborative research
CFTRI, Mysore	Institute	Industrial research	Collaborative research
Cranfield University, School of Aerospace,	Government of UK	Microbial biotechnology	Collaboration (for joint proposal submission along with University of York)

Partner	Profile	Focus Area	Type of Association
CSIC, Madrid	Institute	Research in the field of bioprospecting	Collaborative research
CSIRO Energy Transformed Flagship, North Ryde, New South Wales	Australian Research Institute	Microbial biotechnology	Collaborative project partners
DBT-ICGEB Center for Advanced Bio-energy Research, Center for Genetic Engineering and Biotechnology, New Delhi	Research Institution	Microbial biotechnology	Funding support
DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, Mumbai	Research Institution	Microbial biotechnology	Collaborating project partners
Deakin University	Academic Institute	Nanobiotechnology research and higher degrees by research	Collaborative research; support for higher degrees by research
Delft University of Technology, Netherlands	University	Consultancy	Collaborative research
Department of Chemical Engineering for Process System Computations, Curtin University, Perth, Western Australia	Government of Australia	Microbial biotechnology	Collaborative project partners
Department of Chemistry, University of Delhi, Delhi	Academic Institute	Microbial biotechnology	Collaborative project partners
Department of Genetics, University of Delhi, South Campus	Academic Institute	Developing anthracnose resistance in chilli and tomato	Collaborative research
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	Not-for-Profit Research Institute	Resource efficient and cleaner production (RECP)	Collaborative research
DIBER, DRDO	Research Organization	Bioresources utilization	Collaborative research
Dr H S Gour University, Sagar	Academic Institute	Biotransformation of nanomaterials	Collaborative research
Dr H S Gour University, Sagar	Academic Institute	Diversity studies in Indian earthworms using DNA barcodes	Collaborative research
ECN, The Netherlands	Research Organization	Climate change	Collaborative research
Ecofys	International Research Organization	Climate policy	Collaborative research
Finnish Meteorological Institute (FMI)	Government of Finland	Meteorology	Funding
Finnish Meteorological Institute (FMI)	Government of Finland	Microbial biotechnology	Collaborative project partners
Galvanizing Groundswell of Climate Action	Network	Climate change	Collaborative research and dialogue platform
German Development Institute (DIE)	Research Organization	Climate change	Collaborative research and dialogue platform
Green Chemistry Center of Excellence, 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)

Partner	Profile	Focus Area	Type of Association
Helmholtz Center for Environmental Research, Leipzig, Germany	Government of Germany	Microbial biotechnology	Collaborative project partners
Helsinki Metropolia University of Applied Sciences (Metropolia)	Government of Finland	Project support	Collaborative project partners
ICAR–Indian Agricultural Research Institute, New Delhi	Research Institute	Virtual joint centre: India–UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
ICAR–Indian Institute for Wheat and Barley Research, Karnal	Research Institute	Virtual joint centre: India–UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
ICAR–Indian Institute of Rice Research	Research Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
ICAR–Indian Institute of Soil Science, Bhopal	Research Institute	Virtual joint centre: India–UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
ICAR–Indian Institute of Wheat Research	Research Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
ICAR–National Research Center for Plant Biotechnology, New Delhi	Research Institute	Nitrogen fixation and rice biotechnology	Collaborative research
ICAR–National Rice Research Institute	Research Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
ICIMOD	International Research Organization	Climate change research	Collaborative research
IGNCA	Institution	Preservation of cultural heritage	Funding support
IGV Institut für Getreideverarbeitung GmbH, Germany	Institute	Research in the field of agriculture	Research partner
IIT, Kharagpur	Institute	Industrial research	Collaborative research
India Meteorological Department (IMD)	National Research Network	Atmospheric modelling	Research collaboration
Indian Agricultural Research Institute	Research Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
Indian Council of Forestry Research and Education	Government Research Agency	Mid-career training programme for senior IFS officers	Training support
Indian Institute of Chemical Technology (IICT), Hyderabad	CSIR Institute, Government of India	Microbial biotechnology	Collaborative project partners
Indian Institute of Technology (IIT), Delhi	Government of India	Microbial biotechnology	Collaborative project partner

Partner	Profile	Focus Area	Type of Association
Indian Institute of Technology, Guwahati	Research Institute	Microbial biotechnology	Collaborative project partners
Indian Institute of Technology Guwahati	Research Institute	Nitrogen fixation and rice biotechnology	Collaborative research
Indian Institute of Technology Delhi	Academic Institute	Consultancy	Collaborative research
Indira Gandhi National Forest Academy	Training Organization	Mid-career training programme for senior IFS officers	Training support
Institute for Energy Economics Japan	Research Institution	Energy efficiency, renewable energy	Collaborative research
Institute for Global Environmental Strategies	Research Institution	Capacity building on climate change, energy efficiency	Collaborative research
Institute for Global Environmental Strategies	Think Tank	Climate change	Collaborative research
Institute of Advanced Studies for Science and Technology (IASST), Guwahati	DST Unit, Government of India	Microbial biotechnology	Collaborative project partner
Institute of Chemical Technology, Mumbai	Research Institute	Lignocellulosic residue hydrolysate assimilation using microalgae	Collaborative research
Institute of Transport Economics, Norwegian Centre for Transport Research	International Research Organization	Climate change and transport research	Collaborative research
International Center for Integrated Mountain Development (ICIMOD)	Intergovernmental Organization of Countries in Hindukush Region	Mountain development	Lead of HI-AWARE consortium
International Growth Center	Research Organization	Cities	Funder
International Growth Center (IGC)	Research Centre	Solid waste management	Funding support
International Water Management Institute (IWMI)	Research Organization	Research on water issues	Collaborative research
Jamia Hamdard University, New Delhi	Institute	Education	Collaborative partner
Jeonju University, Jeonju, Korea	Government of Korea	Microbial biotechnology	Collaborative project partner
John Innes Centre, UK	Institute	Virtual joint centre: India-UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
Korea Maritime and Ocean University, Busan, Korea	Government of Korea	Microbial biotechnology	Collaborative project partners
M S University, Baroda	Institute	Virtual joint centre: India-UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
Michigan State University, USA	Institute	Research in the field of integrated pest management	Collaborative research
Ministry of Earth Sciences (MoES)	National Research Network	Monsoon research	Research collaboration

Partner	Profile	Focus Area	Type of Association
Mizoram University	Institution	Central university, teaching various UG, PG, MPhil, PhD level courses	Workshop partner Event organized on Sustainable management of indigenous knowledge: A north east perspective
Monash University	International University	Research on infectious disease, epidemiology, public health, and preventive medicine	Collaborative research
Motilal Nehru National Institute of Technology (MNNIT), Allahabad	Institute	Microbial biotechnology	Collaborative project partners
National University of Singapore (NUS)	International University	Higher education and research	Collaborative research
National Bureau of Agriculturally Important Microorganisms	Academic Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
National Centre for Medium Range Weather Forecasting (NCMRWF)	National Research Network	Atmospheric modelling	Research collaboration
National Environmental Engineering Research Institute (NEERI), Nagpur	Research Institute	Consultancy	Collaborative research
National Institute for Plant Genome Research	Research Institute (Government funded)	Early detection of phytopathogens	Collaborative research
National Institute of Hydrology (Belagavi and Roorkee)	Institute	Hydrology	Collaboration on research projects
National Institute of Interdisciplinary Science and Technology, Thiruvananthapuram	CSIR Institute, Trivandrum, India	Microbial biotechnology	Collaborative project partners
National Institute of Plant Genome Research, New Delhi	Research Institute	Nitrogen fixation and rice biotechnology	Collaborative research
National Institute of Technology	Institute	Alternate energies	Collaboration on research projects
National Institute of Technology, Suratkal	Institute	Water resource management	Knowledge partner and collaborators
National Research Center for Plant Biotechnology (New Delhi)	Research Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
Natural Resources Defense Council	International Environmental Organization	Climate change research	Collaborative research

