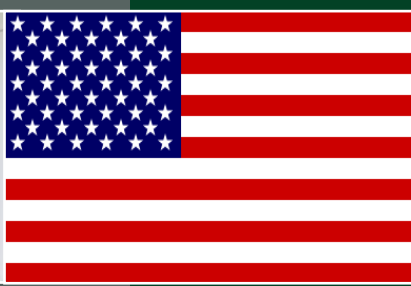
Indo-U.S. Joint Clean Energy Research and Development Center



A Status Report




सत्यमेव जयते

Ministry of Science and Technology
Government of India

Recognizing the need to address climate change, ensure mutual energy security, and build a clean energy economy that drives investment, job creation, and economic growth; Prime Minister Manmohan Singh and President Barack Obama launched the **U.S.-India Partnership to Advance Clean Energy (PACE)** under the U.S.-India Memorandum of Understanding to enhance cooperation on Energy Security, Energy Efficiency, Clean Energy and Climate Change. This MoU was signed on November 24, 2009 during Prime Minister Singh's visit to the United States.

As a priority initiative under the PACE umbrella, the U.S. Department of Energy (DOE) and the Government of India signed an agreement to establish the **Joint Clean Energy Research and Development Center (JCERDC)** on November 4, 2010 during President Obama's head of state visit to India. The JCERDC is designed to promote clean energy innovation by teams of scientists and engineers from India and the United States.

Joint Clean Energy Research and Development Center

OBJECTIVE

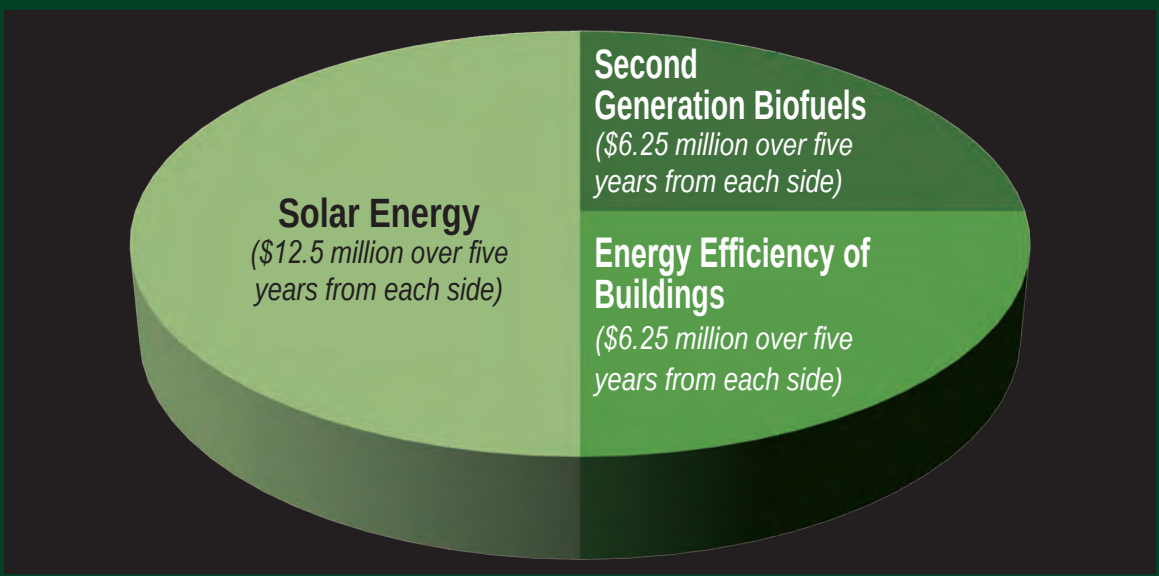
The overall aim of the JCERDC is to facilitate joint research and development on clean energy to improve energy access and promote low-carbon growth. To achieve this objective, the Indo-US JCERDC supports multi-institutional network projects using a public-private partnership model of funding.

FUNDING MECHANISM

	Total Contribution for 5 years	Total for 5 years
US Government *- Department of Energy (DOE)*	$ 25 million	**$ 100 million (or more)**
Indian Government *- Department of Science & Technology (DST)* *- Department of Biotechnology (DBT)*	Eqv. to $ 25 million	
The Consortia partners would contribute the matching amount or more		

The program is being administered in India by the Indo-U.S. Science and Technology Forum (IUSSTF).

PRIORITY AREAS AND GOVERNMENT FUNDING



MANAGEMENT MECHANISM

The Indo-U.S. Steering Committee on Clean Energy Science and Technology Cooperation is co-chaired by India's Deputy Chairman of the Planning Commission and the United States Secretary of Energy. This committee provides high-level review and guidance for the activities of the JCERDC. A Joint High-Level Experts Panel of twelve prominent private and public sector academic experts would provide the JCERDC with critical suggestions and insights and also act as an advisory body for the Steering Committee.In September 2013, Project Monitoring Committee (PMC) review meetings were held for all three consortia to monitor the first-year progress in conformity with the outputs, milestones, targets and objectives of the Project. The PMC for each consortium comprised of eminent experts from the relevant field and members of GOI/IUSSTF.

INTELLECTUAL PROPERTY MANAGEMENT

Intellectual Property Rights (IPR) are subject to Annex I- Intellectual Property (IPR Annex) of the Agreement on Science and Technology Cooperation between the Government of the United States of America and the Government of the Republic of India (S&T Agreement; 2005), the respective standard IPR provisions of the Parties and the project annexes of the participants to the extent it is not in contravention with the IPR annex and the associated IP framework allocation document.

