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Second Generation Biofuels

A WORLD MUCH GREENER



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The Energy Independence and Security Act of USA (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. The *U.S.-India Consortium for Development of Sustainable Advanced Lignocellulosic Biofuel Systems* is a collaborative effort between Indian and U.S. institutions under the **Joint Clean Energy Research and Development Center (JCERDC)** initiated by the Governments of India and the United States to accelerate transition to a low-carbon, high-performance and energy-secure economy. The Biofuel Consortium addresses the second generation biofuels R&D priority area of the JCERDC, 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 as well as biofuel. The consortium is jointly led by the **Indian Institute of Chemical Technology (IICT)**, Hyderabad, India and the **University of Florida**, Gainesville, USA.

VISION

The major goal of this consortium is to develop and optimize selected non-food biomass (high yielding varieties of sorghum, pearl millet, bamboo and switch grass)-based advanced biofuel systems and bio-based products like biogas and lignin-based high value polymers 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 overall economics and sustainability of biofuel production and supply systems.

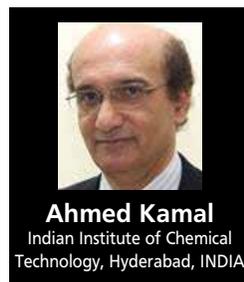
CONSORTIUM OBJECTIVES

The research is grouped under three broad thrust areas or Work Programs (WP):
 WP1 – Feedstock development and supply
 WP2 – Biorefinery technologies
 WP3 – Sustainability, marketing and policy

Feedstock development and supply (WP1):

This program focuses on breeding high yielding switchgrass and sorghum in the U.S. and sorghum, pearl millet and bamboo cultivars in India that can be grown on marginal lands. These marginal lands have been identified as those lands that are flood and drought prone in the United States along the Mississippi and Missouri river flood plains in the Midwestern states, and salinity and drought prone areas in Central, Western and Southern states of India. Specific objectives are to:

- Improve production potential and feedstock quality using genomics



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CONSORTIUM PARTNERS

INDIA	UNITED STATES OF AMERICA
Lead Institution: Indian Institute of Chemical Technology (IICT), Hyderabad	Lead Institution: University of Florida (UF), Gainesville, Florida
Other Partners: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad; Directorate of Sorghum Research (DSR), Hyderabad; Jawaharlal Nehru Technological University (JNTU), Hyderabad; Tamil Nadu Agricultural University (TNAU), Coimbatore; Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV), Gwalior; Centre for Economic and Social Studies (CESS), Hyderabad; Indian Institute of Technology-Delhi (IITD); Indian Institute of Technology-Madras (IITM)	Other Partners: University of Missouri (UM), Columbia, MO; Virginia Tech, Blacksburg, VA; Montclair State University (MSU), New Jersey; Texas A&M University, College Station, TX
Industry Partners: Abellon Clean Energy Ltd., Ahmedabad; Hindustan Petroleum Corporation Ltd. (HPCL), Bangalore	Industry Partners: Green Technologies LLC, Gainesville, FL

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

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.

Biorefinery Technologies (WP2):

The overall goal of this work program is to improve lignocellulosic biomass processing technologies for fermentable sugar production and subsequently their conversion to biofuel. Biofuels targeted are ethanol in India and butanol in the United States. An additional emphasis of this program is on processing and utilization of waste streams for recovery of nutrients, and bio-product production. It is envisioned that this approach would ensure that the biofuel is manufactured with minimal environmental impact and there are additional revenues for the biorefinery. This work program is also well positioned to accelerate deployment of commercial systems both in the U.S.A. and India due to the availability of a pre-commercial scale biorefinery at the University of Florida. Objectives of this work program are to:

- Develop biocatalysts for production of advanced biofuels, and optimize pretreatment and fermentation processes.

- Develop co-products and applications from biorefinery waste streams that minimize environmental impacts and maximize revenues.

Sustainability, marketing and policy (WP3):

Despite the significant potential for the expansion of advanced biofuels production in the U.S. and India; the environmental, economic, and social consequences of dramatically increased harvesting of advanced biofuels feedstocks have not been systematically analyzed. This lack of information limits our ability to ensure long-term sustainability of these feedstock practices and forecast sustainable feedstock supply and development of biofuel systems in both these countries. Understanding the sustainability of biofuels supply and demand systems is a critical component for private sector investments and government policy making. Objectives of this work program are to:

- Analyze and develop certification protocols and sustainability standards.
- Assess energy requirements and emissions, and perform economic analysis.
- Undertake supply chain management analysis.