Partner	Profile	Focus Area	Type of Association
Netherlands Institute of Ecology (NIOO-KNAW), The Netherlands	Research Institute	Consultancy	Collaborative research
New Climate Institute	Research Institution	Climate change	Collaborative research
New Energy and Technology Development Organisation	Research Institution	Energy efficiency, smart grids	Partnership
NIBR, CIENS	Research Institution	Climate change	Partner
NIBR, NIVA, CICERO	Research Institution	Resilience to climate extreme events in rural India	Research partner in Jalna district, Maharashtra
NIT, Silchar	Institution	Technology-related institution	Workshop partner; Event organized on Role of ICT in preservation and conservation of traditional knowledge
NITK, Surathkal	University	Consultancy	Collaborative research
Norwegian Institute for Urban and Regional Research	International Research Organization	Climate change research	Collaborative research
Norwegian Institute for Water Research	International Research Organization	Climate change research	Collaborative research
Oxford Policy Management Ltd (OPM)	International Research Organization	Climate change	Collaborative research and funding
Pakistan Agriculture Research Council	Government Research Institute	Advisory to Ministry of Food Security and Research	Partner
Phycospectrum Environmental Research Centre and Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Bhavnagar	Research Institute	Whole of supply chain approach for algal biofuel production	Collaborative research
Punjab Agricultural University, Ludhiana	Academic Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
Punjab Agricultural University, Ludhiana	Academic Institute	Testing of joint biofertilizer product	Contractual research
Punjab Agricultural University, Ludhiana	Academic Institute	Nitrogen fixation and rice biotechnology	Collaborative research
Punjab University	Government of India	Microbial biotechnology	Collaborative project partners
Queensland University of Technology (QUT)	Academic Institute	Pentose sugar assimilation by algae	Collaborative research
Sustainable Bioenergy Solution for Tomorrow (BEST)	Research Programme	Rural biomass survey	Knowledge support
Tempere University of Technology (TUT)	Government of Finland	Microbial biotechnology	Collaborative project partners
The Energy Conservation Center, Japan	Research Institution	Energy efficiency	Funding

Partner	Profile	Focus Area	Type of Association
The Research Council of Norway	International Research Organization	Transport (general), Climate change	Collaborative research
The Research Council of Norway	International Research Organization	Climate change	Funding
Tsinghua University	International University	Climate policy	Collaborative research
UNICA, Italy	Institute	Environmental toxicology	Collaborative research
University of Agricultural Sciences, Bangalore	University	Agricultural research	Collaborative research
University of Agricultural Sciences, Dharwad	Academic Institute	Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	Collaborative research
University of Agricultural Sciences, Dharwad	University	Agricultural research	Collaborative research
University of California, Davis, USA	Institute	Metabolomics	Collaborative research
University of Cape Town	International University	Climate policy	Collaborative research
University of Delhi, South Campus, New Delhi	Academic Institute	Control of anthracnose disease in chilli/tomato by RNAi technology	Collaborative research
University of Delhi, South Campus, New Delhi	Institute	Nitrogen fixation and rice biotechnology	Collaborative research
University of Dusseldorf, Germany	Institute	Research in the field of agriculture	Collaborative research
University of Eastern Finland	International University	Partnership for the mid-career training programme for IFS officers	Training support
University of Guyana	International University	Feasibility study for biodiversity centre at the University	Knowledge support
University of Hyderabad, AP	Institute	Virtual joint centre: India-UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
University of Laguna, Spain	Institute	Research in the field of bioprospecting	Research partner
University of Leicester, United Kingdom	Academic Institute	Effects of air pollution on microbes	Collaborative research
University of Leiden, The Netherlands	Institute	Training/workshop	Collaborative research
University of Maribor, Slovenia	University	Chemistry and chemical engineering	Collaborative research
University of Oxford, UK	International University	Virtual joint centre: India-UK Nitrogen Fixation Centre (IUNFC)	Collaborative research
University of Rhode Island	International University	Water resources management	Collaborative research
Wageningen University & Research, The Netherlands	University	Consultancy	Collaborative research
World Resources Institute	International Research Organization	Climate change and capacity building	Collaborative research and funding
World Resources Institute	International Research Organization	Climate change research	Collaborative research
Yale University	International University	Partnership for the mid-career training programme for IFS officers	Training support

Banks and Financial Institutions

Partner	Profile	Focus Area	Type of Association
ADB (Asian Development Bank)	Multilateral	Regional cooperation on climate change adaptation in South Asia	Consultancy for SAARC (South Asian Association for Regional Cooperation)
International Development Research Centre	Funding Agency	CSR	Funding
JICA	Funding Agency	Carrying out JICA-funded projects in Uttar Pradesh, Arunachal Pradesh, etc.	Funding support
NABARD	Development Bank	Capacity building	Support for projects
Shakti Sustainable Energy Foundation	Funding Agency	Climate change	Funding
Small Industries Development Bank of India	Public Sector Bank	Energy efficiency and cluster development in MSME sector	Funding
United States Agency for International Development (USAID)	International Funding Organization	Water, sanitation, and hygiene (WASH)	Funding support
World Bank	Funding Agency	Consultancy services for baseline survey for UDWDP and GEF-SLEM project in Uttarakhand and MHWDP in Himachal Pradesh aided by World Bank	Consultancy support
YES Bank	Bank	Knowledge partnership with TERI for Yes Bank Natural Capital Awards	Knowledge partner

Domestic and Multinational Corporations

Partner	Profile	Focus Area	Type of Association
Ayurved Ltd, New Delhi	Private	Animal healer	Collaborative research
Al Maktaba Al Hadissa Publishers, Lebanon	Publisher	TERI children books translated for the Lebanon market	Funding support
Chem Fab Ltd	Corporate, India	Carbon sequestration through plantation activities at Chem Fab Ltd	Collaborative research
Coal India Ltd	Corporate, India	Sanitation	Funding support
Coal India Ltd	Corporate, India	Forest and agriculture based livelihood activities	Collaborative research
Credit Valley Conservation, Canada	Private	Water resource management	Knowledge partner and collaborator
DBT-IOC Centre for Advanced Research on Bioenergy, R&D Centre, Indian Oil Corporation, Faridabad	Indian Oil Corporation R&D Centre, India	Microbial biotechnology	Funding support

Partner	Profile	Focus Area	Type of Association
Dhaka Chamber of Commerce & Industry (DCCI), Bangladesh	Not-for-Profit Trade Organization	Promote private sector enterprises and businesses with advocacy, awareness, and policy inputs to government	Collaborative research
GIPCL	Corporate, India	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	Collaborative research
GlaxoSmithKline Consumer Healthcare Limited		Climate change, global warming	Assessment, review, evaluation
Hindalco Industries Ltd	Corporate, India	Reclamation of back filled area of Bauxite mines through afforestation activities at HINDALCO, Lohardaga, Jharkhand	Collaborative research
Indian Oil Corporation Ltd	Corporate Organization	Lignocellulosic residue hydrolysate assimilation using microalgae	Collaborative research
Institute of Reservoir studies, ONGC, Ahmedabad	Corporate Sector	Microbial biotechnology	Collaborative project partners
ITC		Water auditing	Funding support
ITC	Corporate, India	Development of clonal propagation techniques	Collaborative research
Jain Irrigation Systems Ltd	Corporate	Manufacturers of drip and sprinkler irrigation systems and components	Collaborative research
Jain Irrigation Systems Ltd	Corporate	Irrigation water use efficiency	Funding support
Kafmar	Private Company	Cleaning water bodies	Collaboration on research projects
Lavasa Corporation Ltd	Corporate, India	Biodiversity compliance document for Lavasa	Collaborative research
National Cleaner Production Center (NCPC), Sri Lanka	Not-for-Profit Guarantee Company	Consultancy and advisory services, information dissemination, training, and capacity building, policy advocacy	Collaborative research
NHPC	Corporate, India	Valuation of the socio-economic and environmental costs and benefits of hydro power projects in India: Case study of two selected projects including Bhakra Nangal Project and the Uri Project	

