2012 ANNUAL REPORT

A Year of Strides

CSTEP

CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

To enrich the nation with technology-enabled policy options for equitable growth

The Year 2012

A Year of Strides

CSTEP is now eight years old and is fast growing as a large institution with a number of researchers working in new and challenging projects. Though the number of projects has increased, CSTEP ensures that assignments enabled with science and technology are taken.

Energy studies are now, as was the case last year, taking up large resources. We had completed a multi-year study on energy efficiency in the cement industry analysing data from plants which resulted in a detailed report with clear recommendations for improving the process efficiency and reducing carbon emission. We are delighted with the industry's acceptance of our recommendations which provide a template for the Perform, Achieve and Trade initiative. This augurs well for our pursuing similar studies in other industrial sectors as well. We have also taken up iron and steel sector for a similar study as this industry is one of the largest emitters of carbon-di-oxide.

Every nation wants to harness renewable energy from solar, wind and a few other minor resources. But, truth is, most are deterred by the high costs and other limitations such as the intermittency of wind or sunshine not being available for all hours of the day. The challenges are therefore in overcoming these inherent limitations and reducing costs. In this context, two major studies from CSTEP are worth noting. One is on the realistic cost of solar power: CSTEP has developed a user friendly software that assesses the economic viability of concentrated solar thermal power. The other is on wind power where there are major problems on location, land usage and intermittency. Our studies indicate that it is possible to overcome some of these with storage systems and by building large grids that can compensate for intermittency. As a part of this programme we are also carrying out fundamental studies on lithium ion battery systems that may overcome the present limitations. This is a challenging assignment because of the complexities involved in improving energy efficiency and keeping the electrodes and the electrolytes intact for long term performance.

Successful development of renewable energy is a global problem that is being pursued by many laboratories in the world. CSTEP is a member of a major Indo-US project on solar energy with over a dozen participants from both countries. The team consists of members from universities, laboratories and industries and has a mandate to develop options for making solar energy viable. CSTEP

Energy Rush

"Every nation wants to pursue the harnessing of renewable energy, solar, wind and a few other minor resources. But, truth to tell, most are deterred by high costs, intermittency etc.."

"The challenges are in overcoming these…"

finds the mission challenging and is already exploring the solar energy's constraints. There is yet another transnational collaboration where CSTEP along with partner institutes in India and England has initiated a first of its kind project to study climate trends, growth and mitigation for Karnataka.

The Security Studies group, in the past year continued its work on examining technologies and policies that affect the management of large scale disasters. Various approaches to simulation, analysis and training were explored. Apart from this, the group has been exploring technologies for disaster management, especially the use of game engine technologies for transforming 2D building maps to 3D walkthroughs that can be useful to responders for incidents in closed urban areas. The group will continue to explore technologies, policies and develop tools that may be used for mitigation, preparedness and response for emergency and disaster situations.

Modelling is an important tool in scientific research and has, like elucidating the structure of DNA, accounted for scientific and technological breakthroughs. But this approach becomes difficult for studying human behaviour where we have to contend with millions of variables and their interactions. The phenomenal growth of computers with their processing power and speed is removing the constraints imposed on modelling complex systems. In the coming years, we propose to build a major computing and analysis platform named DARPAN that will have the capacity to analyse a multitude of options from which a few can be suggested for decision making. We are excited by this approach and hope to spend a considerable time in the coming year in making this platform work. Decision making, will then have a new tool and will be exalted by its capacity to analyse and choose from several possibilities.

CSTEP continues to get funding and intellectual support from global and Indian institutions. IDRC is continuing its support as also the OAK Foundation with sizeable grants. The Shakti Foundation has been a source of constant support in our energy studies. The Planning Commission, Defence Research and Development Organisation, Ministry of New and Renewable Energy, Ministry of Power, Department of Science and Technology and the Government of Karnataka have all been supporting us with projects and often using our studies for making their decisions. CSTEP is now strong with over 50 researchers from various disciplines and is fast becoming a well-integrated interdisciplinary institution. Our analysts come from all parts of the country and gender equality is enthusiastically pursued. Our team has moulded into a friendly and competent faculty with an average age in the thirties. The annual budget hovers around Rs 12 crores. And what we now urgently need is a campus!

CSTEP continues to provide a challenging and yet friendly environment.

Dr V. S. Arunachalam

Chairman

Dr Anshu Bharadwaj

Executive Director

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About CSTEP

CSTEP is a 'not for profit' research organisation incorporated in 2005 u/s 25 of The Companies Act, 1956. Its vision is to enrich the nation with technology enabled options for equitable growth. CSTEP has grown to become a multi-disciplinary policy research organisation in the areas of Energy, Infrastructure, Materials and Security Studies. Its research team is inter-disciplinary and has over 50 members with specialisation in science, engineering, management, economics, policy and social sciences.

CSTEP is recognised as a Scientific and Industrial Research Organisation by the Ministry of Science and Technology, Government of India. The Center is supported by grants from domestic and international foundations, industry trusts and government. Grants and donations made to CSTEP are eligible for exemptions u/s 80(G) of the Income Tax Act, 1961. CSTEP is also registered under the Foreign Contribution (Regulation) Act, 2010.

The Board

Dr V. S. Arunachalam, Chairman and Founder, CSTEP

Dr Arunachalam, former Scientific Advisor to the Raksha Mantri (SA to RM), is a Distinguished Service Professor at Carnegie Mellon University, Pittsburgh. He is also an Honorary Professor at University of Warwick, UK. As SA to RM, he has served ten Defence Ministers of India, five of whom were also Prime Ministers. Dr Arunachalam has made significant contributions to science and has also established institutions and industries for harnessing technology. At DRDO, he initiated India's major defence projects such as the Light Combat Aircraft and the Integrated Guided Missiles programmes. He is a member on the Advisory and Editorial Boards of several universities and foundations including the Materials Research Society Bulletin. He is a recipient of numerous honours and awards including Shanti Swarup Bhatnagar Prize for Engineering Sciences and the Padma Vibhushan.

Shri Prafull Anubhai

Shri Prafull Anubhai is a management consultant and is associated with educational institutions such as the Indian Institute of Management Ahmedabad, Ahmedabad Education Society (AES) etc. He is also the Chairman of the Ahmedabad University. He is actively involved with Saptak (An Indian Classical Music organisation). He has over 30 years of experience as Chief Executive Officer of textile manufacturing operations and presently is a Director in companies like Birla Sun Life, GRUH Finance Ltd., Mahavir Spinning Mills Ltd., etc.

Prof. M. G. K. Menon

Professor Menon has held positions such as Director, Tata Institute of Fundamental Research, Secretary, Department of Science and Technology, Director General, CSIR, and Scientific Advisor to RM. He was a Member of Parliament–Rajya Sabha, and Minister of State for Science & Technology. Prof. Menon is a recipient of several honours including the Padma Vibushan.

Prof. S. Ranganathan

Professor Ranganathan is an Emeritus Professor, Indian Institute of Science and Homi Bhabha Visiting Professor, National Institute of Advanced Studies, Bangalore. A specialist in Physical Metallurgy and Materials Engineering, Prof. Ranganathan has made outstanding contributions in field-ion and electron microscopy, structure of interfaces and quasicrystals. He is a recipient of the Platinum Medal from the Indian Institute of Metals, MRSI medal and the Materials Science Prize from the Indian National Science Academy.

Prof. Raj Reddy

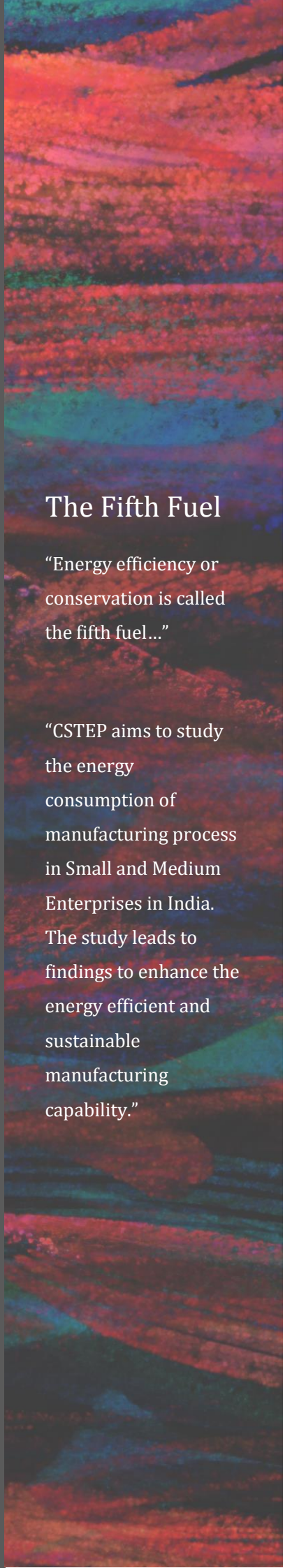
Professor Raj Reddy is the Mozah Bint Nasser University Professor of Computer Science and Robotics in the School of Computer Science at Carnegie Mellon University. His research interests include the study of human-computer interaction and artificial intelligence, universal digital libraries, role of ICT in developing economies. He is a member of the US National Academy of Engineering and the American Academy of Arts and Sciences. Prof. Reddy's awards and honours include the Legion of Honour from France, the Padma Bhushan, the ACM Turing Award, the Honda Prize and the Vannevar Bush Award.