U.S. and Indian scientists of the U.S.-India Consortium for Development of Sustainable Advanced Lignocellulosic Biofuel Systems visit the University of Florida's Stan Mayfield Biorefinery Pilot Plant, January 29, 2013.

U.S.-INDIA COLLABORATION

The tasks to be accomplished by the center have been neatly divided between participating institutions as under:

- University of Missouri to provide technical help in feedstock matching.
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to exchange germplasm and also to provide technical help in developing new flood tolerant sorghum cultivars at the University of Missouri.
- Scale-up and process data from University of Florida cellulosic ethanol biorefinery will be shared with the Indian consortium.
- The ethanol conversion biocatalyst developed at the University of Florida will be shared with the Indian consortium.



- University of Florida cellulosic biorefinery will be available for Indian consortium for training purposes.
- Development of an integrated biorefinery with a focus on effluent treatment and by-product utilization.
- US Consortium members will provide 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.

CONSORTIUM MANAGEMENT

The U.S.-India 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 will 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 (Thiruvalluvar University). The PSC will meet once a year to review the overall progress and suggest suitable ways to meet the proposed milestones.

The Project Coordinator, Dr. Ahmed Kamal (IICT) will coordinate the project implementation, while the task leads – Dr. P.



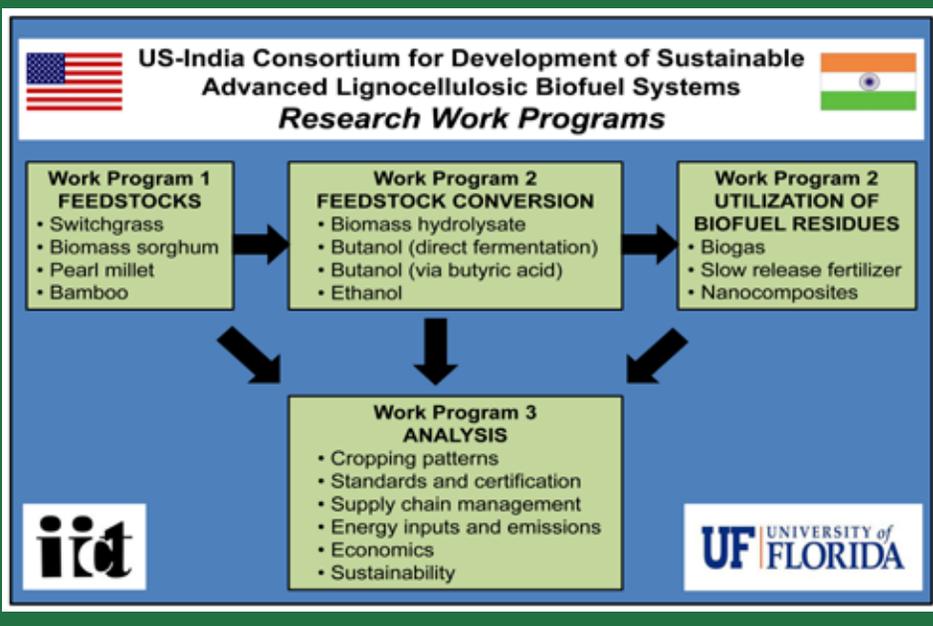
Investigators & Field Staff Training Sessions :
Madhya Pradesh: May 2013 (left)
Gujarat: July, 2013 (right)

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 is responsible for meeting the deliverables/milestones defined in their respective work package(s). In the U.S., WP1 is led by Dr. Shibu Jose (University of Missouri-Columbia), WP2 is led by Dr. Pratap Pullammanappallil (University of Florida), and WP3 is led by Dr. Janaki Alavalapati (Virginia Tech).

Farmers visiting multi-location trial of Sorghum at RVSKVV, Gwalior



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



DELIVERABLES

- Locally adapted high biomass abiotic stress tolerant switchgrass, sorghum, pearl millet and bamboo cultivars yielding >18 t/ha dry biomass.
- Low input advanced feedstock production system.
- Optimized pretreatment methods for the above mentioned feedstock.
- Enzyme formulation for saccharification of pretreated feedstock.
- Recombinant biocatalysts for the efficient conversion of saccharified hydrolysates prepared from sorghum, pearl millet and bamboo feedstock to ethanol.
- Recombinant biocatalyst for the conversion of saccharified switchgrass hydrolysate to butyrate.
- Efficient fermentation process for high ethanol and butanol recovery.
- Sustainability standards and certification protocols.
- Energy, emission, economic analysis and supply chain management report for

For more information,
please visit :
<http://biofuels.ifas.ufl.edu/>

commercialization of lignocellulosic biofuel production.