Partner	Profile	Focus Area	Type of Association
Nirmal Seeds Pvt. Ltd	Corporate Organization	Nutritionally improved mustard and disease-resistant okra	Collaborative research
Oil India Ltd. R & D Centre, Duliajan, Assam	Corporate Sector	Microbial biotechnology	Collaborative project partners
OMNI Agro	Private	Biopesticide	Technology transfer
OTBL	Corporate	A CSR initiative 'Protectors of the Environment' to engage children into creative thinking and develop competence in environment conservation	Funding support
Pune Metal Finishers Association (PMFA)	Association	Resource efficient and cleaner production (RECP)	Collaborative research
Ramboll- Environ Foundation, USA	Corporate, Foreign	Environmental, health and social issues	Supports for projects
SABMiller India	Corporate	Manufacturers of beverages	Collaborative research
Shell Group of Companies	Private Sector	Modeling and scenario analysis of the energy sector	Knowledge partner
SINTEF, Norway	Private	Bioresources utilization	Collaborative research
Tetra Pak India Pvt. Ltd	Corporate, India	Waste management	Funding support
Toyota Foundation	Private	Community empowerment	Support for projects

NGOs/Foundations

Partner	Profile	Focus Area	Type of Association
Action for Food Production (AFPRO)	NGO	Community-based adaptation	Collaborative research
Action for Food Production (AFPRO)	NGO	Watershed development and climate resilience in rural India	Implementing partner in Jalna district, Maharashtra
Adelphi Research, Germany	Not-for-Profit Research Institute	Policy analysis and strategy consulting	Collaborative research
EIRC Consultancy Pvt. Ltd	Not-for-Profit Organization	Consultancy	Collaborative research
Inspire Network for Environment	NGO	Environmental Awareness	Funding
INTACH	Non-profit NGO	Water quality	Funding
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
Louis Dreyfus Foundation	Foundation	Microfarming and education	Funding support
MS Swaminathan Research Foundation, Chennai	Not-for-Profit Organization	Agricultural research	Collaborative research
SaciWATERS	NGO	Water research	Knowledge partner

Partner	Profile	Focus Area	Type of Association
Shakti Sustainable Energy Foundation	Foundation	Climate policy, energy efficiency, power	Funding
Shakti Sustainable Energy Foundation	Foundation	Energy efficiency, demand-side management	Partnership
Sir Ratan Tata Trust	Foundation	Extending reach through e-Library	Funding support
Society for Environmental and Economic Development Nepal (SEED Nepal)	Non-Government Organization (Not for Profit)	Providing solutions for enhancing productivity, preventing industrial pollution, providing better working environment, and improving the quality of life	Collaborative research
STENUM Asia Sustainable Development Society (STENUM Asia), India	Not-for-Profit Society	Consulting in resource efficiency for industries	Collaborative research
The Mountain Institute	Non-Government Organization	Biodiversity, sustainable development, Eastern Himalayas	Partner
Toyota Foundation	Private	Community empowerment	Support for projects

Multilateral and Bilateral Organizations

Partner	Profile	Focus Area	Type of Association
Climate Technology Centre and Network (CTCN)	International Organization	Climate change	Collaborative partner
DFID	Multilateral Funding Organization	Policy formulation and implementation	Capacity building and knowledge partner
DFID	Multilateral Funding Organization	Modeling and scenario analysis of a sustainable and secure energy future for India	Knowledge, research partner, and consortium member
European Commission	Multilateral Body	Low-carbon development and emission strategy	Knowledge partnership and consortium member
International Finance Corporation	Multilateral	Climate-resilient housing and private sector participation in adaptation	Client: Consultancy for Nepal and Bangladesh
International Finance Corporation	Multilateral Organization	Energy efficiency in SME sector	Funding
International Transport Forum	Multilateral Organization	Transport and other allied sectors (An organization under OECD)	Indian transport data collection, collation and updation, and dissemination of data
IUCN	International Organization	Best practices for watershed development in Indian Himalayan region	
Swiss Agency for Development and Cooperation	Bilateral Organization	Promoting energy efficiency in the MSME sector	Partnership agreement
United Nations Development Programme	Multilateral Organization	State biodiversity strategy and action plan under BIOFIN project	Collaborative research
UNECA	Multilateral Organization	Climate change and capacity building	MoU

Partner	Profile	Focus Area	Type of Association
UNIDO	Multilateral	Development, production, and distribution of marketing periodicals on concentrated solar technologies—quarterly magazine and bi-monthly newsletter	Funding and networking
United Nations Development Programme	Multilateral Organization	Sustainable development	Collaborative research
United Nations Environment Programme	Multilateral Organization	Energy efficiency	Funding, partnership
United Nations Industrial Development Organization (UNIDO)	Multilateral Organization	Energy efficiency, renewable energy	Funding support and partnership
United Nations Industrial Development Organization (UNIDO)	Multilateral Organization	South-South collaborative training programme on issues pertaining to sustainable energy for all	Knowledge exchange partner for South–South collaboration
United Nations Industrial Development Organization (UNIDO)	Multilateral Organization	South–South collaborative training programme on issues pertaining to sustainable energy for all	Knowledge exchange partner for South–South collaboration
WWF, USA	International Organization	Food security	Collaborative research



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Knowledge Contributions

Representation in National and International Expert Group Committees

- » Balakrishnan Malini. Expert member for DST Engineering & Technology Development under Women Scientists Scheme-B (WOS-B)
- » Balakrishnan Malini. Expert member for DST Water Technology Initiative programme
- » Balakrishnan Malini. Member of Chemical Division Council of Bureau of Indian Standards (BIS).
- » Banerjee Manjushree. Dissemination Approach of Improved Biomass Stoves in Indian Himalayan Region. Asia Clean Energy Forum, Manila, Philippines.
- » Datta A. Associate, National Academy of Agricultural Sciences, India.
- » Datta A. Reviewer, Research Grant Council, China.
- » Datta A. Reviewer, TeaGasc, Ireland.
- » D'Souza Fraddy. Member of Technical Advisory Committee (TAC) of Goa State Pollution Control Board (GSPCB), Goa.
- » Dhingra Sunil. Member of Steering Committee on Biofuels of TIFAC.
- » Ghate A T. Member. Committee to review FAME India Scheme (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India), under the chairmanship CEO & PD, NATRIP as per the directions of Department of Heavy Industry, Ministry of Heavy Industries and Public Enterprises. [February 2017 – Present]
- » Ghate A T. Member of Peer Review Committee for the Research Symposium organized as part of the Urban Mobility India (UMI) Conference and Expo organised by Ministry of Urban Development, Government of India [July–November 2016].
- » Ghate A T. Member of International Scientific Committee (ISC) of CODATU 2017 [June 2016–November 2017].
- » Ghate A T. Member. G-3 Committee: Reduction of Carbon Footprint in Road Construction and Environment constituted by the Indian Roads Congress [March 2016/2017].
- » Ghate A T. Member. G-4 Committee: Mechanization & Instrumentation Committee constituted by the Indian Roads Congress [March 2016–2017].
- » Ghate A T. Member. Member, Expert Committee on Urban Transport Planning constituted by the Institute of Urban Transport (India) under the aegis of Ministry of Urban Development, Government of India [2014–present].
- » Ghate A T. Member. Advisory Committee to monitor and review the development of Knowledge Management Centre (KMC), Ministry of Urban Development, Government of India (2014–present).
- » Ghate A T. Member. Global and Regional Steering Committee of the Global Energy Network for Urban Settlements (GENUS), a network facilitated by UN-Habitat.
- » Ghate, A.T. Member, Institute of Urban Transport (India).
- » Kaushik, N. Member, IUPAC Plant Protection Committee.
- » Kaushik, N. Member, Expert Committee of DBT Biocare Programme.
- » Kaushik, N. Member, Expert committee of BIRAC industrial projects
- » Kaushik, N. Member, Editorial Board of Elsevier journal *Heliyon*.
- » Kaushik, N. Guest Editor of Springer Journal *Phytochemistry Review*.
- » Kumar S. Member, CED-30, Sectional Committee, BIS.
- » Kumar Amit. Linking Energy and Climate Objectives: Solutions for Cities. European Policy Centre Seminar on 'Achieving the Sustainable Development Goal on Energy in Developing Countries—What Role for the EU?' Brussels.
- » Kumar Amit. CCS in India. World Energy Congress 2016. Istanbul.
- » Kumar Amit. Energy Trilemma & India. World Energy Congress 2016. Istanbul.
- » Kumar Amit. Sustainable Energy Technologies and Enhancing RE Capacity. COP22. Marrakesh.
- » Kumar Amit. Technical Training on Renewable Energy Technologies. South-South Collaboration Framework. Bogota and Santa Marta.
- » Malik J K. Representation in National Expert Committee, Steering Committee for Fuel Efficiency Standards for HDVs in India, PCRA, India.
- » Mathur Ritu. Co-lead of Sustainable Growth Working Group of the U.S.–India Energy Dialogue led by NITI Aayog (formerly Planning Commission of India).
- » Mathur Ritu. Member of Board of Climate Strategies (CS)—An International Research Platform with its Secretariat based in the UK.
- » Pal P. Member, Empanelment Committee for Empanelment of Energy Auditors on PCRA's Panel. Petroleum Conservation Research Association (PCRA).
- » Pai Panandiker Ashwini. Member, Goa State Expert Appraisal Committee (SEAC) Endorsed by Ministry of Environment, Forest and Climate Change (MoEF&CC), New Delhi.
- » Palit D. Jury Member, Mahindra Rise Prize Solar Challenge.
- » Palit D. Member, Steering Committee, Energy for All Partnership, Asian Development Bank.
- » Palit D. Member, Technical Committee, Implementation of Decentralized Distributed Generation under Deendayal Upadhyaya Gram Jyoti Yojana.
- » Pandey S. 2007–till date. Member, Research Advisory Committee of Central Pollution Control Board.
- » Pandey S. 2007–till date. Member, Standard Setting Committee on Waste constituted by Bureau of Indian Standards.
- » Pandey S. 2012–till date. Member, Expert Group on Critically Polluted Area constituted by Ministry of Environment, Forest and Climate Change, Government of India.