INDIA-U.S. ENERGY DIALOGUE 2012

Shri B. K. Chaturvedi, Member, Planning Commission of India and Dr. Steven Chu, Secretary, U.S. Department of Energy (DoE), co-chaired the India-U.S. Energy Dialogue on September 28, 2012, in Washington DC. The U.S.-India Energy Dialogue was launched on May 31, 2005 to promote increased trade and investment in the energy sector, through identification of further areas of co-operation and collaboration, while actively working with both the public and private sectors. Five working groups have been set up under the initiative in areas, e.g., oil & gas, coal, power and energy efficiency, new technologies & renewable energy and civil-nuclear co-operation. The two sides lauded the successful implementation of the decision by Prime Minister Dr. Manmohan Singh and President Obama in November 2010 in Delhi to establish a "virtual" Joint Clean Energy Research

and Development Center (JCERD), which is the first bilateral initiative designed specifically to promote clean energy initiative by team of scientists from India and the United States, with a total joint committed funding from both Governments of US $ 50 million. The research consortia, which represent reputed science and technology institutions of both countries, made detailed presentations on their plans of action and research outcomes. Both sides expressed satisfaction at the progress made during the Dialogue process, including in the working groups and industry roundtable and re-iterated their respective commitments to continue the process of enhancing energy co-operation between the two nations.

Text Courtesy: Embassy of India, Washington D.C.
http://www.indianembassy.org/prdetail2033/press-release---us-india-energy-dialogue

Solar Energy Research Institute for India and U.S. (SERIIUS)

SERIIUS
Consortium Leadership

India	U.S
Co-Director Kamanio Chattopadhyay, IISc-Bangalore	**Co-Director** David Ginley, NREL
Deputy Managing Director Pradip Dutta, IISc-Bangalore	**Deputy Managing Director** William Tumas, NREL
Research Thrust Leaders	**Research Thrust Leaders**
Sustainable Photovoltaics Juzer Vasi, IIT- Bombay	**Sustainable Photovoltaics** Maikel Van Hest, NREL
Concentrated Solar Power Pradip Dutta, IISc-Bangalore	**Concentrated Solar Power** Subhash Shinde, SNL
Solar Energy Integration Anshu Bharadwaj, CSTEP-Bangalore	**Solar Energy Integration** Henry Wills, Rand Corporation

VISION AND GOALS

The vision of the Solar Energy Research Institute for India and the United States (SERIIUS), co-led by the Indian Institute of Science at Bangalore (IISc) and the National Renewable Energy Laboratory (NREL) at Golden, CO, is to create an environment for cooperation and innovation "without borders" to develop and ready emerging and revolutionary solar electricity technologies toward the long-term success of India's Jawaharlal Nehru National Solar Energy Mission and the U.S. DOE SunShot Initiative.

The overall goal of SERIIUS is to accelerate the development of solar electric technologies by lowering the cost per watt of photovoltaics (PV) and concentrated solar power (CSP) through a binational consortium that will innovate, discover, and ready emerging, disruptive, and revolutionary solar technologies that span the gap between fundamental science and applied R&D, leading to eventual deployment by sustainable industries. SERIIUS will address critical issues in fundamental and applied research, analysis and assessment, outreach, and workforce development. Throughout this joint effort, a key element is engaging a significant base of Indian and U.S. industry that is dedicated and committed to developing solar energy for both countries.

OBJECTIVES

- *Focus efforts on high-impact fundamental and applied R&D to create disruptive technologies in PV and CSP.*
- *Identify and quantify the critical technical, economic, and policy issues for solar energy development and deployment in India.*
- *Overcome barriers to technology transfer by teaming research institutions and industry in an effective project structure, cutting the time from discovery, to technology development and commercialization, through effective coordination, communication, and intellectual property management plans.*
- *Create a new platform for bi-national collaboration using a formalized R&D project structure, along with effective management, coordination, and decision processes.*
- *Create a sustainable network from which to build large collaborations and foster a collaborative culture and outreach programs, including the use of existing and new methodologies for collaboration based on advanced electronic and Web-based communication to facilitate functional international focused teams.*
- *Create a strong workforce development program in solar energy science and technology.*

Prof. Kamanio Chattopadhyay and Dr. Lawrence Kazmerski making a presentation on the project at the India-U.S. Energy Dialogue 2012

CONSORTIUM MANAGEMENT

SERIIUS has implemented an effective and efficient management plan overseen by highly experienced scientific leaders to enable high-impact R&D, as well as coordination and communication among diverse teams across the three research thrusts. The consortium has established a SERIIUS Council—comprising the directors, research thrust leaders, competency coordinators, and industry board members— to monitor, review, and recommend adjustments of technical activities.

The organization and management structure is designed to facilitate the successful execution of the SERIIUS vision, objectives, and strategy. The underlying fundamental principle is that all work and responsibilities are co-shared by individuals and organizations both in India and the United States. Empowered India-U.S. partnership is the culture of SERIIUS. The scientific leaders of SERIIUS are empowered by an energetic, leading-edge research and problem-solving environment within an organizational structure that assures that research is focused, flexible, and agile.

SERIIUS has an Executive Oversight Board composed of the leadership of the key organizations engaged in the consortium. This Board ensures that the consortium operations conform to the standards, ethics, legalities, and environmental, safety, and health quality of those organizations— as well as providing a commitment to excellence, cooperation, and facilities use from those key entities. SERIIUS governance has a strong management component (SERIIUS Council) within the central leadership framework that ensures conformity with the SERIIUS objectives and shared, transparent, and equitable decision-making. The Industry Board is composed of core industry partners to provide their expert guidance toward accelerated commercialization of relevant industry-driven research, and to establish and co-fund projects of interest directly. The Technical Advisory Board (TAB) of research authorities is the independent technical review and guidance arm of the Institute. During the first year, the TAB has been constituted and the first meeting between the TAB and the consortium leadership team has been held through webinar and teleconferencing.