ACHIEVEMENTS THUS FAR

Though not too old in terms of the time since it has been in existence, the consortium has already begun to make an impact. Some of the salient achievements till date are listed below :

- Two switchgrass and sorghum lines were identified for high biomass traits and abiotic (drought and flood) stress tolerance in the U.S.
- Small-scale field planting has proven that switchgrass is highly productive on marginal lands compared to corn and soybean.
- Large scale field trials in collaboration with farmers were initiated this summer.
- Genomic-assisted breeding initiated for sorghum and will begin next summer for switchgrass.
- Five sorghum cultivars and three farmer-preferred pearl millet cultivars were identified and distributed to farmers for small scale cultivation on marginal lands of Central, Western and Southern India.
- Multi-location trials for high biomass sorghum and pearl millet are currently in progress at Madhya Pradesh (Khargone, Dewas, Gwalior and Lahar); Gujarat (Modasa, Vithalpara, and Khus); Tamil Nadu (Coimbatore and Bhavanisagar); Karnataka (Gangavathi) Telangana (ICRISAT and DSR) and Andhra Pradesh (ANGRAU, Bapatla)
- Twenty bamboo germplasms were collected, mother plants were established and inter simple sequence repeat (ISSR) study completed.
- Biomass compositional analysis (cellulose, hemicellulose and lignin content) protocols standardized in India to align with methods used by U.S.A. consortium.
- Screening of cultures for cellulolytic enzymes and β -glucosidase has been carried out.
- Steam explosion protocol for pretreatment has been standardized. Commercial cellulolytic enzymes have been procured from various

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biodiversity, thus supporting millions of agricultural and forest-dependent livelihoods. The ecosystem services hinge upon the varied and extensive forest cover across this region, that is under increasing threat of degradation from over-exploitation, infrastructure development and climate change. In order to create a scientific understanding of the causes of forest degradation, its conservation and restoration, with a special reference to the Western Himalayas, **Ghazala Shahabuddin** (Centre for Ecology, Development and Research, New Delhi) and **Timothy Gregoire** (Yale

University, New Haven) organized an Indo-US workshop titled *Forests of the Western Himalaya: conservation and restoration of ecosystem services in a time of climate change*. The workshop aimed at building multi-disciplinary and multi-institutional research collaborations on Himalayan ecology issues, increasing opportunities for training and learning through institutional collaborations and strengthening ties between scholars and conservation practitioners. ●

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- sources and analyzed for their efficacy to saccharify pretreated biomass.
- The Stan Mayfield Biorefinery Pilot Plant operated by the University of Florida is fully operational and is processing sugarcane bagasse to cellulosic ethanol at 10,000 gallon fermentation level. Ethanol yield using this process averages about 70 gallons of ethanol per dry ton of bagasse.
- A genetically engineered *Escherichia coli* for production of butyric acid constructed and further work is in progress to optimize this construct.
- The sustainability analysis program in the USA has developed an agent based model for assessing economic impacts of biofuel markets along the supply chain.
- The India consortium has administered survey questionnaires and conducted focus group discussions to collect baseline information on socioeconomics and land use in targeted regions of Central (Madhya Pradesh) and Western (Gujarat) states of India.
- Economics and emission data were collected for current practices of farmers/growers to understand and estimate how the energy crops under the project would impact current economy and environment.
- Two joint project meetings of the U.S.A. and India consortia were held at the University of Florida, Gainesville and two capacity building workshops were held in India. ●

TiEcon 2014 : Fostering Entrepreneurship

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Dr. Pooja Mukul from the Bhagwan Mahaveer Viklang Sahayata Samiti (BMVSS) Jaipur, Endowment Awardee, delivered a brief talk on the 'Affordable and User-Centric Knee Joints' which is currently being developed in partnership with Dr. Krista Donaldson, D-Rev (Design Revolution), San Francisco. Endowment Fund grantees, One Breathe Inc., was awarded in the TiE50 category for their work in the field of Life Sciences for their Low cost affordable Mechanical ventilator.

The following Endowment Awardees showcased their technologies at the Tech Expo.

- Mr. Michal Depa, Chief Technical Officer - *Mobile Phone based HbA1c Analyzer*
- Mr. Nishith Chasmawala, Co-Founder & Chief Executive Officer, Consure Medical- *A Novel device to manage fecal incontinence in non-ambulatory patients*
- Mr. Tanmaye Seth, Marketing Manager, Aquagri Processing Private Ltd., and Ganesh Vishwanath, Founder, GloBridge Ventures LLC. - *Cultivated sea plants based organic bio-stimulants*". ●