Shri Ashok Vasudevan

Shri Vasudevan is co-founder of three food businesses in the US, India and Australia. Presently, he is the Chief Executive Officer of Preferred Brands International, a Connecticut-based food company and Tasty Bite Eatables Limited in India, and Chairman of Preferred Brands Australia Pty Ltd., a Melbourne based sales and marketing company.

Dr Anshu Bharadwaj, Director, CSTEP

Dr Bharadwaj holds a PhD in Engineering and Public Policy and Mechanical Engineering from the Carnegie Mellon University (CMU). He is a B.Tech in Mechanical Engineering from the Indian Institute of Technology, Kanpur with a PGDM from the Indian Institute of Management, Calcutta. He was in the Indian Administrative Service and worked with Government of Karnataka in various capacities for about 15 years. His research interests are in emerging technologies and fuel options for India's low carbon inclusive growth. His expertise includes computational modelling and systems.



The Fifth Fuel

"Energy efficiency or conservation is called the fifth fuel…"

"CSTEP aims to study the energy consumption of manufacturing process in Small and Medium Enterprises in India. The study leads to findings to enhance the energy efficient and sustainable manufacturing capability."

Energy

As the world population and its affluence increases, greater demands are placed on sources of energy. Equally important is energy efficiency or conservation which is called the fifth fuel. India's energy efficiency is the fifth lowest in the world meaning the GDP to energy consumption ratio is very poor. Hence, there is a need for improving energy efficiency.

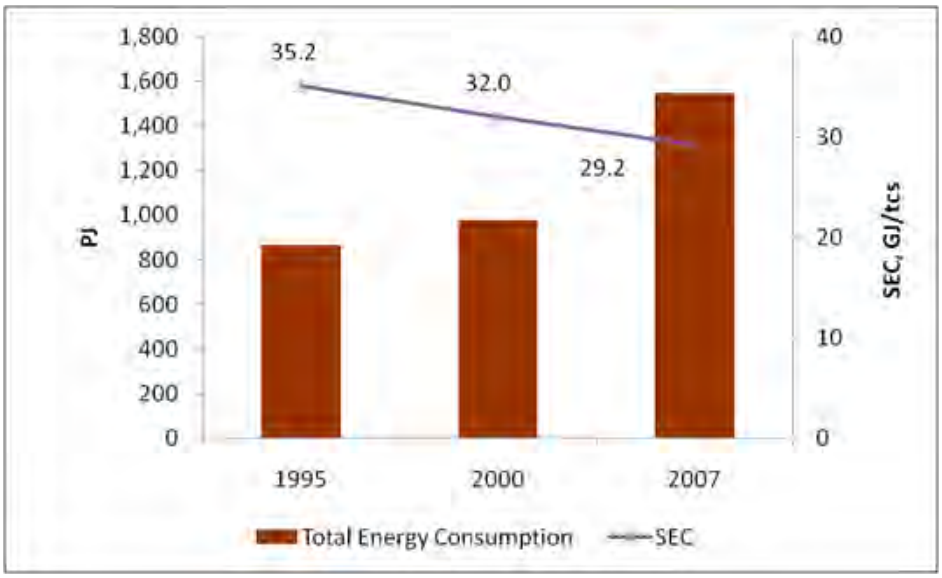
Energy Efficiency and Sustainability

The Energy Efficiency and Sustainable Program (EESP) at CSTEP aims to study the energy consumption of manufacturing process in Small and Medium Enterprises (SME) in India. The study leads to enhancing energy efficient and sustainable manufacturing capability.

Iron and Steel

EESP has taken up an integrated study of Iron and Steel industry in India to support the Bureau of Energy Efficiency (BEE) in implementing the Perform Achieve and Trade (PAT) mechanism for improving energy efficiency in this sector. PAT, under the National Mission for Enhanced Energy Efficiency, is one of the flagship programmes launched by BEE, and the Ministry of Power, Government of India. The study is to provide BEE with extensive data, models and analysis of energy efficiency related indicators of Indian Iron and Steel industry. The research team has generated comprehensive material and energy balance model for Blast Furnace – Basic Oxygen Furnace system, Direct Reduced Iron and Electrical furnaces. The application of these models is to determine the effect of different parameters on system performance in terms of energy and emissions. The team has used the process simulator ASPEN plus to model the processes.

As a part of this project, the team visited a few major Iron and Steel plants for collecting data and attended several stakeholder meetings organised by BEE to bring both the industry and the policy regulators in a forum.



Historical Energy Consumption and SEC of Iron and Steel Industry*Sources: Singhal [2009], CSTEP Estimates*

The team had conducted a similar study for the Indian Cement Industry during 2010-12. The study provided major inputs to the target setting methodology of PAT mechanism. BEE has implemented the research findings for enhancing the energy efficiency targets of the designated industries. The project involved several plant visits to understand the ground level scenario of production and operation, which acted as a platform to interact with key personnel for effective knowledge transfer. A report was released in March 2012, documenting the processes and outcomes.

The EESP team has also performed a low carbon study for industries and power sectors. The study assisted the Planning Commission towards the creation of the 12th Five Year Plan. Apart from these activities, the group has also conducted substantial research on energy efficiency of buildings and consumer durables.

Clean Coal Technologies

According to a World Bank Report, 56% of rural households in India do not have access to electricity. The nation's dependence on oil and gas imports is expected to increase to meet the projected energy demand. Hence it is necessary to utilise the resources efficiently to address the challenges of climate change and energy security. As one of the policy efforts from the Government of India, the National Mission on Clean Coal Technologies (NMCCT) envisages to build an indigenous Multi-Feed Gasification Technology plant for power generation (MFGPG) and production of hydrogen, where coal, biomass, Municipal Solid Wastes (MSW), petcoke etc. can be used as feed. NMCCT is considered as the ninth mission under the Prime Minister's National Action Plan for Climate Change (NAPCC).

It is also important to develop an indigenous clean gasification technology for converting various feeds (Biomass, MSW, high ash coals). This technology is essential to utilise waste from agriculture, industry and urban MSW to generate energy. This technology rightly finds its place to tackle the energy crisis and energy security. CSTEP focuses on the need for the right policy to enable the growth of this technology.

CSTEP is working on a project with Vehicle Research and Development Establishment, Ahemdanagar, a DRDO laboratory, and Thermax, Pune (initiated in Nov-2012) to examine the techno-economic feasibility of setting up two MFGPG pilot plants. A feasibility report is being prepared. Case studies specific to Indian scenarios, supply chain management of raw materials and products and development of models for commercialisation will also be covered.

Study of Potential for Widening the Coverage of Perform Achieve Trade

CSTEP, in the Cement and Iron & Steel sectors, has developed scenarios providing energy efficiency options in context to PAT.

BEE, the nodal agency regulating the PAT programme, has identified 478 industrial plants called Designated Consumers (DC) with a total annual energy consumption of 165 million tonnes of oil equivalent (Mtoe) in the first cycle of PAT. The expected energy savings during 2012-15 (fiscal year) is calculated to be around 6.86 Mtoe for all the seven energy intensive sectors– Aluminium, Cement, Chlor Alkali, Fertiliser, Iron and Steel, Pulp and Paper, Textile, Thermal Power Plant.

CSTEP will create a database of industrial units and provide PAT focussed techno-economic and policy analyses for the second cycle. The study extends the scope of PAT to include additional industrial units that have not been included in the first cycle. Including additional units in the second cycle would increase energy savings and thereby the number of Energy Saving Certificates (ESCs) that can be traded.

Green-Growth, Low-Carbon and Climate Change-Resilient Development for Karnataka

Karnataka is focused on promoting economic growth which is sustainable and equitable. Since energy is the key to both stimulating an inclusive economic growth and reducing the green-house-gas emissions and other environmental impacts, there is a need for a green energy path with renewable sources of energy that reduces dependence on imported fossil fuels. Yet, there is little research on climate change or policy development at the state-level, though most policy decisions are taken by the state. This

project aims to bridge this gap by building a robust, fact-based, state-level green growth strategy that will accelerate Karnataka's development and serve as a model for other states in the country.

The project, initiated in November 2012, is supported by the Global Green Growth Institute (Korea based) and partners with Bangalore Climate Change Initiative Karnataka (BCCI-K) led consortium which includes the Indian Institute of Science, University of Agricultural Sciences, London School of Economics and Political Science, Institute for Social and Economic Change, and Indian Institute of Technology, Delhi.