SERIIUS Researchers at the National Solar Thermal Test Facility at Sandia National Laboratories

Research and development is organized under Research Thrusts, with cross cutting competencies under the Competency Gateway, both of which report directly to the Co- Directors. The research projects are coordinated by Project Leads, who are accountable to the Thrust Leaders.

COLLABORATIVE ASPECTS

The SERIIUS management plan has been developed and designed to encourage and facilitate partnering between Indian and U.S. institutions— from management and administration through the activities of the co-led research projects and cross-cutting competencies.

SERIIUS Web Gateway is now fully operational, providing information about the Consortium to the public, establishing a special and secure "Consortium Collaboration Tool" for sharing research information among SERIIUS partners, and social media links (Facebook and Twitter). Consortium communications have advanced with teleconference and videoconference schedules established for Leadership, Research Thrusts, and Research Projects. SERIIUS has also implemented a new teleconference structure where each thrust has either a teleconference or a videoconference twice a quarter. These events include both thrust leaders and all project leaders. Inter-SERIIUS-partner organization visits have also begun to blossom, and are key to ensuring research interactions, sharing of results, and fostering relationships.

SERIIUS has started developing a future work force through a Fellowship and Scholars Program that involves exchange of students and postdoctoral researchers among SERIIUS partners. The review team has chosen the first eight scholars and scholarships have been offered. Additional outreach programs includes an annual conference along with focused workshops and short term courses. The first SERIIUS annual conference is planned for April 2014.

KEY DELIVERABLES

- *Sustainable Photovoltaics (PV) based on earth-abundant, available materials using novel process and processing technologies with performance potential comparable to or exceeding existing systems.*
  - *Non Silicon (CIGS, CZTS, Organic Photovoltaics etc.) Solar Cells materials and devices of efficiency greater than current state of art.*

India	U.S.
LEAD INSTITUTION **Indian Institute of Science, Bangalore**	**LEAD INSTITUTION** **National Renewable Energy Laboratory, Golden**
OTHER PARTNERS Indian Institute of Technology – Bombay (IITB); Center for the study of Science, Technology and Policy (CSTEP); International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI); Solar Energy Centre (MNRE); Indian Institute of Technology – Madras (IITM); Indian Association for the cultivation of Science (IACS)	**OTHER PARTNERS** RAND Corporation; Sandia National Laboratories (SNL) ; Lawrence Berkeley National Laboratory (LBNL); Arizona State University; Carnegie Mellon University; Colorado School of Mines ; Massachusetts Institute of Technology ; Purdue University; Stanford University; University of Central Florida (Florida Solar Energy Center); University of South Florida; Washington University-St. Louis
INDUSTRY PARTNERS Bharat Heavy Electricals Limited (BHEL); Clique Developments Ltd ; Hindustan Petroleum Corp. Ltd; Moserbaer Ltd; Thermax Ltd; TurboTech Precision Engineering Ltd; Wipro Ltd.; UL India Pvt. Ltd.	**INDUSTRY PARTNERS** Alpha (Cookson Electronics); Corning Incorporated; SunEdison, LLC; Solarmer Energy Inc.

- *Develop Solar grade Silicon and demonstrate 30% energy savings in production.*
- *Demonstrate efficiency >20% cell using Solar grade Silicon developed under the project.*

➢ *High-efficiency, scalable, distributable Multiscale Concentrated Solar Power (CSP) for high as well as moderate solar insolation areas in deviation from conventional steam based CSP, which are efficient only at large scales (>50 MW), and require high source temperature (high DNI).*

- *Development of distributed CSP (100 kW – 1 MW) for high solar insolation areas based on Supercritical CO_2 Brayton cycle having >50% cycle efficiency at relatively lower receiver temperature and (700-800°C) compared to air Brayton cycle, and pressure range of 70-200 bar.*
- *Organic Rankine Cycle (ORC) systems (25 kW-1 MW) for moderate solar insolation areas; including two stage scroll expansion to achieve efficiency> 70%: cost efficient parabolic trough solar collector for ORC systems with targets as cost of collector <Rs 5000/m^2; Optical efficiency >70%; Temperature of operation: 200°C to 230°C; and thermal loss <2%; Non-flammable and environmentally friendly organic fluid mixtures.*

➢ *Solar Energy Integration (SEI)*

- *Technology roadmaps, techno-economic and environmental analysis, and assessment reports.*
- *Solar-energy integration and storage analysis.*

ACHIEVEMENTS THUS FAR

Sustainable Photovoltaics

➢ *Initial development of a clear understanding of the dust and soiling problems in India and the development of a coatings-based mitigation strategy.*

➢ *Development of new polymers for DSSC and OPB based on starting molecule, computational analysis and initial device development.*