- » Pandey S. 2015–till date. Member, Expert Advisory Committee on Waste Management under Technology Systems Development Programme of DST.
- » Pandey S and Manuja S. 2017–till date. Member of Technical Working Group on Waste Management—Climate Bonds Initiative, United Kingdom.
- » Pandey S. Life Member. Indian Association for Environment Management.
- » Pant Dinesh Chander Expert Group Member of India Biogas Association.
- » Prakash S. Member, Centre for Transportation Research and Management, Delhi.
- » Prakash S. Fellow, Institute of Rail Transport.
- » Rahiman R. Member, Working Group on 'The Role of Disaster Risk Reduction and Climate Change Adaptation for Building Urban Resilience', Children and Youth Assembly, Habitat III, Quito, October 2016.
- » Ramanathan K. Member of the Central Advisory Committee of the State Advisory Committee of the Delhi Electricity Regulatory Commission (DERC), 2016/17.
- » Saxena A K. Member of the Electrical Energy Storage Systems Sectional Committee, ETD 52, Bureau of Indian Standards (BIS), 2016/17.
- » Sethi G. Member, Screening Committee of Petroleum Conservation Research Association (PCRA).
- » Sethi G. Member, Energy Management Sectional Committee of Bureau of Indian Standards (BIS).
- » Sethi G. Member, Examination Advisory Committee for Energy Managers and Energy Auditors, Bureau of Energy Efficiency, Ministry of Power, Government of India.
- » Sethi G, Member, Steering Committee on Technology and Quality Up-gradation support to MSMEs, Ministry of MSME, Government of India.
- » Shardul Martand. Representative for UN Sustainable Development Solutions Network (SDSN) Youth in South Asia, India.
- » Shardul Martand. Member of the Alliance of CSOs for Clean Energy Access (ACCESS), India.
- » Shardul Martand. Member of the Global Capacity Building Hub for UN's Sustainable Energy for All Initiative, India.
- » Shardul Martand. Member Leadership Committee. Students Alumni and Advisory Council (SAAC). Global MDP Secretariat. The Earth Institute. Columbia University.
- » Shardul Martand. International Conference on Education as a Driver for Sustainable Development Goals, India.
- » Sharma Arvind. Member of ET-28 Committee for Development of Standards.
- » Sharma Arvind. Member of ETD -23 Committee for Lamps and Related Equipments Sectional Development.
- » Singh Raina. Member, Working Group on 'Urban Development with reference to Natural and Climate Change related Disasters', 6th Asia Pacific Ministerial Conference on Housing and Urban Development [2016/2017].
- » Singh Raina. Member, Consultation Committee for Asian Cities Climate Change Resilience Network, India [2016–present].
- » Singh Raina. Associate Member, Institute of Town Planners, India [2012–present].
- » Sundar S. Member, Expert Committee, Asian Environmentally Sustainable Transport Forum set up by UNCRD.
- » Sundar S. Member, Committee Constituted by the Hon'ble Supreme Court of India on Road Safety.
- » Sundar S. Member, Board of Directors of the SLoCaT Foundation, a global partnership on Sustainable, Low Carbon Transport (SLoCaT), under the United Nations.
- » Vasudevan N. Member, Committee of BEE for Revision of Syllabus for Energy Managers and Energy Auditors Examination.

Representation in National and International Journals

- » Bhattacharya Sailaja. Reviewer for various Elsevier, Wiley, and Springer international journals.
- » Manuja S. Member, Review Panel, PHI Learning Pvt Ltd.
- » Mathur R. 2015–till date. Reviewer of *The Energy Journal*.
- » Mathur R. 2014–till date. Reviewer of *Journal Environmental Policy and Governance*.
- » Mathur R. 2000–till date. Reviewer of *Energy Policy; Energy Economics*.
- » Pandey S. Member, Editorial Board, *ICE: Waste and Resource Management*.
- » Pandey S. Member, Review Panel, *Waste Management*, Elsevier.