This project is the first major initiative in the country to create a green growth strategy at the state level.

It focuses on six sectors– power, industry, transportation, agriculture, forestry and waste – pursued in three work streams: green economy strategy, climate resilience strategy and financing strategy. While the first stream focuses on key mitigation policies and sustainable low-emission pathways, the second complements it by examining climate vulnerability and key adaptation policies. The final stream assesses international, national, and state-level funding mechanisms to implement these strategies.

As part of this project, CSTEP initiated an analysis document assessing Karnataka's development plans & major policies and identified barriers to policy implementation. This analysis would be valuable in recommending implementable green growth strategies for the state. The preparation of GHG inventory, particularly for the industry and power sectors also is at an advanced stage. In addition, in a first of its kind analysis within the organization, the team began engaging with TIMES, an energy system modelling software, to explore long-term cost-effective and low emission pathways for the state.

A Green Growth Strategy Report for the state will be released in the coming year.

Solar Thermal

Solar thermal energy is positioned as an important renewable option in the global energy scenario. CSTEP is engaged in exploring opportunities and identifying challenges that are involved in the development of Concentrated Solar Thermal Power (CSP) in India. Solar thermal group at CSTEP looks into these aspects and envisages developing simulation models for assessment and bankability of CSP technologies.

Engineering Economic Policy Assessment of Concentrated Solar Thermal Power Technologies for India

On behalf of the Ministry for New and Renewable Energy (MNRE), Government of India, CSTEP completed a study titled "Engineering Economic Policy Assessment of Concentrated Solar Thermal Power Technologies for India".

Detailed engineering and cost models were developed for Parabolic Trough technology. The engineering model takes into account heat transfer analysis of the absorber tube, power block performance under design and off design conditions, transients in power generation during cloud cover and thermal losses during shutdown. The option of using thermal storage and hybridisation is also considered for optimum power generation. The hourly simulation model uses the concept of Solar Multiple to determine optimum size of the solar field. The economic model evaluates the Levelised Cost of Electricity (LCOE) and Internal Rate of Return (IRR) of a project based on component costs, operation and maintenance costs, financial metrics etc.

A desktop simulation tool has been developed to evaluate the techno-economic performance of Parabolic Trough technology. This tool has inbuilt Direct Normal Irradiance data for 22 stations in India and can evaluate plants with capacity ranging from 1-100 MW with thermal storage and hybridisation options.

Concentrated Solar Thermal Power Technologies

For Linear Fresnel and Solar Tower, a gross methodology to assess viability of these technologies has been addressed. The Linear Fresnel Reflector using a heat transfer fluid is considered for the present analysis as there are significant advantages compared to Direct Steam Generation. For analysis of a solar tower, an open air receiver with molten

salt as Heat Transfer Fluid was considered. With respect to Dish Stirling engine, it was observed that commercial viability of such a system is yet to be established.

The study also considers options of hybridisation with natural gas, thermal energy storage, cooling by air condensing. It is recommended that a CSP plant should have either thermal storage or hybridisation for reliable power generation. The challenges with indigenisation and manpower requirements have also been discussed. It is seen that there is a huge potential for cost reduction through indigenisation and opportunities for increasing jobs in the solar industry. Finally, policy recommendations for accelerating CSP deployment in India have been made. These recommendations pertain to the creation of land banks, thrust on indigenisation of CSP components, incorporation of storage and hybridisation, R&D focus on small scale CSP and bankability issues.

Solar Energy Research Institute for India and the United States

The Solar Energy Research Institute for India and the United States (SERIIUS) was launched to create a bi-national network for fostering new ideas and collaborations to expedite a sustainable industry. SERIIUS is developing disruptive technologies through foundational research in photovoltaics (PV) and concentrated solar power (CSP) to address the critical barriers for solar energy development in India that intersect the grand challenges for solar energy in the US.

The programme is jointly funded by the Joint Clean Energy R&D Center (JCERDC) through the Government of India and the US Department of Energy (DOE). The Consortium is also supported by more than 30 partners from India and the US.

SERIIUS seeks to develop emerging revolutionary solar electricity technologies towards the long-term success of India's Jawaharlal Nehru Solar National Energy Mission and the US (DOE) SunShot Initiative. This is a novel initiative to support joint research and development of solar energy, next generation biofuels, and energy efficiency in buildings. This five-year project aims at developing technologies for near commercial deployment.

The researchers are carrying out fundamental and applied research, analysis and assessment, outreach, and workforce development through specific bi-national projects in three research thrusts:

Sustainable Photovoltaics: To develop next-generation materials, devices, and advanced manufacturing processes tailored to needs, environment, and resource availability of India and the US.

Multi-scale Concentrated Solar Power: To overcome critical science and engineering challenges for reliable multi-scale (including small 25–500 kW) CSP systems.

Solar Energy Integration: To identify and assess key technical, economic, environmental, and policy barriers, enabling a research agenda for technical readiness in India and to benefit the US.

CSTEP along with partner organisations will study solar PV and thermal technology status and identify the critical R&D gaps, highlight R&D priorities, analyse existing policy framework for solar energy in India and provide technical, economic, environmental policy analyses, prepare a report on resource assessment and technology roadmaps for PV and Concentrated Solar Power in India.

Addressing the Challenges to Renewable Energy Manufacturing in India: Horizon 2032

India has set ambitious targets envisaging a 15% renewable energy penetration in the national grid by 2020 in its National Action Plan on Climate Change. It is clear that at the national level solar and wind resources offer the largest potential for future Renewable Energy based generation and hence a considerable scale-up can be expected in deployment of these technologies. Hence, it is necessary to explore indigenous manufacturing capabilities for both wind power and solar energy devices and components.

Hence the World Institute of Sustainable Energy (WISE), Pune and CSTEP have jointly initiated a project to analyse the entire value chain of wind power (onshore and offshore), solar power (Photovoltaic and Concentrated Solar Power) and corresponding storage (Battery and Molten Salt) technologies. CSTEP will focus on the solar side, while WISE will cover the wind power aspect.

The on-going study that estimates the indigenous manufacturing and import mix requirement helps in developing long term policy and regulations in solar and wind system and components manufacturing and establishes a roadmap for scaling up renewable energy technology.

CSTEP is currently examining the existing manufacturing base for solar energy in India and will evaluate the economic viability for scaling up indigenous manufacturing base. A database of component level manufacturers in the solar manufacturing value chain is being established. While identifying manufacturers, the competitive advantage of imports and indigenous manufacturing for the Indian solar industry will also be examined.

With the available knowledgebase on solar energy, researchers have analysed the challenges in terms of materials, technology, and manufacturing process of solar PV, thermal and storage technologies. A crucial step in analysing the supply chain of each component was to categorise the primary components of each system into sub-components which were further classified into core, customized and common elements.

The analysis was conducted for PV – Monocrystalline Si, Amorphous Si and CdTe, Solar Thermal - Parabolic Trough and Solar Tower and Storage - NaS battery and Molten Salt storage technologies.

This study will provide phase-wise recommendations on technology development, policy and regulations to meet future demand and suggest approaches to overcome challenges to scale up solar manufacturing in India for 2032 timeframe.

Nuclear Power

Nuclear power is a vital constituent of India's future energy mix. India's present nuclear power (installed capacity) is 4,780 MW, which contributes about3% of the total electricity. The country's plan to commission six new pressurised heavy water reactors (PHWRs) each of 700 MW capacity, two 1,000 MW light water reactors and a Prototype 500 MW Fast Breeder Reactor (FBR) is expected to increase India's nuclear power capability to 20,000 MW by 2020.

Studies on nuclear power focus on the socio-economic acceptability and technical viability of nuclear power in India. A recent study examined the option of rapid development of fast breeder programme in India. The study also proposed the possibility of importing weapons dismantled surplus plutonium (Pu) on a commercial basis under international safeguards to accelerate India's fast reactor programme.

The team at CSTEP analysed the possibility of using global plutonium stockpile and reprocessing facilities to accelerate India's civilian nuclear power programme and meet its growing energy need. Researchers suggested that import of Pu will help India meet its growing energy requirements by building a large number of FBRs and pave way for eventual utilisation of Thorium for India's energy security. Simultaneously it helps to eliminate weapons grade Pu which is a source of considerable risk and concern to the global community.