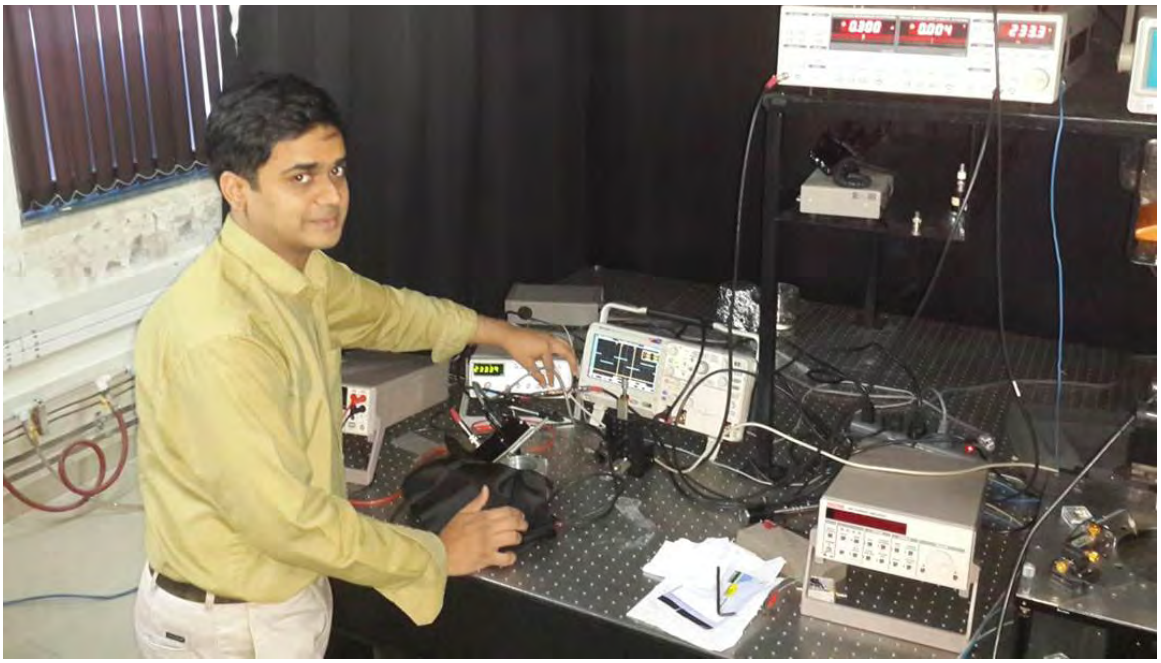
➢ *Initial CZTS electro-deposition showed correct phase formation without hydrazine.*

➢ *Developing a comprehensive database for reliability vs. climate across India to provide a basic understanding of failure modes and produce mitigation strategies.*

➢ *A- InZnO TCO with conductivity of 2100 S/cm from metal targets .*

➢ *EL electroluminescence technique develop -ment as a tool to evaluate HIT solar cells.*

➢ *Approach developed and tests on initial 1cm^2 and subsequent 25cm^2 samples were accomplished. Initial results were very promising that this could be an important basic diagnostic for HIT and other solar cells.*



Multi scale Concentrated Solar Power

- *Optimization of ORC and Supercritical CO_2-based cycles.*
- *Complete technical design of a research (laboratory scale) supercritical CO_2 test loop for closed Brayton cycle.*
- *Design of a tubular serpentine receiver; CFD model predicts efficiency of 74%.*
- *Development of a (Cu-Sn)-based novel hemispherical highly reflective intermetallic mirror material with > 93% reflectivity.*
- *Design of a laboratory scale molten-salt-loop system for high temperature storage in Brayton cycles.*
- *Optimization of scroll geometries for small-scale ORC.*

