LORRE

LABORATORY OF RENEWABLE RESOURCES ENGINEERING

(www.purdue.edu/LORRE)

Strategic Plan 2014 – 2019

Discover, Educate, Translate

LORRE

"There are science and the applications of science, bound together as the fruit of the tree which bears it"

Louis Pasteur

PURDUE UNIVERSITY

Preface

The Laboratory of Renewable Resources Engineering (LORRE) was founded in 1978. Its programs have evolved with the emergence of industrial biotechnology. The field and the technology motivated an assessment of how LORRE should position its programs and plan for the future. Consequently, LORRE faculty, staff and students initiated work starting with a retreat at the Daniels Center in October, 2011, to define a process and framework for developing a strategic plan. Presentations by LORRE staff members set the stage for vigorous discussions under the thoughtful guidance of Bill Baitinger, who served as facilitator. The retreat set in motion a two-year process where new directions, challenges and opportunities were analyzed and a strategic plan to address these was developed.

As Director of LORRE, I invite you to help us to achieve our goals and to begin to capture the promise of sustainable fuels, chemicals, and bioproducts through engineering of renewable resources.

Sincerely yours,

Michael R. Ladisch
Distinguished Professor and Director
Laboratory of Renewable Resources Engineering
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Who We Are

The Laboratory of Renewable Resources Engineering (LORRE) was founded in 1978 as an interdisciplinary center between the Colleges of Engineering and Agriculture. LORRE's first research mission was to address ways to alleviate potential transportation fuel shortages brought on by tensions in the Middle East. The Laboratory focused on conversion of lignocellulosic residues – wood chips, corn stover/cobs/fiber, straw, and sugarcane bagasse – into fuel ethanol. While biofuels continues to be a research theme, LORRE's work has evolved to address the foundational science and engineering of the broader topic of transforming renewable resources to bioproducts in a sustainable manner. LORRE is defined through its research, while its impact is realized through the students and post-doctoral scholars from diverse disciplines who graduate from its programs.

What We Do

LORRE, in partnership with academia, government, and industry carries out fundamental research, educates students, publishes findings, and develops prototypes and software that serve to translate laboratory discoveries into industrial use. The laboratory's work addresses engineering and molecular fundamentals of bioreactor design, genetic engineering of yeast, protein purification, bioseparations, systems biology, chemical catalysis, and process scale-up. Examples of translation and ongoing developments illustrate areas of impact and relevance.

Translation
Alcohol Drying
Catalytic Reactors
Cellulose Pretreatment
Liquid Chromatography
Waste to Electrical Energy
Xylose Fermenting Yeast

Ongoing Developments
Bioenergy
Biofuels
Bioproducts
Bioseparations; Chromatography, Adsorption, and Membranes
Microfluidic Pathogen Detection

How We Do It

LORRE combines fundamental research with engineering to develop new technologies, publish research results, and construct prototypes that embody the new technology. LORRE faculty and professional staff also disseminate new knowledge through professional society meetings, invited lectures, and the classroom. Translation of discoveries into tangible processes and functional prototypes is part of what differentiates our students' education, and LORRE, from many other programs. LORRE's interdisciplinary approach provides the foundation for its discovery and educational missions.

What We Hope To Achieve

LORRE aspires to lead Purdue University and its peer groups at other universities in providing experiential-based technical training, grounded in the fundamentals of basic research at the intersection of engineering and biology. We will combine research with translation of new discoveries into prototypes and commercial applications. Translation is critical to the emergence of the new bio-economy on which a sustainable future will depend for life and society as we know it. LORRE's goal is to lead by example and teach its students to do the same so that they will prosper in a world where metrics of academic achievements such as grades, publications,

and core curricula, while absolutely necessary, are only an entry point for success. "Discover, Educate, Translate" is the priority. Education of students to become future engineers and scientists in the emerging field of industrial biotechnology is an outcome.

Who We Work With

LORRE's access to and cooperative work with numerous on- and off-campus resources, enables the latest scientific instruments and techniques to be used in the laboratory's fundamental research, as well as to catalyze translation of research into prototypes. Collaborators and partners are in the Colleges of Engineering, Agriculture, Science, and Technology, as well as Discovery Park.