Wind Power

Re-assessment of On-shore Wind Power Potential in Karnataka and Andhra Pradesh

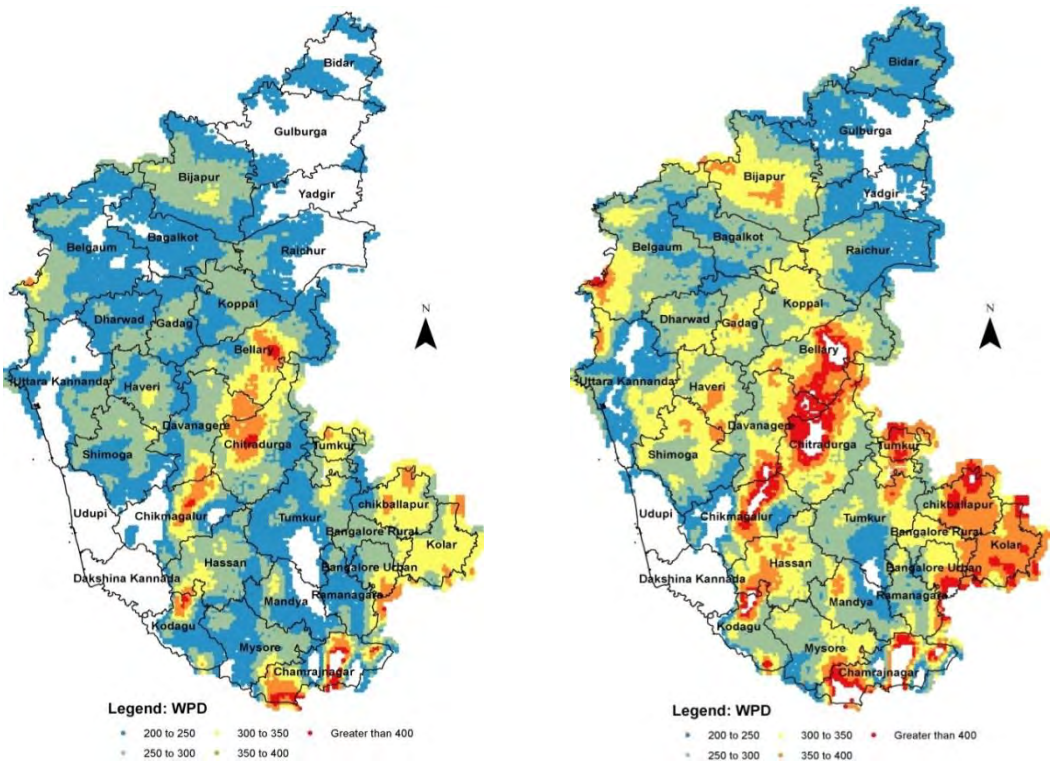
India's wind power installed recently has a capacity of around 18 GW with an estimated potential of 102 GW at 80 m hub height. However, several recent studies in the public domain have indicated that the wind power potential is underestimated.

In the wake of revised estimates for India, CSTEP took-up a study to re-assess the potential of on-shore wind energy in the states of Karnataka and Andhra Pradesh, which account for more than one-fourth of the wind potential in the country.

The current installed capacity of wind power in Karnataka and Andhra Pradesh is 2,143 MW and 248 MW respectively. These states have projects planned for an additional 7,000 MW and 2,000 MW of wind power respectively.

CSTEP undertook a GIS-based assessment of wind energy potential at higher hub heights of 80,100, and 120 m, on various land types such as agricultural land, waste land and scrub-forest land for Karnataka and Andhra Pradesh. Aspects related to cost of generation of wind power, implications of resource intermittency on the operation of the grid, storage options, levelised cost of energy and resultant policy implications were analysed. These reassessments reflect technology advancements that allow wind turbine installations at hub heights of 80-120 m. The current global trend is also to install more powerful wind power generators with name plate capacities of 1-4 MW.

A report discussing the potential assessment, costs and grid implications for these two states will be released in the coming year.



Locations with Wind Power Density > 200 W/m2 at 100m hub height and 120m height for Karnataka

Framework for National Wind Mission

Wind Power did not attract attention as a major contributor to India's energy mix even with India installing about 18,000 MW with an overall potential estimated at only 50,000 MW. This coupled with the associated intermittency challenges made wind a difficult energy source to deal with. As a result, the wind power generation had not grown significantly in recent years. However, the renewed potential estimates 102 GW for India has given some impetus to this industry.

This study initiated recently aims to develop a case for a National Wind Mission, to provide the necessary policy thrust for large scale wind power development in India. As part of the study, CSTEP will develop a country-wide zonal assessment of high potential regions, land-use policies in various States, transmission infrastructure, storage at policy level, manufacturing and indigenisation capabilities, and analyse Central and State policies for incentivising development of Wind power.

A framework identifying all concerns and gaps in existing policies will be analysed enabling a roadmap to be rolled out to align with other existing renewable energy missions such as the National Solar Mission.

Decision Support Tools

"The computational medium is the experimental substrate on which we build and experiment with multi-scale models and their interactions that arise in the syntheses of technological possibilities and social needs for infrastructure…. "

Infrastructure

Development of infrastructure is vital for India's economic and social growth. CSTEP works with a theme that is inclusive and sustainable. The unifying theme in all the work is that each study uses innovative applications of theories from computing. The computational medium is the experimental substrate on which we build and experiment using multi-scale models and their interactions that arise in the synthesis of technological possibilities and social needs for infrastructure. The medium is used in relating to images, data, and ideas–along with simulations, with the goal of creating policy-related decision support tools.

Urban Poverty Survey

Continuing the project initiated in 2010 on Urban Poverty Survey, CSTEP analysed the links between shelter, mobility and the livelihood of the urban poor. The analysis focused on a comparison of the living conditions of core and peripheral slum dwellers. The core-periphery model helps us to understand how slum dwellers in inner city have better opportunities compared to their peripheral counterparts.

The project illustrates the process of redevelopment and the living conditions of two slums. One was demolished from GoriPallya and later moved to Hosbalunagar, beyond Jalahalli (relocated/rehabilitated) and another Tank Mohalla, which was rebuilt in the same place (in situ). This analysis is based through fieldwork and interviews done in both the areas, to understand the two types of redevelopment of slums.

The analysis provides insights into understanding patterns that help to design sustainable and democratic policy alternatives.

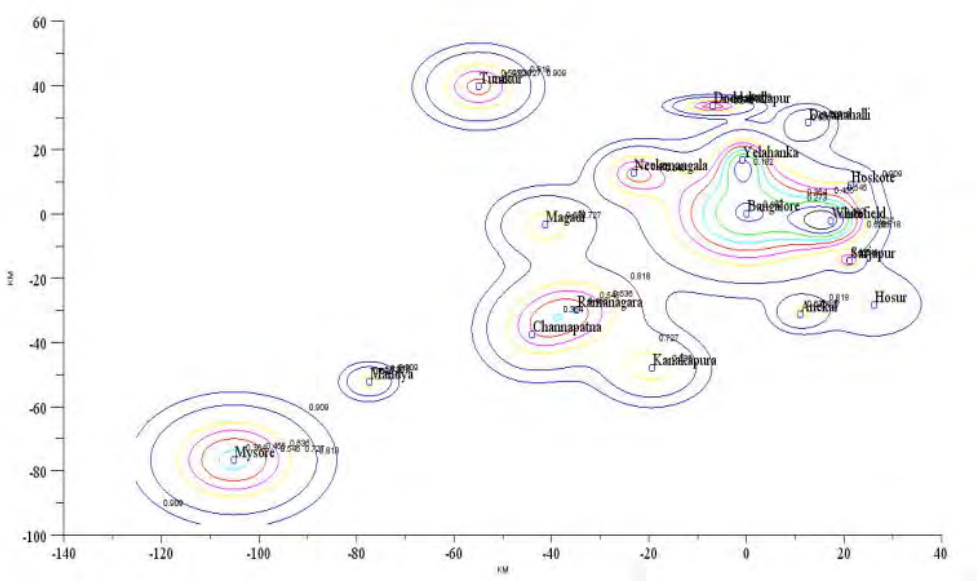
Saving Cities, Building Towns

Continuing the project initiated in 2010, CSTEP studied the need for integration, revitalisation and renewal of the smaller towns and cities to make urbanisation sustainable.

The report outlines major patterns and trends in urbanisation and urban growth in India, highlighting the State of Karnataka where the primacy of Bangalore overshadows the development of all other cities in the State. It examines the role of strategising urban population growth, understanding the effects of land use conflicts that pose major challenges to local and regional ecosystems.

In this context an approach to regional planning and also strategies for sustainable development has been suggested. The report also suggests strategies for integrated socio-economic, and infrastructure strategies for Ramanagaram, the silk city.

The approach and the strategies are holistic and thus can be replicated for other cities and regions.



Interlinking the cities for better planning

Scenarios: Shaping India's Future

The Planning Commission felt that India needs to develop a new methodology to accelerate more inclusive, more sustainable, and faster growth than what was planned earlier.

With this view the Planning Commission, Government of India undertook a review of its purpose and performance. The Planning Commission interfaced with close to 1,000 civil society organisations, industries, policymakers and research organisations and undertook an extensive exercise to prepare alternative scenarios of India's future. These discussions led to the identification of several major forces, which are likely to impact India's future.