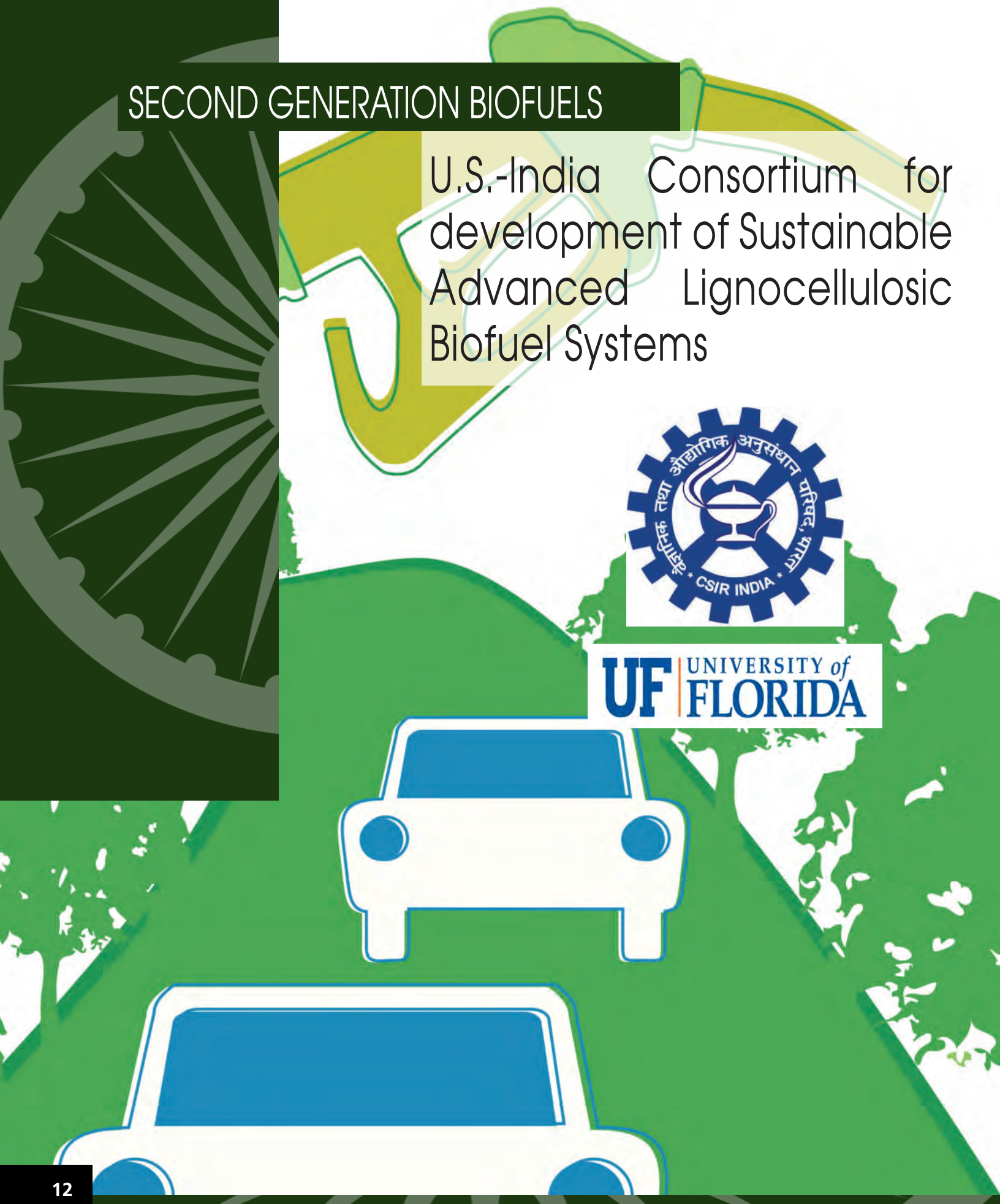
Solar Energy Integration

- *Developed Initial roadmap for solar power in India till 2032.*
- *Developed GIS enabled tool for resource and potential assessment for Karnataka as an illustration: Methodology developed to assess the potential of both CSP and PV.*
- *Developed open-source computational models with an intuitive graphic interface for use in assessment of Parabolic Trough Technology (made available through the SERIIUS website).*
- *Modeled energy storage requirements (including economic analysis) for the future Indian grid with significant renewable penetration.*
- *Prepared initial draft of the report -'Roadmap for Grid Scale Energy Storage for India'.*
- *Developed coupled solar PV- battery models for grid storage applications.*

for more details, please visit : http://www.seriius.org/

SECOND GENERATION BIOFUELS

U.S.-India Consortium for development of Sustainable Advanced Lignocellulosic Biofuel Systems



VISION AND GOALS

The Energy Independence and Security Act (EISA, 2007) mandates that the United States must use 21 billion gallons of second generation biofuels per year by 2022, while the National Biofuels Policy of India approved on December 24, 2009 proposes an indicative target of 20% blending of biofuels by 2017. This can be made possible with the sustainable production and use of biofuels from non-food based feedstock which can increase energy independence, reduce greenhouse gas (GHG) emissions, and promote healthier land-use while providing additional jobs and income to both rural American and Indian communities. In order to achieve the common goals on development of sustainable, replicable feedstock production, logistics, processing, and biofuels distribution systems in these two countries, a well-coordinated and synergistic approach is needed. The present project addresses this through the U.S.-India Consortium for development of Sustainable Advanced Lignocellulosic Biofuel Systems, emphasizing sustainable feedstock cultivation and supply, biochemical conversion technologies for production of second generation biofuels with minimal environmental impact, and analysis of overall sustainability and supply chain of feedstock.

The major goal of this project is to develop and optimize selected non-food biomass (high yielding biomass and bmr varieties of sorghum, sweet sorghum, pearl millet, bamboo and switch grass)-based advanced biofuels systems and bio-based products like biogas and lignin-based byproducts for the U.S. and India. The successful completion of the project is expected to benefit both nations by delivering a working model for feedstock production and supply, biochemical conversion approaches and technologies that have been validated on pre-commercial scale systems, and the overall economics and sustainability of biofuel production and supply systems.

CONSORTIUM OBJECTIVES

- *Improve feedstock (production potential and feedstock quality) using genomics and breeding tools and identify locally adapted cultivars and their optimization for large-scale production.*
- *Develop production logistics and identify soil and environmental criteria to ensure a commercially successful advanced feedstock production system.*
- *Development of biocatalysts for production of advanced biofuels and co-products and optimization of pretreatment and fermentation processes.*
- *Minimizing environmental impact and maximizing revenues from bio-refinery waste streams.*
- *Analysis and development of certification protocols and sustainability standards.*
- *Assessment of energy requirements and emissions.*
- *Supply chain management analysis.*

COLLABORATIVE ASPECTS

- *University of Missouri to provide technical help in feedstock matching.*
- *International Crops Research Institute for the Semi-Arid Tropics to exchange germplasm and also to provide technical help in developing new flood tolerant sorghum materials at the University of Missouri.*
- *Scale-up and process data from University of Florida cellulosic ethanol biorefinery will be available to the Indian consortium.*
- *University of Florida cellulosic biorefinery will be made available for Indian consortium for training purposes.*
- *The ethanol conversion technology of the University of Florida will be shared with the Indian consortium*
- *Development of an integrated bio-refinery with a focus on effluent treatment and by-product utilization.*

Consortia Partners

India	U.S.
LEAD INSTITUTION	**LEAD INSTITUTION**
Indian Institute of Chemical Technology, Hyderabad	**University of Florida, Gainesville**
OTHER PARTNERS	**OTHER PARTNERS**
International Crops Research Institute for the Semi-Arid Tropics- Hyderabad; Directorate of Sorghum Research-Hyderabad; Jawaharlal Nehru Technological University-Hyderabad; Tamil Nadu Agricultural University; Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya, Gwalior; Centre for Economic and Social Studies; Indian Institute of Technology-Delhi ; Indian Institute of Technology-Chennai	University of Missouri Virginia Tech Montclair State University Texas A&M University
INDUSTRY PARTNERS	**INDUSTRY PARTNERS**
Abellon Clean Energy Hindustan Petroleum Corporation Limited	Show Me Energy Green Technologies