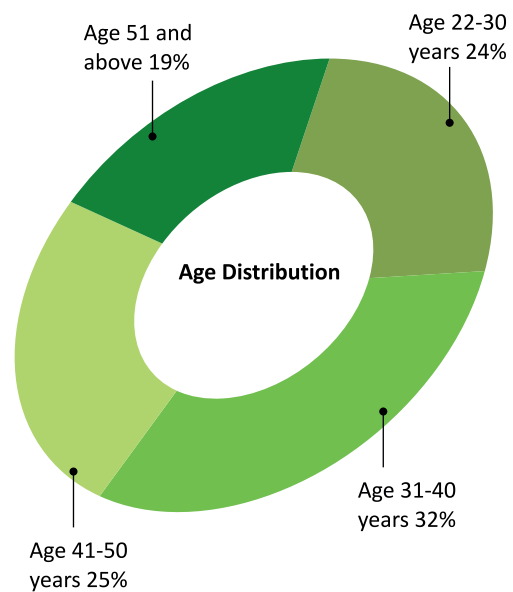
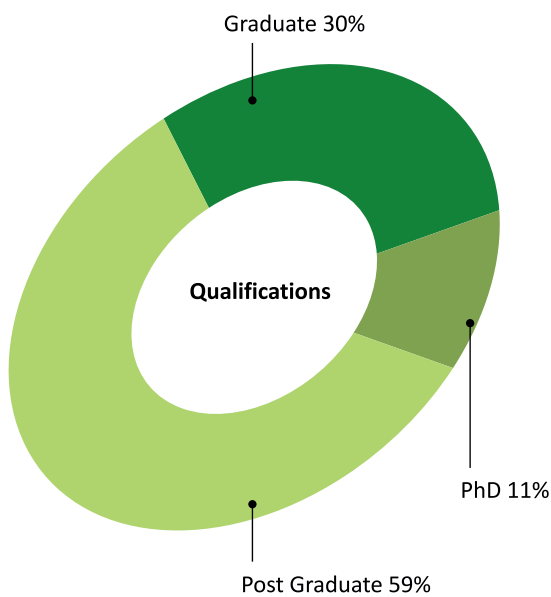
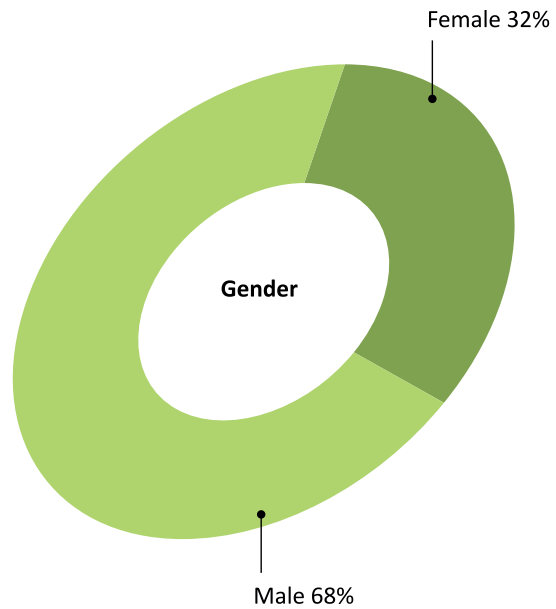
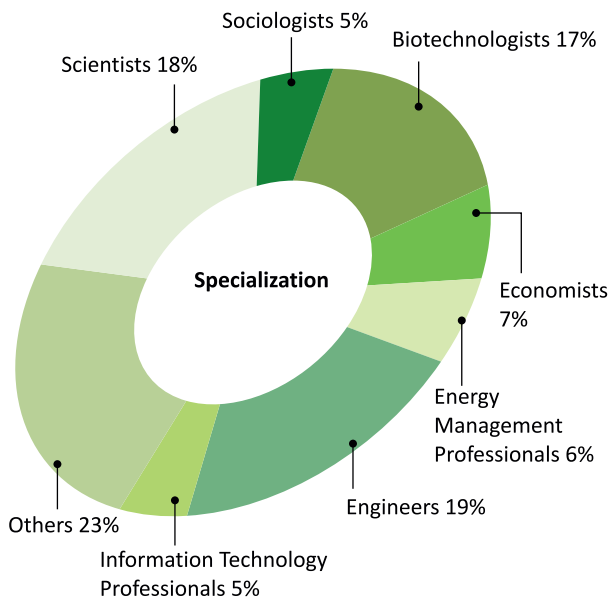


7

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.



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 2016/17.



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.

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.

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.





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.

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.



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.

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, nanobiosensors, nanocarrier-formulations, nanodelivery of agrochemicals, and seed coating formulations.



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.



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 state-of-the-art 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.





Smart Mini/Micro Grid Facility at RETREAT, Gual Pahari

It demonstrates the use of smarter control of distributed energy sources, combined with intelligent management of loads to improve the efficiency and reliability of the overall mini-grid system.

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.

TERI Gram

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



Test Bed Facility, Gual Pahari

The Energy and Resources Institute (TERI) and Somfy India Pvt Ltd have come 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.



Appendices

Earth Science and Climate Change

Centre for Environmental Studies

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- » Datta A, Pandey S, Malik J K, and Sharma S K. 2017. **Environmental Pollution.** In: Dhar Chakrabarti (ed.) *Planet, People and Progress – Beyond 2015.* New Delhi:TERI.
- » Datta A, and Sharma, S. 2016. **Inventory of air pollution in India: Domestic sector.** In: Kumar A and Sharma, S (eds) *Air Pollution in India.* New Delhi:TERI.
- » Datta A, and Sharma S. 2016. **Inventory of air pollution in India: Agriculture residue burning.** In: Kumar A and Sharma, S (eds) *Air Pollution in India.* New Delhi:TERI.
- » Datta A, Malik J K, Ekade S, and Grover S. 2016. Chapter: Environment. *TERI Energy and Environment Data Diary and Yearbook (TEDDY).* New Delhi: TERI. Available online at <<http://www.teriin.org/projects/teddy/>>.
- » Goel A, and Kumar P. 2016. **Vertical and horizontal variability in airborne nanoparticles and their exposure around signalised traffic intersections.** *Environmental Pollution* 214:54–69.
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- » Malik J K and Sharma, S. 2016 Other Sectors. Chapter 10. In: Sharma S and Kumar, A (eds) *Air Pollution in India.* New Delhi:TERI.
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- » Sharma S, Sharma P, and Khare M. 2017. **Photo-chemical transport modelling of tropospheric ozone: A review.** *Atmospheric Environment* 159:34–54.
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Centre for Global Environmental Research

- » Barreto, N J C, Mesquita, M d S, Pedra, G U, Bader, J, Toniazzo, T, and Bhardwaj, S. 2016. **Investigating the intra-seasonal climate signal through Maximum Covariance Analysis: A case study for tropical Brazil and India.** Royal Statistical Society 2016 Conference, 5–8 September, University of Manchester, Manchester, United Kingdom. doi: 10.13140/RG.2.2.19297.92007.
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Energy, Environment and Technology Development

- » Dhingra Sunil. Assessment of agricultural biomass for pellet production in Uttar Pradesh, India—International Conference on Challenges in Sustainable Development from Energy and Environmental Perspective, 2017. Rural Electrification and Livelihood Generation for Women Enterprises in Rural India: Experience of Implementing Two-Stage Biomass Gasifiers.
- » Das Piyali. **Patent published in 2016 “An Automated Programmable (Pneumatic) Logic Controller (PLC) based Dual Heating Mode Equipped Pyro Reactor for Biofuel Generation and Method of Working for Same”** (Docket No. 7100, CBR No. 4764, Application No 248/DEL/2014, Ref. No./Application Type: E-2/423/2015-DEL, Pages 30, Claims 10). **Principal Inventor: Dr Piyali Das.** Co –Inventor(s): Mr Agneev Mukherjee, K Minu.
- » Ram N K. Poster presentation at UN day celebrations, October 24, 2016, theme: innovation. In India, UN India has partnered with NITI Aayog and XPRIZE, to shortlist breakthrough innovations from across the country especially in the sectors of health, education, renewable energy and sustainable development. A case study on two stage biomass gasifier was shortlisted as one of the entry for the event through a poster and a table top model presentation.
- » P Raman. Need for a multi-dimensional evaluation method for analyzing the performance of biomass cookstoves: Efficiency, emissions and comfort factors. ‘2016’ Forum of Renewable Energy Promotion in Developing Countries.” 17–20 November 2016, China Agricultural University, Beijing, China.”
- » P Raman. Efficient utilization of available energy sources and use of alternative energy sources for clean environment and sustainable development. “8th Annual Sustainable Development Congress Week”, organized by Alleem Knowledge Center. 12–13 December 2016, Sharjah, UAE.

Environmental and Industrial Biotechnology

- » Subudhi S, Mogal S K, Kumar N R, Nayak T, Kumar T A R, Rao P V C, Choudhary N V, Shah G, Gandham S, and Lal B. 2016. **Photo fermentative hydrogen production by a new strain; *Rhodobacter sphaeroides* CNT 2A, isolated from pond sediment.** *International Journal of Hydrogen Energy*. 41: 13979– 3985 (Impact factor: 3.6).
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- » Subudhi Sanjukta. **Indo-UK joint workshop on 'Development of Rural Bio refineries in India: From Waste to Wealth'**, jointly organized by TERI (Dr Sanjukta Subudhi) and University of Delhi (Prof R Sharma) and university of York and this workshop was granted by University of York under the with the funding from BBSRC, UK.