The Planning Commission and CSTEP developed systems dynamics models to provide a rigorous grounding for interaction of these forces and develop plausible future scenarios. The forces identified included aspirations of citizens, demographics, democracy and its institutions, resource availability and uses, science and technology breakthroughs, innovations in business models, information-communication revolution and global and regional security threat.

A systems approach generated numerous alternative scenarios and three were considered. In one, the country muddles along. The system cries for reform and we initiate some reforms. However, these are piecemeal. The centralised governance and big business continue to dominate leading to growing impatience and unrest.

In the second scenario, the country remains stuck in centralised governance and exerts control in the face of demands for devolution, with mega schemes and projects and by redistribution of wealth through subsidies. The resulting impatience and protest and political logjam put us under severe stress, risking the falling apart of the political union itself.

Finally, there is a scenario where the flotilla advances, where the federal governance system encourages local governance institutions and small enterprises, creating livelihood opportunities with efficient and equitable utilisation of resources.

The scenarios explain the consequences of our choices and the policy options we have.

This work forms a part of Planning Commission's 12thPlan document 'Scenarios: Shaping India's Future'.

Materials Research

Li ion Battery Research

The battery research at CSTEP is aimed at predicting new battery materials utilising multi-scale (atomistic–nano-meso - macro) material modelling and data mining methods with possible application in alternate clean technology areas.

The two main requirements of a battery are to store large amount of energy and deliver high power. Our research encompasses both these aspects. While our search for cathode materials with high voltage can lead to higher energy density, lithium ion diffusion studies can lead to higher power. Artificial Neural Network (ANN) modelling, quantum mechanical Density Functional Theory (DFT), Molecular Dynamics (MD) and Nudged Elastic Band (NEB) are the simulation methodologies used.

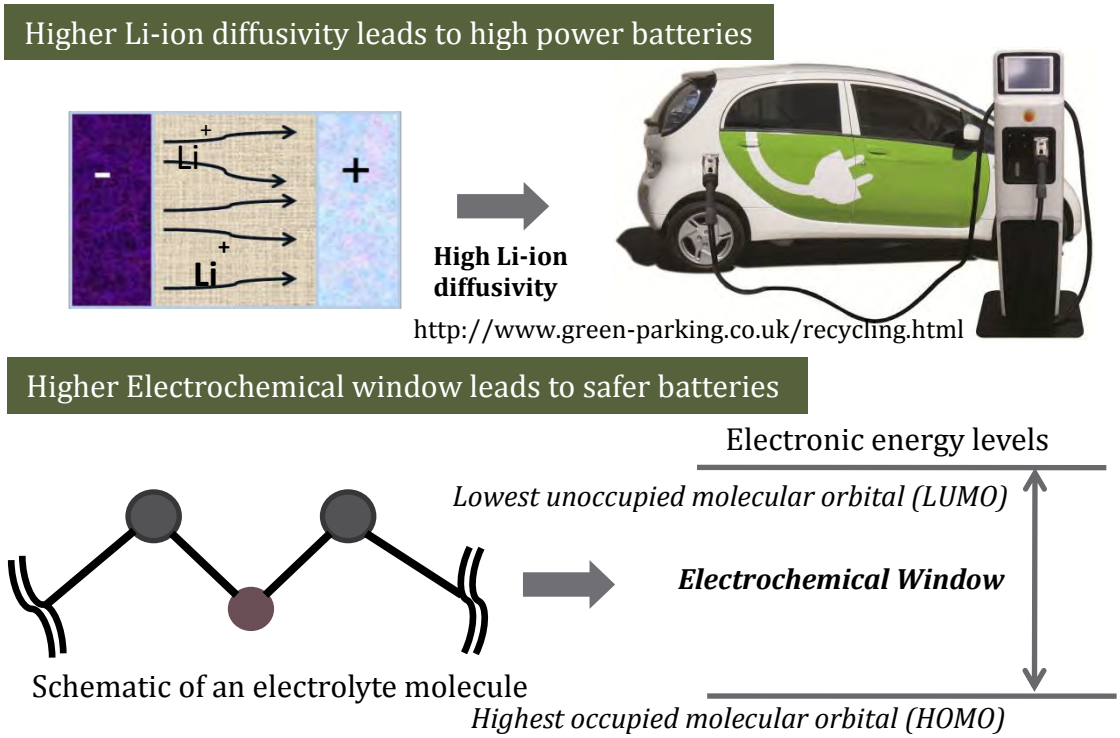
Transition metal oxides and phosphates of lithium (Li) are high performing cathode materials for Li ion battery. With the goal to further improve the performance of these compounds, we studied systems resulting from modifying their chemistries. For example, our simulations showed that while Aluminium substitution increased the voltage of $LiCoO_2$, it reduced it in case of $LiFePO_4$ and $LiCoPO_4$. Further, covalency of transition metal – oxygen bond was seen to play a key role in determining battery voltage. With a number of similar calculations (of chemistries resulting by metal ion substitution), we determined the electronic origin of changes in voltages. Our findings provided a platform for a rational design of cathode materials in Li batteries with enhanced voltages. Other calculations include topological analysis of electronic charge density in lithiated and delithiated forms of olivine phosphates ($LiMPO_4$); an important class of materials for cathode in Li batteries used in electric vehicles.

The group has also contributed to developing computational tools. We developed a method of using Artificial Neural

New Battery Materials

"Transition metal oxides and phosphates of lithium are high performing cathode materials for Li-ion battery. With the goal to further improve the performance of these compounds, we studied systems resulting from modifying their chemistries...."

Network techniques for predicting electrochemical potential (voltage) of cathode materials in combination with first-principles based quantum mechanical calculations. The proposed method can be used to predict the lithium ion battery voltage if a new material is chosen as cathode.



Graphical representation of Li ion battery Application

Rare Earth Elements and Energy Critical Elements

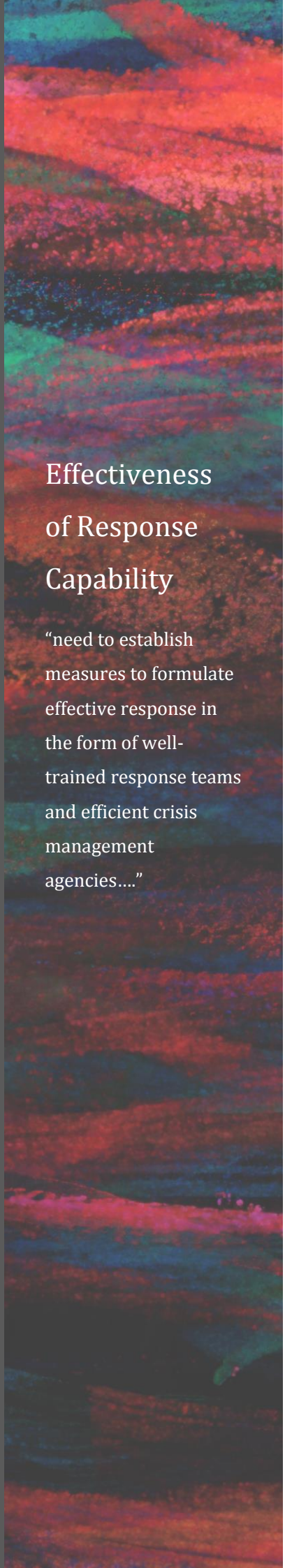
Rare Earth Elements (REEs) and Energy Critical Elements (ECEs) are extensively used in clean energy applications such as wind energy turbines, hybrid car batteries/electric motors, solar energy collectors, and defence-related systems. There is a need for development of an appropriate strategy for their indigenous production, based on the analysis of availability, identification, exploration and discovery of economically extractable deposits in India.

In view of increased demand for REE and near monopoly of supply from China, there is a need to develop national policies and implementation strategies for ensuring the indigenous supply of REE.

Hence, the Ministry of Mines, Government of India, formed a Steering Committee to formulate a strategy for the government to provide short, medium and long term options along with proposals for specific policy and legislative interventions. In association with CSTEP, an initiative was taken to review the status of availability of REEs and ECEs with regard to their exploration, extraction and processing technologies.

CSTEP and Centre for Techno-Economic Mineral Policy Options prepared a position paper on:

- current status of REE and ECE like gallium, indium, germanium, selenium, lithium etc.
- identified their industrial and strategic applications
- reviewed sources of supply, economics, supply chain etc.
- developed strategies for intensifying exploration
- identified techno-economic issues
- made recommendations on restarting domestic REE/ECE production, examining extraction processes, creation of process R&D facilities to develop extraction and recovery processes on an on-going basis to meet actual needs in specific situations.



Effectiveness of Response Capability

"need to establish measures to formulate effective response in the form of well-trained response teams and efficient crisis management agencies…."

Security Studies

There have been a number of incidents such as floods in Mumbai, Delhi, and North Karnataka, fire accidents in Bangalore, Mumbai and Kolkata etc. Incidents of blasts or shooting in crowded areas have plagued urban centres. This highlights a need to establish measures to formulate effective response in the form of well-trained response teams, efficient crisis management agencies and also measure the effectiveness of the response capability. These measures or indicators will aid in re-organising and restructuring of units to aid better in responding during future incidents. Also, using these indicators for training exercises will help in comparing incidents among a number of teams.