Purdue Resources That Enable LORRE's Work
Discovery Park (Proteomics, Genomics, Imaging)
Weldon School (BME) Instrument Shop
ABE/University Machine Shops
ITaP; ECN Computing
Purdue Agricultural Research Farms
Pre- and Post-award Centers
Office of Technology Commercialization

Why We Do It

LORRE, working together with other engineering and scientific disciplines wishes to make an impact in the science, technology, and people who will build the new infrastructure and define new approaches to the ageless global challenges of energy, food, and water.

The science for improving productivity of arable land, and the processing of the resulting agricultural products to value-added molecules is carried out at the lab bench, the greenhouse, or in a fermenter or shake flask. However, the implementation of the new technology requires systematic engineering of systems and processes. Without this, up-scaling may be perceived as too risky or expensive to be pursued by industry. Engineers who are able to up-scale new discoveries are critical, and LORRE will help to address this need.

Solutions will come in the form of process unit operations that enable large-scale manufacture of products with inherently small economic margins, and for which large project capital investments are needed to attain the economies of scale required to meet the demands of a global society consisting of more than 7 billion people. The potential is immense, as is the need for the engineers and scientists who will up-scale discoveries and help build a new economy based on sustainable, renewable resources.

Immediate opportunities in renewable resources are in extending the use for non-renewable resources by combining them with renewable ones in cases where the economic drivers for renewable products are attractive. This will help to promote the growth of renewable resources in a systematic manner, leading to greater sustainability.

In the future, the definition of success will include evidence of translating university discoveries into tangible and sustainable societal benefits. The current industrial infrastructure cannot take full advantage of the special properties of renewables, and is less efficient in utilizing these products than it could be. The work of LORRE aspires to define technology that will enable renewable resources to fit into established industries in transportation, fuels, electrical power, food, feed, fiber, or chemicals, and to replace existing infrastructure with the new industrial biotechnology, as the opportunity arises.

Values and Guiding Principles

Research	Provide the national and international community with quality research and educational experiences for students and post-doctoral scholars who participate in this research.
Collaboration	Work together with colleagues at Purdue University, and with other universities, laboratories and industry, to combine diverse viewpoints and resources in the pursuit of new knowledge applicable to a global economy.
Diversity	Provide an environment that fosters diversity of people, nationalities, research ideas, and opinions in order to catalyze fresh ideas and new knowledge.
Excellence & Quality	Instill a sense of excellence in all of its researchers and students so the quality of the research and its outcomes are world-class.

Mission

LORRE's mission is to prepare students to be world-class engineers, scientists, and academicians in the sustainable processing of renewable resources into alternate fuels and value-added biomolecules, and in technologies that contribute to safe foods, clean water, and human health.

Vision

Faculty and students, working together with our peers in multiple disciplines in academia, industry and government, will address fundamental questions and emerging opportunities in renewable resources that:

1. Explore core concepts at the interface of engineering, biology, biochemistry, and process economics.
2. Develop a comprehensive understanding of the molecular structure, function, and potential of biological materials through biocatalysis and bioseparations.
3. Translate laboratory discoveries into beneficial tools and technologies through publications, patents, prototypes, products and partnerships.

To start the process of creating a renewable world, students in LORRE will receive formal coursework and laboratory experiences in biotechnology, bioprocess engineering, bioseparations, and microbial engineering for producing fuels, chemicals, and bioproducts from renewable resources. Discoveries will form the basis for developing prototype molecules, microorganisms, and processes for testing and commercialization.

Objectives and Five Year Plan

Future opportunities for research topics will build upon the international character and global impact of renewable resources utilization. Emerging trends focus on renewable feedstocks that have the capability of reducing the carbon footprint of transportation, shelter, safe food and clean water. To help address these needs, LORRE will work with government agencies and industry to reduce the costs of processing of low carbon footprint feedstocks.

