Proposal for Biobased Industry Center Grants Program

**Project Title:** Techno-economic evaluation of fermentable sugar production from corn, sugarcane, and lignocellulosics for the manufacture of bioplastics

**Project Leadership:**
<table>
<thead>
<tr>
<th>Name (PI/Co-PI)</th>
<th>Department</th>
<th>Phone No.</th>
<th>E-mail</th>
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<tbody>
<tr>
<td>David Grewell</td>
<td>ABE</td>
<td>515-294-2036</td>
<td><a href="mailto:dgrewell@iastate.edu">dgrewell@iastate.edu</a></td>
</tr>
<tr>
<td>Melissa Montalbo-Lomboy</td>
<td>ABE</td>
<td>515-294-5472</td>
<td><a href="mailto:melissam@iastate.edu">melissam@iastate.edu</a></td>
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**Research Priority Addressed by this Project:**
Costs, structure, and prices in markets to grow, ship, and process biomass and biobased products.

**Objectives:**
1. To compare the various processes for producing fermentable sugars from sugarcane, corn, and lignocellulose in terms of energy, cost requirements, and greenhouse gas emissions using process engineering software ASPEN Plus and GaBi software.
2. To compare the farming supplies (fertilizers, fuels, seeds, etc) and energy balances for producing sugarcane, corn and lignocellulose before it reaches the bioplastics plants using process engineering software (ASPEN).
3. Use the model to determine promising feedstocks for the manufacture of bioplastics.
4. Use the above objectives to identify and eliminate the lowest efficiency unit operations of biomass production.

**Approach:**
With the increased concerns on global warming and fluctuating petroleum prices, great attention has been given to the use of biorenewable resources as an alternative to petroleum. This has also led to the innovation of bioplastics made from biorenewable materials. Recently, the bioplastics industry has grown into a promising industry that not only reduces greenhouse gas emissions, but it is also environmentally friendly because of product biodegradability. Some of the most common bioplastics in the market today are polylactic acid (PLA), starch-based thermoplastic (SBT), Polyhydroxyalcanoate (PHA), and cellulose polymers (CEL).

The largest productions of bioplastics such as PHA and PLA employ fermentation. The process uses fermentable sugars from a carbohydrate feedstock such as sugarcane or corn and ferments the sugar into monomers. These monomers are then polymerized into bioplastic resins. For example, in bio-polyethylene production, the fermentable sugar is converted into ethanol, which is dehydrated into ethylene monomers.

The largest producers of bioplastics, Braskem, Dow, and Solvay announced that they are planning bioplastic plants in Brazil dedicated to the production of polyethylene and “green” polyvinylchloride from sugarcane. Sugarcane, which is grown largely in Brazil and India, is an inexpensive feedstock that can easily produce fermentable sugars for ethanol production. Sugarcane can be grown year round in tropical locations, such as Brazil, and produces fermentable sugars directly without the need to hydrolyze starch. Therefore, it has been considered a more cost effective feedstock option than corn.

In the United States, intensive research has focused on lignocellulosic biomass as a potential feedstock to compete with sugarcane because it is cheap and abundant. Lignocellulosic biomass can be derived from woody materials, agricultural residues, and dedicated energy crops. They are mainly composed of cellulose, hemicellulose, and lignin formed into a very strong matrix. However, due to the recalcitrant nature of lignocellulosic biomass, it is more difficult to release the fermentable sugars compared to sugarcane or starchy resources such as corn.
Some of the research questions that this proposal aims to answer are:

- Which feedstock is most cost and energy competitive for the bioplastics industry?
- Does the U.S. have enough biomass to supply the biofuels and bioplastics industry?
- Are bioplastic made in tropical climates more economical and environmentally friendly compared to season regions?

In this project, we plan to conduct a study to compare these three types of feedstocks in terms of energy, cost, and greenhouse gas emissions by creating a process simulation model based on published literature and conduct life cycle assessment (cradle to refinery gate) based on their material and energy balances. The main difference that our proposed study has from other techno-economic studies is that the work will be focused toward the bioplastics industry; therefore, the model will stop after fermentable sugar production because it is assumed that the downstream processes will be the same for all three feedstocks.

**Work Plan and Schedule:**

The evaluation of energy and costs required to process sugarcane, corn, and lignocellulose into fermentable sugars will be conducted using ASPEN Plus engineering process simulation software and GaBi LCA software. The main input data to be used in the simulation will be obtained from laboratory and pilot scale results published in the literature. Three models will be created in ASPEN Plus using three types of feedstock (corn, sugarcane, and lignocellulose (including switchgrass, corn stover and woody sources)). The state-of-the-art technology used in full-scale plants will be used to simulate the process. In order to compare the various processes fairly, a common amount of plastic will be used to calculate back to the beginning of the process. Also, the energy and cost comparisons will be expressed in per unit weight of plastic materials at the end of the production process. The simulation will also determine which process provides the most cost and energy efficient feedstock for the refinery.

Below is the timeline for the project activities.

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<th>Months</th>
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<td>1. Literature search and review</td>
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<td>2. Aspen Plus &amp; GaBi LCA modeling</td>
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<td>3. Farming supplies and energy balances</td>
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<td>4. Publication and conferences</td>
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<td>5. Progress and Final Reports</td>
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**Budget** (indirect not allowed)

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<td><strong>TOTAL</strong></td>
<td><strong>$49,982</strong></td>
</tr>
</tbody>
</table>
DAVID GREWELL

PROFESSIONAL PREPARATION
The Ohio State University  Welding Engineering  BS 1989
The Ohio State University  Welding Engineering  MS 2002
The Ohio State University  Welding Engineering  Ph.D. 2005

APPOINTMENTS
2005 - Present  Assistant Professor, Agricultural and Biosystems Engineering, ISU, Ames, IA
2007 - Present  Courtesy Professor, University of Erlangen-Nuremberg, Germany
2001 - Present  President, Grewell Engineering Consultant, Ames, IA
1992 - 2001  Product Manager, Branson Ultrasonic Corp., Danbury, CT
1989 - 1992  Research Engineer, Edison Welding Institute, Columbus, OH

PUBLICATIONS (+30)
Five publications directly related to the present proposal

Five additional publications related to the present proposal
Melissa T. Montalbo-Lomboy

Education
PhD: Biorenewable Resources and Technology
Iowa State University (ISU), Ames, Iowa, 2006-2008
MEng: Food Engineering and Bioprocess Technology
Asian Institute of Technology (AIT), Thailand, 2003-2004
Bachelor: Chemical Engineering
University of St. La Salle (USLS), Philippines, 1996-2001

Employment
• Iowa State University, Ames, Iowa
  Post-doctoral Research Associate, January 2009 – present
• Iowa State University Extension, CIRAS, Ames, Iowa
  Project Coordinator (USDA BioPreferred Program), February 2009 - present
• Iowa State University, Ames, Iowa
  Visiting Scholar/Researcher, January - March 2006
  Carried out research on ultrasonics as liquefaction pretreatment of corn for ethanol production
• Asian Institute of Technology, Pathumthani, Thailand
  Research Associate, 2004-2006
  Conducted research on environmental engineering and management with project focused on membrane separation technology in wastewater.
• Asian Alcohol Corp., Negros Occidental, Philippines
  Research assistant, QC analyst, & Wastewater Treatment Plant supervisor, 2002
  Worked as quality control analyst in quality assurance laboratory. Assisted in yeast improvement experiments of the plant’s R&D department. Supervise the plant’s wastewater treatment plant.

Publications