- *U.S. Consortium members are providing technical help to Indian partners towards development of certification protocols and sustainability standards, energy and emission efficiency, supply chain management, and economic analyses to assess viability of advanced biofuels.*

MANAGEMENT

The Indo-U.S. Consortium for development of sustainable advanced lignocellulosic biofuel systems is being led by CSIR-Indian Institute of Chemical Technology (IICT), Hyderabad, India, which will be responsible for the smooth functioning of the project to achieve the targets with the help of a three-tier management system including an administrative setup, consortium leader and the individual partnering institutes. The administrative setup comprises of a Technical Advisory Committee (TAC) and a Project Steering Committee (PSC). The TAC would meet at least once a year (or more if required). The TAC will review the project work execution and render technical inputs to achieve the approved milestones and deliverables. The TAC members include Dr. C.L.L. Gowda (ICRISAT), Dr. B.D. Kulkarni (National Chemical Laboratory), Dr. Pankaj Patel (Abellon Clean Energy), Dr. B. Ramachandran (IIT-Madras) and Dr. K. Ramaswami (Tamil Nadu Agricultural University). The PSC members include Dr. C.L.L. Gowda (ICRISAT), Dr. B.D. Kulkarni (NCL), Dr. Pankaj Patel (Abellon Clean Energy) and Dr. P. Gunasekaran (Madurai Kamraj University). The PSC would meet once a year to review the overall progress and suggest suitable ways to meet the proposed milestones.

The Project Coordinator, Dr. Ahmed Kamal will coordinate the project implementation, while the task leads - Dr. P. Srinivasa Rao (Work Package 1), Dr. C Ganesh Kumar (Work Package 2), and Dr. Beena Patel (Work Package 3) will coordinate the execution of the respective Work Packages by closely interacting with the investigators. Each principal investigator would be responsible for meeting the deliverables/ milestones defined in their respective work package(s).

In the US consortium WP1 will be led by Dr. Shibu Jose (University of Missouri-Columbia), WP2 will be led by Dr. Pratap Pullammanappallil (University of Florida) and WP3 will be led by Dr. Janaki Alvalapati (Virginia Tech).

Participants of the Joint Project Meeting of the U.S.-India JCERDC for Development of Sustainable Advanced Lignocellulosic Biofuel Systems at the University of Florida, Gainesville

DELIVERABLES

- *Identify locally adapted high biomass abiotic stress tolerant sorghum, pearl millet and bamboo cultivars.*
- *Develop a low-input advanced feedstock production system.*
- *Optimize efficient pretreatment methods and identify biomass-based enzyme formulation for saccharification.*
- *Develop efficient fermentation processes for high ethanol and butanol recovery.*
- *Develop standardization and certification protocols and prepare energy, emission, economic analysis and supply chain management report for commercialization of lignocellulosic biofuel production.*

ACHIEVEMENTS THUS FAR

- *A total of 471 hybrids were produced by deploying A1, A2, A3, and A4 cytoplasmic male sterile systems and data analysis is in progress.*
- *The high biomass sorghum/pearl millet multi-location trials are being conducted at ICRISAT (2), DSR (1), UAS-R (2), ANGRAU (1), RVSKVV (4), Abellon (3) and TNAU (2).*
- *Multi-location trials for sorghum and pearl millet are currently in progress at Madhya Pradesh (Khargone, Dewas, Gwalior and Lahar); Gujarat (Modasa, Vithalapara, and Khus); Tamil Nadu (Coimbatore and Bhavanisagar); Karnataka (Gangavathi) and Andhra Pradesh (ICRISAT and DSR).*
- *The biomass composition analysis protocol for sorghum was standardized at ICRISAT.*
- *Farmer's days were organized to select farmers who preferred sorghum and pearl millet cultivars at Gwalior, Morena, Khargoan, Dewas (in MP), Modesa and Khas (in Gujarat).*
- *The biomass of promising HBM sorghum and pearl millet lines were supplied to WP2 partners.*
- *Protocols optimized for estimating cellulose, hemicellulose and lignin content.*
- *Screening of cultures for celluloytic and β-glucosidase enzymes has been carried out.*
- *Commercial cellulolytic enzymes have been procured from various sources and analyzed for their efficacy to hydrolyze pretreated biomass.*
- *Steam explosion protocol for pretreatment has been standardized.*
- *Baseline surveys in project target areas of MP and Gujarat has been completed.*

for more details, please visit : http://biofuels.ufl.edu/

U.S.-India Joint Centre for Building Energy Research and Development (CBERD)

CEPT UNIVERSITY
ज्ञानं विज्ञान सहितम्

BERKELEY LAB

VISION AND GOALS

India is an emerging giant with an expanding economy, and a quest for an improved quality of life. The commercial buildings and high-density residential construction industry is experiencing explosive growth. India will add approximately 700 to 900 million square meters of built floor space each year (McKinsey, 2010). The United States is one of the largest energy consumers in the world; with buildings accounting for over 70% of the nation's total electricity use. The potential for building energy savings in both nations is immense - studies have demonstrated that systems-level integration through innovative design and technologies can reduce energy consumption by at least 60% in new construction in India, and at least 10-30% in retrofits in the U.S. relative to local norms and practices. By drawing on the research and technological capabilities of the U.S. and India, substantial energy savings can be achieved.