The Security Studies group has continued its work on examining technologies and policies affecting (a) management of large scale disasters, (b) development of a platform for modelling, analysing and training personnel for the effective management of emergencies/disasters and (c) development of a platform for analysis of Chemical, Biological, Radioactive and Nuclear (CBRN) incidents.

Simulation and Planning of Emergency Management Systems II (SIMPLANEMS II)

Following the Mumbai terror attacks, CSTEP researchers envisioned the development of a platform for modelling the scale and scope of disasters along with institutional and resource arrangements. Continuing from the first phase (wherein a disaster in an urban location was simulated and emergency response was evaluated), the platform was further enhanced to incorporate different components, including training for various individual departments.

In its most current form, the platform is a virtual environment in which one can:

(a) Test and evaluate different institutional arrangements, procedures, and policies

(b) Develop games for training purposes.

For example, one of the scenarios examined in the project was related to a fire incident in a public structure (a mall in Bangalore). The responding agents being considered for the incident were: Fire Brigade, Bangalore City Police, Hospital and Ambulance Services, and Security Personnel at the mall. One important output was a process by which 3D walk-through capabilities could be developed from 2D building plans. These help first responders with better situation awareness within unknown buildings. Another system developed was a web-based tool that used Bangalore city roads as a network for dispatching various types of emergency vehicles from multiple locations, keeping in mind constraints different types of emergency vehicles (based on characteristics like size and weight) and ability of those vehicles to ply on different types of roads.

A computer based procedural exercises to train emergency response personnel has also been developed. These are useful for activities where personnel must follow Standard Operating Procedures (SOPs). Some of the examples created are as follows:

(a) Triage Exercise: Triage is the process of determining the priority of a victim's treatment based on the severity of the victim's condition. It enables trainee responders to become more focused and accurate in their jobs. Given a description (including minimum relevant medical parameters) of the victim, a trainee analyses and tags each casualty with a coloured tag based on the victim's state. The evaluation of trainee's performance is based on accuracy of tagging and time taken to tag each casualty.

(b) CPR Gamedeals with Cardio-Pulmonary Resuscitation, which is indicated for those who are unresponsive with no breathing or abnormal breathing. It is a checklist based game where the user has to select the right options. Their responses (or actions) are evaluated at each stage and incorrect answers won't allow them to progress further. The game was developed using the e-Adventure game engine.

(c) Coordination Protocol Exercise [CPE]: This is a computer based exercise to study/test communication structures, hierarchy, policies and SOPs of emergency response personnel. This exercise was developed on a web-based system to administer and execute network enabled devices.

These tools have been demonstrated to emergency teams and security personnel at the Institute of Nuclear Medicine and Allied Sciences of the Defence Research and Development Organisation.

Process of an emergency management system

Analysis of Large Scale Emergency Incidents

CSTEP has developed a basic tool to assist decision makers in assessing the extent of damage and identifying the vulnerable areas for large scale incidents such as floods, industrial fires or chemical leaks. The prototype developed on a web-based platform uses Geographical Information System (GIS) tools for analysis.

This system can be used during preparation for response to an emergency. It will help the user understand asset availability (i.e. a form of situational awareness of the problem), by executing simulations of incidents and viewing results of the same on a map and in a tabular format.

This can assist the decision makers in assessing the extent of damage and identifying vulnerable areas and possible mitigation strategies. Assets defined in the system include facilities that are used in response to the emergency like open spaces, hospitals, shelters, police stations, fire stations, schools etc.

Chemical Biological Radioactive and Nuclear Studies

Chemical, Biological, Radioactive and Nuclear (CBRN) weapons are considered as weapons of mass destruction and disruption. A comprehensive CBRN disaster management system, to be fully effective in response, must consider all four phases of emergency management: Mitigation, Preparedness, Response and Recovery. Therefore, understanding the impact and effects of a CBRN event is essential to the creation of an effective response system.

A computation and visualisation intensive system that considers factors like disaster intensity, climate, weather, heat index, population density etc. and simulate representation of a CBRN event would be very useful in all of the phases mentioned above. CSTEP has prepared an outline for the development of such a system.

This includes identification of relevant mathematical models and testing the relevance and validity of these models. This has in turn identified possible gaps in the current understanding of such incidents. The challenges associated with development of a real-time response system have also been discussed.

DARPAN

Decision-Analysis for Research and Planning (DARPAN), a high power computing platform where numerous energy scenarios can be modelled to explore the impact on India's economy, environment and security, is being developed at CSTEP. It will potentially aid in formulating India's long term energy strategies and exploring the feasibility of renewable energy integration.

Towards the development of DARPAN, CSTEP has developed a Proof of Concept (PoC) tool and explored problems in integrated urban transport planning and wind power generation for Karnataka. The transportation problem examined high speed rail and expressways for intercity connectivity and covered aspects of mobility, population coverage, environment-friendliness, energy needs and land requirements. The wind energy problem considered aspects related to seasonal and daily variability of wind power, changing load, land availability, proximity to the grid and regulations associated with power tariff.

CSTEP's Demo of DARPAN at Planning Commission on October 17, 2012

When fully developed, DARPAN will assist in the:

a) Analysis of various urban transport strategies, reviewing alternatives and their impact

b) Review of alternate strategies

c) Exam the impact of strategies on different sustainability indicators

d) Visualise the implications from a decision makers' perspective.

e) Compare different scenarios.

The final output generated will be available to the decision maker/s through an easily accessible interface.

Events

Meeting of South Asian Thinks Tanks in Mysore

The participants at the Meeting of South Asian Thinks Tanks in Mysore

CSTEP hosted the second meeting of the International Development Research Centre's (IDRC) Think Tank Initiative from March 4-6, 2012 in Mysore. This meeting brought together 16 leading think tank representatives from Bangladesh, India, Nepal, Pakistan and Sri Lanka along with IDRC, Gates Foundation and UK-DFID. Among them were distinguished speakers, Dr. Kirit Parikh, Founder Director of Indira Gandhi Institute of Development Research and Dr. Debapriya Bhattacharya Distinguished Fellow at the Centre for Policy Dialogue.

The participants discussed a range of issues such as: think tank's role in society, research quality, impact in policy, balance between autonomy and policy engagement, identifying measures of success, organisational evaluation and opportunities to strengthen governance and research capacity.

Release of report on "Study of Energy Efficiency in the Indian Cement Industry"

Mr Kapil Mohan, IAS, (third from left) releasing the report on 'Study of Energy Efficiency in the Indian Cement Industry"

CSTEP released a report on "Study of Energy Efficiency in the Indian Cement Industry" on March 13, 2012. Mr Kapil Mohan, IAS, Managing Director, Krishna BhagyaJala Nigam Limited released the report and stressed the need for energy efficiency in all the aspects of economy in energy intensive manufacturing areas. Dr V S Arunachalam, Chairman CSTEP, emphasised the need for energy efficiency and reduction in green-house gas emissions in a growing economy.

Dr Anshu Bharadwaj, Executive Director, CSTEP, welcomed the participants and elaborated on the contents of the report. Dr S S Krishnan, Principal Research Scientist, CSTEP, who led this study, gave a detailed presentation on energy efficiency technology and policy options in cement manufacturing industries and provided insights for the industry and policymakers.

Mr. Saurabh Diddi, Energy Economist, Bureau of Energy Efficiency, chaired the technical session and provided clarifications to queries from the industry representatives. Mr Shashank Jain, Senior Programme Officer, Shakti Sustainable Energy Foundation, spoke on Energy Efficiency Options. Representatives from Cement Industries such as Ambuja Cements Ltd., Chettinad Cement, Ultra Tech Cement and Madras Cements participated in the workshop.

Lecture Series on "Mathematical Modelling for Public Policy"

Professor Benoit Morel from CMU during a lecture series at CSTEP

Professor Benoit Morel, Associate Teaching Professor, Engineering and Public Policy and Physics from Carnegie Melon University visited CSTEP from October 3 to November 9, 2012 to deliver a series of lectures on "Mathematical Modelling for Public Policy".

He has a wide range of interests and covered several topics on mathematical modelling. Prof. Morel provided CSTEP with a kit containing powerful tools to address problems in public policy. He gave lectures on Optimal Control Problems, Chaos Theory, Stochastic Process, Introduction to Dynamic System in Policy Analysis, Dynamic Programming and Uncertainty using mathematics as the base. He addressed problems of optimisation to exhaustible and renewable resources. He also showed how the former can be deployed optimally and what course the extraction of these resources should take. He discussed another model for making investments under conditions of uncertainty and to build portfolios. He also analysed climate changes using Nordhaus model and its variants. He talked about historic contributions made by the eminent researchers in all these fields which provided a physical perspective to the audience on these topics.