LORRE will provide an entrepreneurial environment to translate laboratory discoveries into commercial use to the benefit of people, Purdue University, and the Laboratory itself. Research, translation, and education will be pursued through international cooperation to address global needs and markets. While periods of changing targets are expected, the fundamentals of bioprocess engineering, micro- and molecular biology, biotechnology and renewable resources will continue to form the foundation of the Laboratory's basic research which addresses:

Feedstocks: Understanding characteristics and properties of wood, agricultural residues, purposely grown energy crops, and aquatic biomass that provide the raw materials for biocatalytic transformation to value-added products.

Biocatalysts and Catalysts: Engineering, characterizing, and developing novel industrial yeast and bacteria, enzymes, heterogeneous catalysts, separations media, and organic molecules that mimic specificity of biocatalysts. LORRE intends to lead the field in engineering solutions that are built around biotechnology or chemical catalysts that mimic the efficiency of biology.

Bioprocess Engineering: Investigating principles that underpin physical mechanisms of catalytic action at liquid and solid interfaces, coupled with separations to efficiently recover and purify the value-added products that result.

Bioseparations: Carrying out fundamental research to define new separations media and processes for efficient recovery and purification of proteins, biomolecules and bioproducts.

Microfluidic Technology: Exploring properties of fluids and proteins at interfaces that enable rapid isolation and separations at the micron and sub-micron scales.

Translation: Up-scaling of technologies resulting from fundamental research into process prototypes, new instruments, and novel molecules at a sufficient quantity or scale to enable testing and demonstration to help raise capital or licensing revenue, and enable new businesses that create jobs in Indiana.

Engagement: Translating LORRE's research through engagement of research sponsors, alumni, and people who might benefit from the technology and hire graduates of LORRE's programs. Publications, presentations and discussions at professional society meetings, and with industry, are an important component of engagement since these meetings enable LORRE to learn about issues where its work may provide solutions.

Goals

The goal of the Laboratory of Renewable Resources Engineering (LORRE) is to offer unique educational opportunities to both undergraduate and graduate students, as well as post-doctoral researchers and visiting scholars, to learn and to make fundamental scientific discoveries that will enable renewable resources to become the foundation of a sustainable industry. Bioprocess engineering will help to define enabling technology. Agriculture will provide the feedstocks. Biology, biochemistry, and chemistry will develop the catalysts. Fundamental research will result in new knowledge, which when translated, will act as the bridge between current and future industrial practice in the sustainable use of renewable resources.

Specific Objectives

Specific objectives for LORRE over the next five years are to:

1. Enhance graduate and post-graduate student components of LORRE's research programs through activities and initiatives that will:

    a. Establish funding to create an Associate Director position, recruit an Associate Director, and fund support staff.

    b. Provide an environment and resources for developing people who are currently faculty in LORRE or who have the goal to become faculty. These people form the core leadership of interdisciplinary research in areas of enzyme and microbial technology applied to food safety, bioproducts and cellulose conversion, bioseparations of proteins and bioproducts, and bioreactor and chemical reaction scale-up for production of biofuels and bioproducts from renewable resources.

    c. Recruit new faculty in the areas of:

        i. Experimental (laboratory-based) systems biology for industrial microorganisms and fermentations including bacteria, yeast, algal, and other eukaryotic systems

        ii. Plant cell or mammalian cell culture, or in an area related to new bioprocessing and new bioproducts that address Purdue University's initiative in the plant sciences.

    d. Graduate at least six graduate students (MS and PhD) per year, by LORRE faculty.

    e. Recruit graduate students in the upper 10% of their peer groups in Agricultural and Biological, Biomedical, Chemical, Electrical, Mechanical, Civil and Environmental Engineering to pursue research in LORRE.

    f. Establish five named graduate fellowships to support PhD students.

g. Establish a consortium-based training fund for supporting continuing education of industrial scientists and engineers through Purdue-based industrial internships at LORRE.
h. Provide formalized programs that will achieve mutually beneficial research outcomes through the work of post-doctoral researchers and visiting scholars from other universities, industry, and government laboratories.