OBJECTIVES

The U.S.-India Joint Centre for Building Energy Research and Development (CBERD) will conduct collaborative research and promote clean energy innovation in the area of energy efficiency in building with measurable results and significant reduction in energy use in both nations. CBERD will focus on the integration of information technology with building controls and physical systems for commercial/high-rise residential units.

The R&D tasks are intended for technology acceleration and include:

Building energy modeling and simulation
Monitoring and benchmarking of buildings
Communication and controls integration
Building envelope and passive design
Advanced HVAC (heating, ventilation, and air conditioning) and lighting technologies
Thermal comfort
Grid responsive buildings
Renewable energy source integration in buildings
Scientific collaboration between U.S. and India

This outcome-based R&D will result in significant energy savings by driving development of cost-effective technologies and their implementation across buildings. CBERD's vision is to build a foundation of collaborative knowledge, technologies, human capabilities, and relationships that position the U.S. and India for a future of high-performance buildings, with accelerated, measurable and significant energy use reduction. The focus on the highest growth sectors, i.e., commercial and high-rise multi-family buildings, targets primarily new construction in India and retrofits and operations in the U.S. While this will create the maximum impact, the results will have spill-over benefits to other building sectors. CBERD will draw from its partners' collaborative R&D and commercial experience to meet the goals of the JCERDC, aligning it to the vision of DOE (U.S. DOE Multi-year Plan, 2011–2015) and GOI (IPC, 2011) as well as to larger industry interests.

CBERD will gain an in-depth analysis of how buildings in India and the U.S. use energy, and create a Lifecycle Performance Assurance Framework (LPAF)that supports building system integration throughout the building's design, construction, and operation. The overall R&D strategy is structured and prioritized to provide guidance on the selection of key technologies and components for each major building system to meet the desired performance levels, and cost-effective solutions.

MANAGEMENT

Over the five-year project period, CBERD Consortia will provide core management support to achieve project objectives, consortium effectiveness and quality at every stage of technology development. The task will allow coordination of Consortia's expertise at different levels, which will help to guide R&D priorities over the five-year period. The management team will evaluate technologies and systems during each stage of the CBERD project to meet performance requirements to ensure R&D success through scientific collaboration and creating deployment pathways. Another goal is to provide oversight efficiently while optimizing management/travel costs. Both LBNL and CEPT have

Consortia Partners

India	U.S.
LEAD INSTITUTION	**LEAD INSTITUTION**
Center for Environmental Planning and Technology (CEPT) University, Ahmedabad	**Lawrence Berkeley National Laboratory, Berkeley**
OTHER PARTNERS	**OTHER PARTNERS**
International Institute of Information Technology, Hyderabad	Oak Ridge National Laboratory
Malaviya National Institute of Technology, Jaipur	University of California Berkeley
Indian Institute of Technology, Bombay	Carnegie Mellon University
Indian Institute of Management, Ahmedabad	Rensselaer Polytechnic Institute
Auroville Center for Scientific Research	**INDUSTRY PARTNERS**
INDUSTRY PARTNERS	Autodesk, Inc.
Asahi India Glass	California Energy Commission
Biodiversity Conservation India	Delphi
Infosys Technologies.	enLighted Inc.
Neosilica Technologies	Honeywell
Oorja Energy Engineering Services	Infosys Public Services
Paharpur Business Centre/Green Spaces	Ingersoll-Rand/Trane
PLUSS Polymers	Lighting Science Group Corp
Philips Electronics India	Nexant
Saint Gobain Corp	Saint Gobain Corp
Schneider Electric India	SAGE Electrochromics
Sintex Industries Limited	SynapSense
Skyshade Daylights	Bay Area Photovoltaic Consortium
Wipro EcoEnergy	City of San Jose
Glazing Society of India	HOK Architects
	Natural Resources Defense Council

formed joint CBERD Management Offices (CMOs) led by the CBERD Directors and Deputies (Principal and Co-Principal Investigators), and supported by the Project Directors (PDs) and CBERD Intellectual Property Offices (CIPO), to manage and coordinate a project of this scale in both countries. In particular this management task will focus on:

- *Communication with the U.S. Department of Energy (DOE) and Government of India (GOI) through the Indo–U.S. Science and Technology Forum (IUSSTF) for project updates, management, and reports (quarterly report to the DOE, semi-annual report to the GOI/IUSSTF, annual reports to both)*
- *Coordination with: a) R&D partners: review of partners' task performance and reports; b) Industry partners to facilitate R&D, technology transfer; c) the Project Advisory Board*
  - *Feedback from Advisory meetings/Partner meetings to review vision*
  - *Coordination for setup/events; schedule Advisory meetings/Partner meetings*
  - *IP management, technology transfer issues*
  - *Budgeting and tracking of expenditure*

COLLABORATIVE ASPECTS

- *The research topics selected address the key barriers to low energy buildings while providing synergism with the existing research efforts in both nations.*
- *CBERD has developed a highly coordinated team consisting of each nation's premiere energy efficiency experts.*
- *An unprecedented set of industrial partners*

and supporting organizations has committed to collaborate with CBERD to develop advanced building technologies to reduce energy consumption. The U.S. partners include Autodesk, Bay Area Photo -voltaic Consortium, ,California Energy Commission, Delphi, enLighted, HOK Architects, Honeywell,Ingersoll Rand / Trane,Lighting Research Center, Lighting Science, Nexant, Natural Resources Defense Council, Synapsense, and Weidt Group. The India partners include Asahi India Glass, Biodiversity Conservation India, Confederation of Indian Industry– Sohrabji Godrej Green Business Center, Glazing Society of India, Indian Society of Heating Refrigerating and Air-conditioning Engineers, Indian Society of Lighting Engineers, Neosilica Technologies, Oorja Energy Engineering Services, PBC Ventures, Philips, Pluss Polymers, Rajasthan Electronics and Instruments Limited, Schneider, Sintex, Skyshade Daylights, and Wipro EcoEnergy. Infosys and Saint Gobain will collaborate in both nations. This deep level of collaboration with industry and other key collaborators will amplify and accelerate advanced building technologies available to the commercial building markets in both nations.