Round Table

The second Round Table on 'Measurement and Verification (M&V) Systems for India' was conducted by CSTEP in collaboration with Alliance for an Energy Efficient Economy on July 18. The theme of the event emphasised on the significance of energy conservation and programs such as M&V acting as an important tool in achieving the goal.

In-House Seminars

1. “Growth of semiconductor nanocrystals”, Priya Mahadevan Associate Professor, SN Bose National Center for Basic Sciences, Kolkata

2. “Informing federal, state and international policy on energy efficiency, smart grid and renewables through systems-analysis”, Priya Sreedharan, Senior Consultant, E3

3. “Lecture series on risk assessment and management”, Dr Henry Willis Associate Director, RAND Corporation, Pittsburgh, US

4. “Dealing with climate change: India's dilemma”, Prof. J. Srinivasan Chairman, Divecha Centre for Climate Change

5. "A framework for ethics in organisations", Shri. Ashok Vasudevan, Chief Executive officer, Tasty Bite, Pune

6. "Climate Change, Transport and Indian cities", Prof. Dinesh Mohan, Volvo Chair Professor Emeritus for Biomechanics and Transportation Safety IIT, Delhi

7. “Smart materials, micro systems and nanotechnology”, Dr Vasudev Aatre, Former Scientific Advisor to the Defence Minister

8. “Social merchant bank approach for energy access to the poor”, Mr Avinash Krishnamurthy, Chief Operating Officer, Small Scale Sustainable Infrastructure Development Fund

9. “Meeting urban governance challenges through public-private collaboration”, Mr V. Ravichandar, Founder, Chairman and Managing Director, Feedback Business Consulting Pvt. Ltd.

10. “Science and technology: Our final hour or our finest hour”, Dr Ronald F. Lehman, Director, Center for Global Security Research, Lawrence Livermore National Laboratory

11. “Aspects of 12thfive-year plan”, Dr ArunishChawla, Officer on Special Duty to Deputy Chairman of Planning Commission

12. “Nuclear Energy”, Dr Srikumar Banerjee, Homi Bhabha Chair at Bhabha Atomic Research Centre

13. “Technology for development – A gender perspective”, Svati Bhogle Founder, Promoter and Managing Director of Sustaintech India Private Limited

14. “Global trends in solar energy research”, Dr Larry Kazmersky, Executive Director for Science and Technology NREL, US

15. “Think tank initiative: Strengthening policy research”, Dr Samar Verma, Senior Program Officer for TTI, IDRC Regional office for South Asia, New Delhi

16. “Institution building: Role of values - Experience of IIM Ahmedabad”, Shri Prafull Anubhai, Chairman, Board of Management, Ahmedabad University

Visitors

- His Excellency M. K. Narayanan, Governor of West Bengal
- Shri Arun Maira, Member, Planning Commission, Government of India
- Shri S. V. Ranganath, IAS, Chief Secretary, Government of Karnataka
- Dr K. Kasturirangan, Member, Planning Commission, Government of India
- Dr Arunish Chawla, Officer on Special Duty to Deputy Chairman, Planning Commission, Government of India
- Dr Samar Verma, Senior Program Officer for Think Tank Initiative, IDRC Regional office for South Asia, New Delhi
- Dr Larry Kazmersky, Executive Director for Science and Technology, National Renewable Energy Laboratory, USA
- Dr George Perkovich, Vice President for Studies and Director, Nuclear Policy Program at Carnegie Endowment for International Peace, USA
- Dr Ronald Lehman, Director, Centre for Global Security Research at Lawrence Livermore National Laboratory, California, USA
- Dr Henry Willis, Associate Director, RAND Corporation, Pittsburgh
- Dr Srikumar Banerjee, Homi Bhabha Chair at Bhabha Atomic Research Centre, Mumbai
- Shri Kishan Dhawan, Chief Executive Officer, Shakti Sustainable Energy Foundation, New Delhi

Publications

Journal Articles

1. V. S. Arunachalam and Anshu Bharadwaj, "The global energy landscape and energy security", *In: Fundamentals of Materials for Energy and Environmental Sustainability (Eds.)* David S Ginley and David Cahen, MRS, Cambridge, University Press, 2012, pp. 26-35

2. Abhik Kumar Das and Jai Asundi, "A simple explicit model approximating the relationship between speed and density of vehicular traffic on urban roads," *Int. J. Critical Infrastructures*, 2012, Vol. 8, Nos. 2/3, pp. 195- 204

3. S. S. Krishnan, N. Balasubramanian and A. Murali Ramakrishnan, "Energy consumption and CO_2 emissions by the Indian mobile telecom industry", *International Journal of Critical Infrastructures,* 2012, Vol.8, No.2/3 pp.156 – 168

4. Shukla M. M. and Asundi J., "Considering emergency and disaster management systems from a software architecture perspective," *Int. J. System of Systems Engineering*, 2012 Vol. 3, No. 2, pp. 129-141

5. Asundi, Jai, Carare, Octavian and Dogan, Kutsal, "Competitive implications of software open-sourcing," *Decision Support Systems*, 2012, Vol. 54, Issue 1, pp.153-163

6. Robin A. King, Sujaya Rathi and H.S. Sudhira, "An approach to regional planning in India," *International Journal System of Systems Engineering*, 2012, Vol. 3, pp. 117-128

7. Abhik Kumar Das, "Analytical derivation of explicit J–V model of a solar cell from physics based implicit model", *Solar Energy*, 86(1) 2012, pp. 26-30

8. Abhik Kumar Das and Jai Asundi, "Using the Gini index to measure the inequality in infrastructure services provided within an urban region", *Int. J. Critical Infrastructures*, 2012, Vol. 8, Nos. 2/3, pp.178-186

9. Niket Narang, Onkar Hoysala, Sagar Arlekar, Amar Chadgar and Jai Asundi, "Developing GIS tools for Planning, Mitigation and Preparedness for Large-Scale Emergencies and Disasters", *International Journal of System of Systems Engineering*, 2012 Vol. 3, No. 2, pp. 142-153

10. Ashish Verma, H.S. Sudhira, Sujaya Rathi, Robin King and Nibedita Dash, "Sustainable Urbanisation using High Speed Rail (HSR) in Karnataka, India", *Research in Transportation Economics*, 2013, Vol. 38, pp. 67-77

11. Jayanth R, Meijer, Sebastiaan and Robin King "Disentangling the complexity of India's agricultural sector" *APSTRACT*, 2012, Vol. 06, Numbers 1-2, pp. 35-42

12. Vivek Vaidyanathan and Robin A. King, "Institutional Analysis of Urban Transportation in Bangalore", *Int. J. System of Systems Engineering*, 2012, Vol. 3, No. 2, pp. 168-180

Newspaper and Magazine Articles

1. Samar Verma and Anshu Bharadwaj, "Why is India freezing out policy research?" *Business Standard*, February 19, 2012

2. Sagar Arlekar and Niket Narang, "Map-making with QGIS", *LINUX For You*, June 12, 2012

3. V. S. Arunachalam, "Agni, Mrs G's wish fulfilled: India's missile man", *Deccan Chronicle*, April 23, 2012

4. AnshuBharadwaj, S. Rajgopal and Debapriya Das, "Power hungry India needs nuke plants",*Deccan Chronicle*, October 10, 2012

5. Arun Maira, Shweta Srinivasan, Abhik Das and Anshu Bharadwaj, "Avoiding a policy stalemate", *Indian Express*, October 12, 2012

6. Anshu Bharadwaj, "Solar and wind power should complement conventional sources", *Deccan Herald*, October 17, 2012

7. V. S. Arunachalam, "Star war ready", *Deccan Chronicle*, December 30, 2012

8. Debapriya Das, S. Rajgopal, Anshu Bharadwaj, "To go nuke or not", *Deccan Chronicle*, December 31, 2012

Reports

1. S. S. Krishnan, Venkatesh Vunnam, P. Shyam Sunder, A. Murali Ramakrishnan and G. Ramakrishna "A Study of Energy Efficiency in the Indian Cement Industry", *CSTEP/E/1,* 2012

2. Anshu Bharadwaj, S. Rajgopal, L. V. Krishnan and K. C .Bellarmine "Economics of Fast Breeder Reactors – Indian Scenario", *CSTEP/E/2,* 2012

3. M. A. Ramaswamy, N. C. Thirumalai, N. S. Suresh, Badri S. Rao, "Review of Global Experience with CSP Technologies", *CSTEP/E/3,* 2012

4. M. A. Ramaswamy, Badri, S. Rao, N. C. Thirumalai, N. S. Suresh, "Estimation of Hourly Direct Normal Irradiance (DNI) for 22 Stations in India", *CSTEP/E/4,* 2012

5. M. A. Ramaswamy, N. C. Thirumalai, N. S. Suresh and Badri S. Rao, "Design Basis for Parabolic Trough CSP Plants"', *CSTEP/E/5*, 2012