Forestry and Biodiversity

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- » Tayal Shresth and Singh Swati. 2016. **Water Energy Food Nexus; Sustainable Urban Development: Necessity of Integrating Water-Energy-Food Dimensions in Developmental Policies** (Review Article). Policy Brief Peer Reviewed.
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- » Tayal Shresth and Grover Sonia. 2016. **Water-Energy Nexus; Water Neutral Electricity Production in India: Avoiding the Unmanageable** (Review Article). Policy Brief, Peer Reviewed.
- » Grover Sonia and Tayal Shresth. 2016. **Climate change-water-energy nexus- understanding the inextricable links.** *Terra Green* 8(12).

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Conferences/Seminars/ Presentations/Patents

Earth Science and Climate Change

Centre for Global Environmental Research

- » Poster Presentation, Modelling Economics of Grassland Degradation in Banni using System Dynamics, Second Asia Pacific Conference of System Dynamics Society, NUS, Singapore, February 2017.
- » Paper Presentation, Modeling Sustainability Scenarios of Renewable Natural Resources and Economic Growth using System Dynamics, 2nd Asia Pacific Conference of System Dynamics Society, NUS, Singapore February 2017.
- » Presentation, Modeling Economics of Grassland Degradation in Banni using System Dynamics, Economics of Climate Change Adaptation, CARIIA Consortium, TERI University, New Delhi, January 2017.
- » Presentation, Modeling Economics of Grassland Degradation in Banni using System Dynamics, Living Lightly, First National Conference on Future of Pastoralism in a changing World, New Delhi, December 2016.

Energy, Environment and Technology Development

- » Dhingra Sunil. 2017. Assessment of agricultural biomass for pellet production in Uttar Pradesh, India—International Conference on Challenges in Sustainable Development from Energy and Environmental perspective, 2017 2. Rural Electrification and Livelihood Generation for Women Enterprises in Rural India: Experience of Implementing Two-Stage Biomass Gasifiers.
- » Das Piyali. 2016. Patent published in 2016 "An Automated Programmable (Pneumatic) Logic Controller (PLC) based

Dual Heating Mode Equipped Pyro Reactor for Biofuel Generation and Method of Working for Same" (Docket No. 7100, CBR No. 4764, Application No 248/DEL/2014, Ref. No./Application Type: E-2/423/2015-DEL, Pages 30, Claims 10). Principal Inventor: Dr Piyali Das. Co-Inventor(s): Mr Agneev Mukherjee, K Minu.

- » Ram N K. Poster presentation at UN day celebrations on 24 October 2016. Theme: Innovation.
- » Raman P. 2016. Need for a multi-dimensional evaluation method for analyzing the performance of biomass cookstoves: Efficiency, emissions and comfort factors. "2016' Forum of Renewable Energy Promotion in Developing Countries", 17–20 November, China Agricultural University, Beijing, China.
- » Raman P. 2016. Efficient utilization of available energy sources and use of alternative energy sources for clean environment and sustainable development. "8th Annual Sustainable Development Congress Week", organized by Alleem Knowledge Center, 12–13 December, Sharjah, UAE.

Environmental and Industrial Biotechnology

- » Subudhi Sanjukta. 2017. 'Microbial production of second generation hydrogen via dark fermentation and Microbial production of 2,3-butanediol from renewable biomass'. Joint University of York GCRF IAA Meeting and Departmental Seminar on the theme; 'Stopping the Punjab Choking Delhi'. Green Chemistry Centre of Excellence, University of York, York, UK, 27 March.
- » Subudhi Sanjukta. 2017. 'Microbial production second generation hydrogen through dark fermentation route from renewable biomass: A sustainable process for clean energy production'. Indo-UK workshop on 'Development of Rural Bio-refineries in India: From Waste to Wealth'. Jointly organized by TERI and University of Delhi and University of York (granted by University of York with the funding from BBSRC, UK), University of Delhi, Delhi, 20 February.
- » Subudhi Sanjukta. 2016. 'Fermentative bio-hydrogen production by *Enterobacter cloacae* from lignocellulosic biomass; a second generation feed stock. Twelfth International Oil and Gas Conference and Exhibition (PETROTECH-2016), New Delhi, 5–7 December.
- » Subudhi Sanjukta. 2017. 'Scale up of hydrogen production in 150 liter pilot scale through dark fermentation route by a purified anaerobe'. International Conference on 'Sustainable Energy and Environmental Challenges (SEEC 2017), Centre of Innovative and Applied Bioprocessing, Mohali, 26–28 February.
- » Subudhi Sanjukta. 2017. 'Biotechnological valorisation of gas for production of biofuels and platform chemicals'. Valorization of CO₂ and CH₄ Gas from Anaerobic Digestion, Landfill and Other Biological Processes, DBT-ICT Centre, Mumbai, 9–10 January. Funded by a BBSRC India Partnership Award.
- » Bisht Varsha, Sanjukta Subudhi, and B Lal. 2016. Poster presentation on 'Production and characterization

- of extracellular lipase by *Bacillus* spp TERI Fb and its application in treatment of lipid-based wastewater'. 57th Annual Conference and International Symposium of Association of Microbiologists of India, 25 November, Guwahati University, Guwahati, Assam.
- » Mazumdar Debojyoti, Subudhi Sanjukta, B Lal. 2016. Poster presentation on "Mixotrophic cultivation of fast growing *Chlorella sorokiniana* TERI-A in different acid treated waste lignocellulosic hydrolysate for biodiesel generation." 57th Annual Conference and International Symposium of Association of Microbiologists of India.
 - » Mazumdar Debojyoti, Subudhi Sanjukta and Banwari Lal. 2017. Oral Presentation on 'Production of value added algal biomass and green chemical from biomass based feed stocks'. Indo-UK workshop on 'Development of Rural Bio-refineries in India: From Waste to Wealth', jointly organized by TERI, University of Delhi, and University of York (this workshop was granted by University of York with the funding from BBSRC, UK), University of Delhi, Delhi, 20 February.
 - » Kumar N Ram, Subudhi Sanjukta and Banwari Lal. 2017. Poster presentation (adjudged best poster presentation) on "Dark fermentative bio-hydrogen production from different biomass by *Enterobacter cloacae*". Indo-UK workshop on 'Development of Rural Bio-refineries in India: From Waste to Wealth', jointly organized by TERI, University of Delhi, and University of York (this workshop was granted by University of York with the funding from BBSRC, UK), University of Delhi, Delhi, 20 February.
 - » Verma Dipti, Wu Langping, Das Subhashis, Subudhi Sanjukta, Richnow Hans, Lal Banwari. 2016. Poster presentation on 'Biodegradation of Ops especially chloropyrifos, TCEP and parathion through soil microbes'. International Conference on NextGen@Helmholtz, 2016, Braunschweig, Germany, 28–30 September.
 - » Priya A, Dureja P, Lal B. 2017. Oral presentation on Enhanced 2,3 Butanediol production by a newly isolated *Enterobacter cloacae* strain by step wise process optimization held by the Joint Indo-UK Scoping workshop Development of Rural Biorefineries in India: From Waste to Wealth', University of Delhi, 20 February.
 - » Priya A, Dureja P, Lal B. 2016. Poster presentation on Exploration of microbial production of 2,3 butanediol, acetoin: A green industrial platform chemical for application in fragrance and flavour industries. Green and Sustainable Chemistry Conference, Berlin, Germany.
 - » Priya A, Dureja P, Lal B. Poster presentation on Enhanced 2,3 Butanediol production by a newly isolated *Enterobacter cloacae* strain by step wise process optimization. BRSI 2016, Vellore, India.
 - » Chakraborty, S, Nanthakumar, K, Kumari, M, Jain, P, Subudhi, S, Lal, L, Song, Y, Feng, Q, and Yoo, K. 2017. Improving electrocatalysis contributing to methane production from distillery wastewater, best poster award received at Indo-EU workshop on microbial electrochemical technologies for sustainability: Fuels, chemicals and remediation, Hyderabad, India.
 - » Nanthakumar, K, Kumari, M, Jain, P, Subudhi, S, Lal, L, Song, Y, Feng, Q, and Yoo, K. 2016. Poster presentation on Pre-treatment of distillery wastewater for enhanced bio-electrochemical anaerobic methane production, AP-ISMET2016, Busan, South Korea.
 - » Lal et al. 2016. Evaluating the potential of an indigenous thermophilic anaerobic bacterial consortium for enhanced oil recovery, ICABB2016, VIT, Vellore, 23 September.
 - » Lal et al. 2016. Biodegradation of asphalt by *Garciaella petrolearia* TERIG02 for viscosity reduction of heavy oil, 57th Annual Conference of Association of Microbiologist of India, Gauhati University, 24 November.
 - » Lal et al. 2016. Bio-remediation of Fire Resistant Fluid (FRF) used in Turbine Governing Systems Utilizing Microbial Consortia Isolated from Soil—An Approach for Zero Liquid Discharge, Servo Power Meet, Ghaziabad, 23 September.
 - » Lal et al. 2016. Potential of viscosity reducing thermophilic anaerobic bacterial consortium in upgrading heavy oil. Petrotech 2016, Vigyan Bhawan, New Delhi, 5 December.
 - » Lal et al. 2016. Detection and control of sulphate reducing bacteria (SRB) in oil and Gas pipelines. International Conference & Exhibition on Risk-based Inspection & Maintenance, Delhi, 26 August.
 - » Lal et al. 2017. "Isolation, identification and development of methanogens for in situ generation of methane from coal seams. 7th World Petrocoal Congress, New Delhi, 15 February.
 - » Lal et al. 2016. Viscosity reduction of Heavy oil. 10th International Symposium on Fuel and Lubricant, IOCL Faridabad, 18 April.
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Sustainable Habitat