Fieldwork at Malaviya National Institute of Technology Jaipur

- *CBERD-partners in the U.S. and India are all well positioned to transfer results to key building stakeholders in the U.S. and India through existing relationships, on-going projects, and strong ties.*
- *Both LBNL and CEPT, and their partners maintain strong, long-standing connections to U.S. and India energy-efficiency programs through on-going activities, and training and deployment forums.*

KEY DELIVERABLES

- *Lifecycle Performance Assurance Framework (LPAF) of Buildings: Holistic Decision Support System to assess and optimise performance of building in terms of comfort/ service level as well as energy efficiency throughout building design, construction and operation through predicting, measuring, tracking and benchmarking by feedback loop.*
- *Customizable R&D Suite for climate diversity: Strategy options based on occupant needs, weather, local materials used, prevailing codes, regional/ localized building practices and integrating innovative cooling and daylight/ lighting technologies etc.*
- *Tools for enhanced compliance of building standards and Codes: Sound and implementable design specifications benchmarked based on measured data and development of decision tools, algorithms and best practice guide.*
- *Test bed facilities for building efficiency R&D: Continuously develop, design and*

Window testing being conducted at CEPT University-Ahmedabad

demonstrate concepts to promote high efficiency buildings as well as educate and train building stakeholders.

ACHIEVEMENTS THUS FAR

- *Construction of database of building materials including external insulation finishing systems. Establishment of Building material hygro thermal characterization facility.*
- *Database of Cool Roof products along with its characterization and testing. Onsite performance testing of cool roof technology.*
- *Specifications for next generation benchmarking of energy efficient commercial buildings. Energy Performance Index for Hospital and Hotel building types.*
- *Detailed design specification for natural ventilation systems. Implementation ready energy code rule set for automated compliance.*
- *Prototype for Smart Light Fitting Controller based on occupancy, a dynamic window communication system for varying natural light and next generation power strips capable of sensing the equipment connected has been developed.*
- *Development of an online window and fenestration design assessment tool, COMFEN India for architects and engineers. Indian glass database is now part of the International glass database.*
- *Development of solution for monitoring the refrigerant charge in Air Conditioning (AC) systems. Performance evaluation and design guidelines for Earth Air Tunnel Passive cooling system.*
- *Cost benefits assessment of LED lighting systems with other traditional lighting systems.*
- *Performance evaluation of passive building design and construction technology along with design and development of online thermal comfort satisfaction tool contextualized for Indian settings.*

Research Gaps or Critical Barriers	Project Objectives	CBERD Methodologies
Research and Development Innovation		
Lack of building systems integration throughout the design, construction, and operation processes	Evaluate and optimize the integration of building systems using the whole-building approach across the building lifecycle to advance high-performance buildings	Develop a Lifecycle Performance Assurance Framework that stakeholders can use to ensure optimal integration of building IT systems with building physical systems through a building's lifecycle
Lack of specific energy efficiency solutions that will apply to diverse building types	Formulate Building EE R&D strategies targeted to the wide diversity of building types in the commercial including new construction and retrofits	Conduct research and develop guidelines and best practices for building prototypes
Lack of efficiency technologies and applications customized for regional application	Develop a suite of R&D strategies customized for U.S. and Indian applications to help leapfrog transitional technologies while developing and advancing appropriate regional and local low-energy practices and technologies	Develop bilateral transfer of technologies and products between the U.S. and India to help speed the development of regional practices normalized to weather, materials-construction techniques, systems and occupant comfort
Lack of universally accepted, standardized processes for achieving building energy performance targets for technology R&D	Enhance pathways to meet or exceed building standards and codes through decision tools, design specification algorithms, and best practices that are supported by measured data	Establish milestone-driven, short-term, tangible results and long-term goals using comprehensible, actionable data from emerging technologies and their integration
Team Innovation		
Building energy researcher, designer, and developer knowledge limitations in the U.S. and India	Boost the knowledge and capability levels of building energy stakeholders through documentation, education/ training, and demonstration	Facilitate and enable collaboration and information exchange among key academic and research institutes to disseminate building efficiency knowledge broadly among stakeholders
Building industry fragmentation inhibits energy efficiency	Accelerate building efficiency R&D and deployment through a solid, functioning consortium with bilateral public-private partnerships	Establish on-going, sustainable joint consortia that draw on core research and commercial strengths of both nations, with well-defined cooperative responsibilities and roles

LOOKING AHEAD

Keeping in mind the fact that science and technology have since long been an important cornerstone of cooperation between India and the United States, both nations recognize the fact that further collaboration can and would enhance our shared understanding of the planet's climate. The activities of the **Indo-U.S Joint Clean Energy Research and Development Center** would contribute greatly to the sustainability and prosperity of not only our two countries but the world at large by helping diversify energy supply and accelerate the transition to a low-carbon economy.

Consortium Principal Investigators and Co- Principal Investigators with representatives from the Department of Biotechnology, Department of Science and Technology and the Indo-U.S. Science and Technology Forum at the Internal Coordination Meeting on 17 January 2014

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