6. “Scenarios: Shaping India's Future”, Chapter to 12thFive Year Plan, *CSTEP /NGI/1,* 2012

7. “Climate Change and Power Sector”, Chapters Submitted to 12thPlan Draft”, CSTEP/E/6, 2012

8. “Rare earths and energy critical elements - A Roadmap and Strategy for India”,’ *CSTEP/M/1,* 2012

9. M. A. Ramaswamy et al., “Engineering Economic Policy Analysis of Concentrated Solar Thermal Technologies for India”, *CSTEP/E/7*, 2012

Conference and Workshop Presentations

1. Arun Kumar and Arghya Bhowmik, Poster Presentation, “Transition Metal Oxides as Cathode Materials for Batteries: Structure, Stability and Substitution Effects”, at International Conference on Nanoscience and Technology, organised by International Advanced Research Center for Powder Metallurgy and New Materials, *Hyderabad*, January 20-23, 2012

2. Arun Kumar and Arghya Bhowmik, Poster Presentation, “Study of Olivine Phosphates as Battery Cathode Materials from First Principles”, at International Conference on Nanoscience and Technology, organised by International Advanced Research Center for Powder Metallurgy and New Materials, *Hyderabad*, January 20-23, 2012

3. Deepthi Swamy, Poster presentation on, “Modelling Real-time Urban Mobility from Anonymised GPS Vehicle Probes: A GIS-based Case Study for Cab Fleet in Bangalore, India”, at IUSSTF symposium on Indo-American Frontiers of Engineering, *Virginia, USA*, March 1-3, 2012

4. S .S. Krishnan and P. Shyam Sunder., “Integrating Low Carbon and Energy Efficiency Constraints in Sustainable Product Design”, at 22nd CIRP Design Conference, Indian Institute of Science, *Bangalore*, March 28-30, 2012

5. Abhik Kumar Das, “Determination of the Peak Power Voltage using Explicit PLM of an Illuminated Solar Cell”, at IEEE International Conference on Devices, Circuits and Systems, Coimbatore, *March* 15-16, 2012

6. Abhik Kumar Das, “A Simple Method for Determination of the Series Resistance of an Illuminated Solar Cell from Experimental Data”, at 4thInternational conference on Electronics Computer Technology (IEEE-ECECT), *Kanyakumari*, April, 6-8, 2012

7. Niket Narang, Abhik Das, Sagar Arlekar, Jai Asundi “Using GIS to Re-assess Urban Plans based on Changing Industrial Emissions”, at 4thInternational Conference on Electronics Computer Technology (IEE-ICECT), *Kanyakumari*, April, 6-8, 2012

8. S. S. Krishnan, A. Murali Ramakrishnan, V. Venkatesh, P. Shyam Sunder, G. Ramakrishna, “Plant Specific Energy Efficiency Modelling and Analysis of the Indian Cement Industry for Robust Policy Implementation”, at 53rdIEEE-IAS/PCA Cement Industry Technical Conference, *San Antonio*, May 14-17, 2012

9. Anshu Bharadwaj, 'Solar Power for India: A Road to Sustainability?' at The Rio+20, the UN Conference on Sustainable Development, *Rio de Janeiro, Brazil*, June 15-22, 2012

10. S. S. Krishnan and Saptak Ghosh, "Mapping of Waste Balance for Policy Analysis in India", at Waste To Energy Summit, *New Delhi*, July 9-10, 2012

11. Sujaya Rathi and Abhik Das, "An Empirical Geometric Model for City Expansion," at 12thconference on Intelligent Infrastructure, *Kolkata*, November 30- December 4, 2012

12. S. S. Krishnan and Shyam Sunder, "Workshop for Perform, Achieve & Trade scheme for Notified Designated Consumers in Karnataka," organised by Karnataka Renewable Development Limited and BEE*, Bangalore*, December 27, 2012

Participation in Conferences and Workshops

1. Vinay Kandagal, "COMSOL Workshop on Chemical Modelling," organised by COSMOL, *Bangalore*, February 17, 2012

2. Ranganathan P. and Arghya Bhowmik, "XE Tech Workshop on Multicore code Compilation", organised by Intel, *Bangalore*, February 24, 2012

3. Meera Sudhakar, "Low Emissions Development Strategies Global Partnership Collaboration in Action Workshop", organised by National Renewable Energy Laboratory, *London*, March 21-23, 2012

4. Tanmay Sarkar, "An Advanced School on Modelling Complex Oxides", organised by S. N. Bose National Centre for Basic Sciences, *Kolkata*, April 9-12, 2012

5. Deepthi Swamy, "GHG Accounting & Life Cycle Assessment with SimaPro", Training conducted by Simapro India Pvt. Ltd., *Bangalore*, May 10-11, 2012

6. Meera Sudhakar and Mohammed Saquib, "Off grid Solar Power", organised by Observer Research Foundation, *Mumbai*, July 14, 2012

7. Thirumalai N C, "R&D Conclave on New and Renewable Energy", organised by Ministry of New and Renewable Energy, *New Delhi*, August 9-10, 2012

8. Sharath Rao, Nihit Goel, Mohammed Sahil Ali and Shweta Srinivasan, "Financing Strategies for State Action Plans on Climate Change", at Indian Institute of Management, *Bangalore*, September 17, 2012

9. S S Krishnan, "Catalyzing an Era of Green Growth", at Asia Low Emission Development Strategies Forum, *Thailand*, September 18-21, 2012

10. Mohammed Saquib, H S Ramakrishna, Ritesh Jain, Bishal Madhab Majumdar, "Panel Discussion on Grid Stability", organised by Enzen Global, *Bangalore*, September 21, 2012

11. Sharath Rao, Nihit Goel, Mohammed Sahil Ali, Shweta Srinivasan, "Talk on Climate Change and India: Development, Politics and Governance", organised by Centre for Education and Documentation, *Bangalore*, September 26, 2012

12. Jai Asundi, "7th National frontiers of Engineering Symposium for Young Indian Engineers (7NatFOE)", at Indian Institute of Technology, *Guwahati*, October 12-14, 2012

13. Mridula Dixit, "Indo Swiss Symposium: Renewable Energies and Rational Energy End-Use," organised under Indo Swiss Joint Research Programme, *Switzerland*, October 23-25, 2012

14. Jai Asundi and Sagar Arlekar, Invited to, "Indo-German Workshop on Civil Security Research", at Indian Institute of Science, *Bangalore*, November 6-7, 2012

15. Sujaya Rathi, "626 Summit," organised by Quicksand Design Studio, *Gurgaon*, December 10-11, 2012

16. Saptak Gosh, Nihit Goel and Shweta Srinivasan, "Decentralisation and Rural Governance in India", organised by National Council of Applied Economic Research, *Alwar, Rajasthan*, December 17-20, 2012

17. Saptak Gosh, Nihit Goel and Shweta Srinivasan, "Stake Holder Consultation on: Draft of Phase II Policy for National solar Mission", organised by Vasudha Foundation, *New Delhi*, December 20, 2012

18. Meera Sudhakar and Mohammed Saquib, "Action Plan for Comprehensive Renewable Energy Development in Tamil Nadu: Launch of final report and GIS portal", organised by Global Wind Energy Council, *Chennai*, December 27, 2012

19. Mohammed Saquib and Abhijith Sastry, "GIS portal for RE Action Plan for Tamil Nadu", organised by World Institute of Sustainable Energy, *Chennai,* December 27, 2012

Collaborations

CSTEP has collaborated with the following institutes:

- Carnegie Mellon University, Pittsburgh, USA
- Centre for Artificial Intelligence and Robotics, DRDO, Bangalore
- Indian Institute of Science, Bangalore
- Institute for Nuclear Medicine & Allied Science, DRDO, New Delhi
- International Institute for Information Technology, Bangalore
- Lawrence Berkeley National Laboratory, USA
- Manipal University, Mangalore
- National Renewable Energy Laboratory, USA
- Naval Materials Research Laboratory, DRDO, Ambernath
- RAND Corporation, USA
- Shristi School of Art, Design and Technology, Bangalore
- SSN Research Centre, Chennai
- Technical University, Delft, Netherlands
- Wipro, Bangalore

Funding organisations

- Bureau of Energy Efficiency, Government of India
- Central Power Research Institute, Government of India
- Climate Works Foundation, USA
- Defence Research and Development Organisation
- Government of Andhra Pradesh
- Government of Karnataka
- International Development Research Centre, Canada
- Jamsetji Tata Trust, Mumbai
- Ministry of New and Renewable Energy, Government of India
- NarotamSekhsaria Foundation, Mumbai
- Next Generation Infrastructures Foundation, Netherlands
- OAK Foundation, Switzerland
- Planning Commission, Government of India
- Power Finance Corporation of India, Government of India
- Shakti Sustainable Energy Foundation, New Delhi
- SSN Trust, Chennai
- The World Bank

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