GRIHA

Bhalla Ankit and Tyagi Kalpana. 2017. "Impact of Solar Insolation on building envelope in cold climatic zone of India", Sustainable Built Environment: International Conference 03–05 February, IIT Roorkee. Department of Architecture & Planning.

TERI Southern Regional Centre, Bengaluru and Goa

- » D'Souza Fraddy. Presentation on 'Scope for technical start-ups in Goa' at The Entrepreneurship Summit 2016, NIT Goa, 9–11 September. Organized by NIT, Goa.
- » D'Souza Fraddy. Presentation on 'Khazan ecosystem of Goa' at 12th ISOLA Annual Conference at Kala Academy, Goa, 19 January 2017, Organized by ISOLA.
- » D'Souza Fraddy. Presentation on 'TERI Sustainable Technologies' at Recent Advances in Alternate Energy Sources & Technology, 5–10 December 2016, Organized by NIT, Goa.
- » D'Souza Fraddy. Presentation on 'Biofuels: marine macro and microalgae' at Recent Advances in Alternate Energy Sources & Technology, 5–10 December 2016, Organized by NITTR, Goa.

- » Panandiker Ashwini Pai. Presentation on 'Need for Data Inventories' at training workshop for the employees at City of Corporation of Panjim (CCP), Panjim, 18 August 2016.
- » Panandiker Ashwini Pai. Presentation on 'Mangroves and associated ecosystems as potential buffers to climate change' at teachers training workshop, organized by GIZ, 27 July 2016.
- » Panandiker Ashwini Pai. Presentation on 'Charting a path for sustainable consumption of water by different economic sectors in Goa', invited as guest speaker on the occasion of International Youth Day at Goa University, 12 August 2016.
- » Panandiker Ashwini Pai. Presentation on 'Assessing the impact of climate change on water availability in Uguem river sub-basin' at dissemination workshop, 6 October 2016.
- » Panandiker Ashwini Pai. Presentation on 'Sustainable consumption of water and impact of sea level rise in Goa' invited as guest speaker at VicharVedh a programme by Gomantak Vidya Niketan, Goa, 24 September 2016.
- » Ashwini Pai Panandiker. Presentation on 'Sectoral water demand estimation and climate change impact on water availability: Case studies from Goa' at TERI-KAS Resource Dialogue III, 12 April 2017.
- » Patil Kavita. Overview of sustainable water technologies: About River Bank Filtration technology Course Title: - The Economy-Ecology Interface: Role of Sustainable Technologies and Practices, 2 February 2016. Extension Centre Goa, NITTR Extension Centre Goa, at Directorate of Technical Education Bldg. Porvorim Goa.
- » Patil Kavita. Sensor controlled Grid Independent irrigation Riverbank Filtration technology. Recent Advances In Alternate Energy Sources & Technology, 5 & 6 December 2016, NIT, Ponda.
- » Patil Kavita. Thomas Boving and Fraddry D'Souza (2016). Illustrating the Potential of Riverbank Filtration Technology: Case Studies from Southern India. Innovations in sustainable water and waste water treatment systems (ISWATS), 21–23 April 2016, Yashada, Pune, India.
- » Patil Kavita and Boving Thomas. Mitigation Measures for Stormwater Drain Clogging and Street Flooding through Best Management Practices—Case studies from India. National Seminar on Avhaan-Making Construction Disaster Resilient Storm Water, 26 February 2016.
- » Patil Kavita. Importance of water conservation and efficient technologies at Village level Aquifer Management Plan Rajiv Gandhi National Groundwater Training and Research Institute, CGWB, Belagavi, 15 and 16 December 2016, Sattaritaluka, North Goa District.
- » Patil Kavita. Advances with Riverbank Filtration technology. Workshop on Bank Filtration for sustainable drinking water supply. DST-sponsored. Organised by NIH and DHRRC Belagavi, 6–10 February 2017, Water Resources Department, Goa.

Sustainable Agriculture

- » Deshmukh Sunil. 2017. Why Pharmaceutical industry should work on fungal endophytes, International Conference Interface of Physical, Chemical and Biological Sciences (IPCBS-2017) January 11–13, Golden Jubilee Hall, Dr Harisingh Gour Vishwavidyalaya, Sagar.
- » Aggarwal Shivankar. 2017. Screening for antibacterial activity of fungi from Indian marine environments: A possible alternative for new antibiotics for the treatment of skin microbial infections", ICEP2017 19th International Conference on Ethnopharmacology and Pharmacology at Singapore, January 8–9.
- » Kaushik Nutan. 2016. Searching new products from plant and microbes for human and plant health, Indo-Norwegian Joint Workshop on Bioeconomy, September 6–7, Oslo, Norway.
- » Kaushik Nutan. 2016. TERI Technologies for Sustainable Plant Protection, Meeting on Exploration of Technologies Hyderabad, India.
- » Kaushik Nutan. 2016. Metabolomics for understanding the plant chemistry: Comparison of lipid extraction methods for lipid profiling in algae, 251st American Chemical Society National Meeting & Exposition, San Diego, USA.
- » Kaushik Nutan. 2016. Bioprospecting of Biodiversity for Development of Biopesticides, 3rd International IUPAC Conference on Agrochemicals Protecting Crops, Health and Natural Environment: New Chemistries for Phytomedicines and Crop Protection Chemicals, April 5–9, New Delhi, India.
- » Kaushik Nutan. 2016. Validating the Use of Panchgavya in Agriculture, National Brainstorming-cum-Consultative Workshop New Delhi, India.
- » Kaushik Nutan. 2016. Application of Metabolomics in Veterinary Sciences, Workshop on Metabolomics for Plant, Human, and Animal Health, New Delhi, India.
- » Kaushik Nutan. 2016. Bioeconomy. Indo-Norway Workshop on ReFood, New Delhi, India.
- » Srivastava Shivani, Cahill David, Conlan Xavier, and Adholeya Alok. 2016. Rhizophagus irregularis as an elicitor of rosmarinic acid and antioxidants in hairy roots of *Ocimum basilicum*, Plant Biology 2016, Austin, Texas, USA.
- » Deshmukh Sunil. 2016. Why Pharmaceutical industry should work on fungal endophytes. 4th National Workshop on Taxonomy, Biodiversity, Ex situ Conservation and Application of Fungi organized by National Fungal Culture Collection of India (NFCCI) NFCCI-ARI, Pune, June 1–10, Agharkar Research Institute, Pune.
- » Deshmukh Sunil. 2016. Synthesis of Silver Nanoparticles by coprophilous fungi and its antibacterial properties, 43rd annual meeting of Mycological Society of India and a National Conference on "Fungal Biotechnology", November 16–18, Birla Institute of Scientific Research, Jaipur.