2. Establish a pre-eminent, six-person, LORRE Advisory Board consisting of representatives from industry, another university, a government laboratory, Purdue University, and Director of LORRE.

3. Catalyze faculty (academic and research) proposals to obtain sponsored research grants of $1.5 MM/year by 2017, while expanding industrial sponsored research to a sustainable level of 40% of LORRE's budget research, with the balance from federal, international, state and foundation research programs. As part of this activity, develop and submit major multi-investigator grants in the topic areas of:

    a. Bioenergy, bioproducts, and biofuels (DOE, NSF, DOD).
    b. Food and water safety (USDA, FDA, DOD, NIH, EPA).
    c. Recovery and purification of biomolecules and bioproducts (NSF, NIH).

4. Obtain university/donor funding to undertake a major renovation and updating of LORRE laboratory facilities.

Metrics

Benchmark measures will provide metrics for tracking LORRE's progress towards its five year goals. Development of its activities relative to evolution of the field of renewable resources will be compared to peer laboratories and centers at the institutions given in Table 1.

Input measures will be based on quality of graduate students (GRE scores, rank/grade at undergraduate institutions, prior research experience, and diversity).

Output measures will be based on the number of students graduating per faculty member, professional placement of students, research funding, time required for students to complete graduate degrees, annual publication rate of research papers, and technologies translated.

Implementation

This strategic plan will be implemented in March of 2014, beginning with formation of the LORRE Advisory Board.

Private Giving

Giving by friends and alumni of our laboratory and Purdue University is needed to achieve the goals of our laboratory. We will work with the Purdue University Development Office to identify potential donors and to reach out to ask for and obtain assistance.

Table 1: Peer Institutions for Benchmarking

University	Laboratory Name	Director	Description
Chalmers University of Technology	The Linnaeus Centre for Bio-inspired Supra-molecular Function	Lisbeth Olsson	Quantitative, industrial fermentation physiology and metabolic engineering as well as enzyme technology. Research also includes work on tomorrow's industrial raw material; cellulose and hemicellulose where enzymatic hydrolysis/enzymatic modifications is an essential step. http://www.chalmers.se/chem/EN/divisions/industrial-biotechnology
Delft University of Technology	Industrial Microbiology	J.T. (Jack) Pronk	Microbial physiology. Application of genomics approaches to industrial fermentation research. http://www.tnw.tudelft.nl/
Georgia Institute of Technology	Institute of Paper Science & Technology	Art Ragauskas	Research and development center dedicated to exploring opportunities and providing solutions to the strategic, economic and technical challenges facing the forest products and paper industries. http://ipst.gatech.edu/
Iowa State University	Center for Sustainable Environmental Technologies	Robert C. Brown	Promotion, development and demonstration of thermochemical technologies for the production of fuels, chemicals, and power from biomass and fossil fuels. http://www.cset.iastate.edu/
Lund University	Department of Chemical Engineering	Guido Zacchi	Piloting and modeling of pretreatment and conversion processes for converting lignocellulose to ethanol http://www.lunduniversity.lu.se/o.o.i.s?id=24911&task=listEngPerson&username=kat-gza
Michigan State University	AgBio Research (formerly Michigan Ag.Exp.Station)	Bruce Dale	Innovative, leading-edge research that combines scientific expertise with practical experience to generate economic prosperity, sustain natural resources and enhance the quality of life in Michigan, nation and world. http://www.agbioresearch.msu.edu
University of British Columbia	Department of Wood Science	Jack Saddler	Bioconversion of softwoods to ethanol. http://wood.ubc.ca/
University of California, Riverside	Center for Environmental Research & Technology	Charles Wyman	Encouraging partnerships among industry, government, and academia to enhance environmental education, improve the technical basis for regulations and policy, create new technology, and contribute to a better understanding of the environment. http://www.cert.ucr.edu/
Wageningen Agricultural University	Agrotechnology & Food Sci. Group	Johan Sanders	Processes that optimize use of biomass feedstock. http://www.wageningenur.nl/en/Expertise-Services/Chair-groups.htm