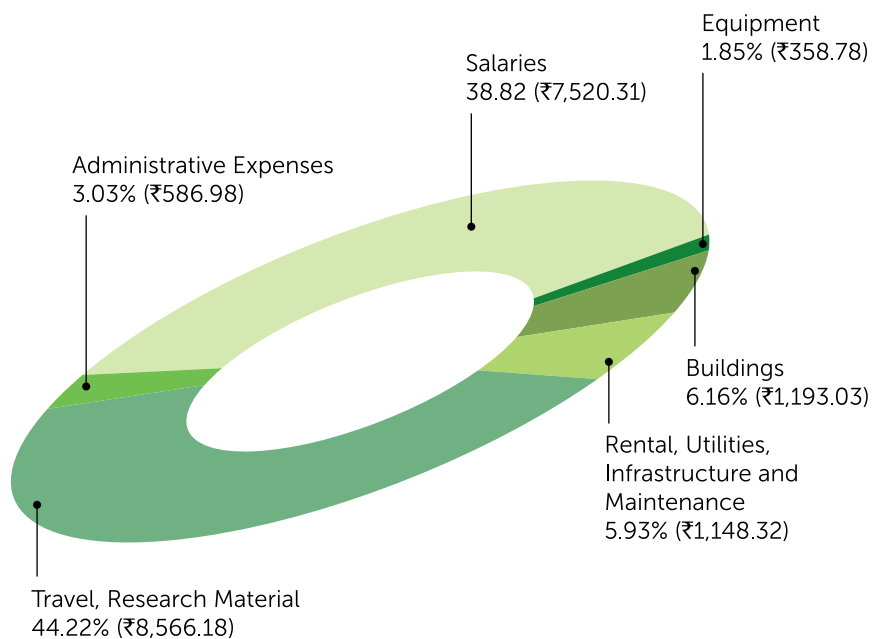
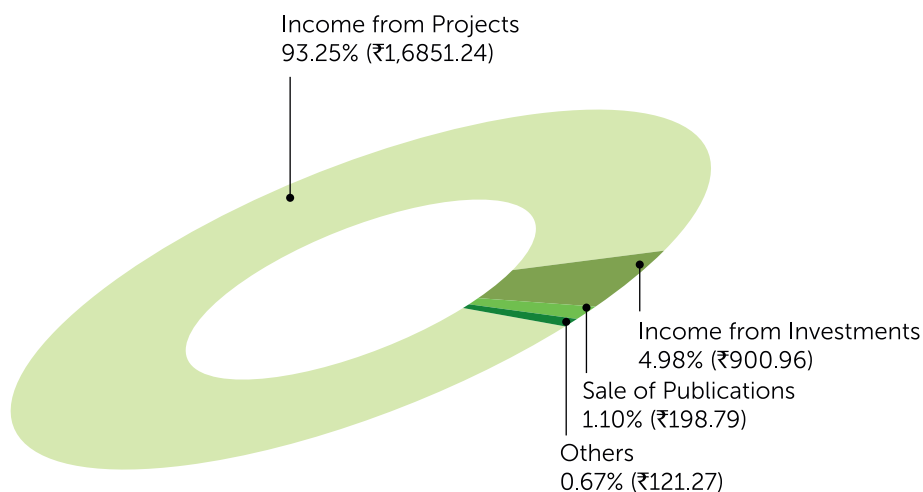


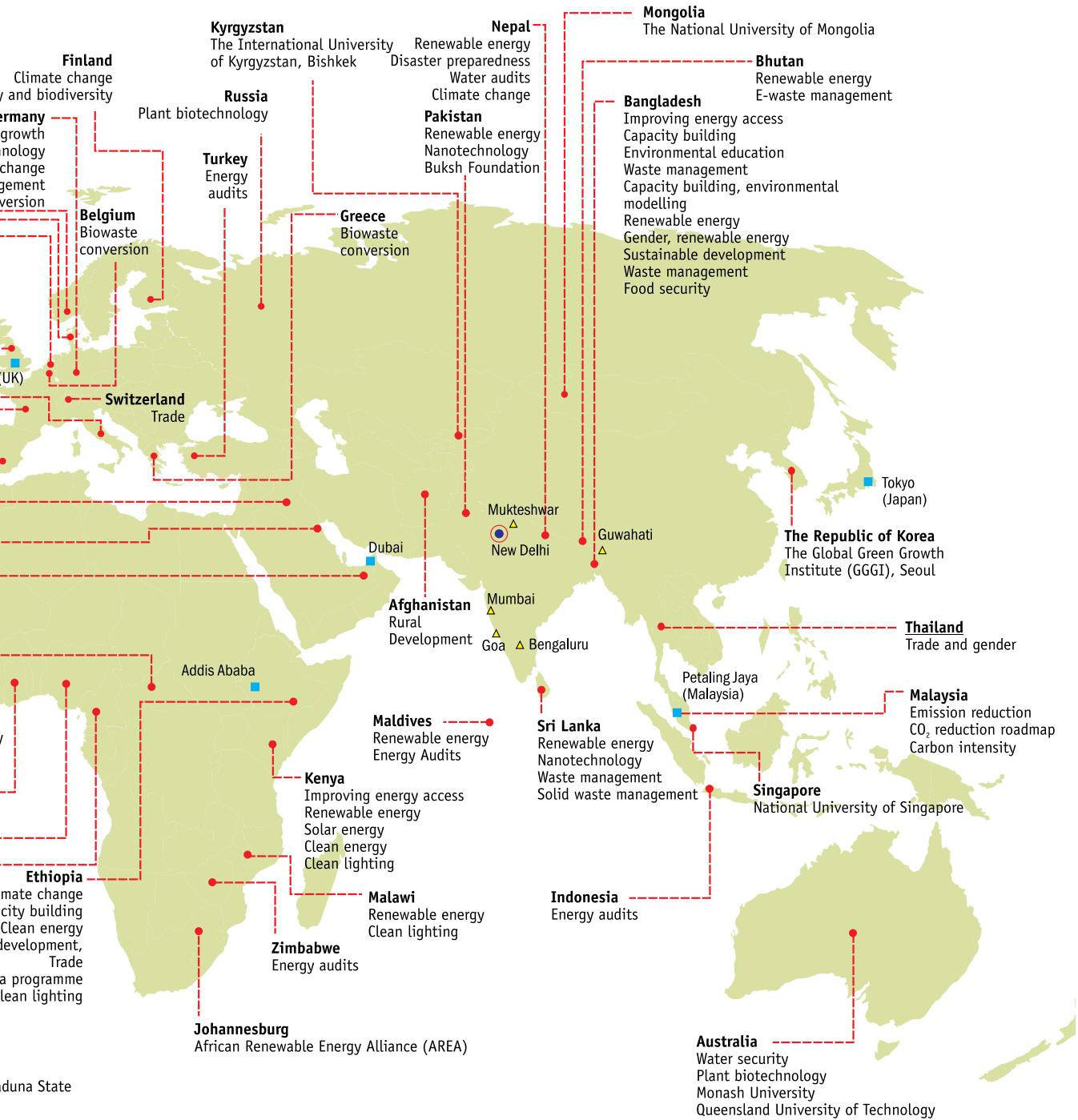
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Financial Summary

Financial Summary

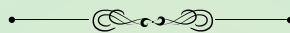
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Centre ■ TERI Overseas Centre ● TERI's Activities

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