Introduction to Renewable Energy – Biomass

Captured solar energy from biological systems currently plays a large role in human society through agriculture and small-scale domestic use. Expanding the use of biomass for large-scale energy services could help reduce the greenhouse gas intensity of the energy system. Because photosynthesis captures CO_2 from the air, the resulting carbon-based feedstock can be processed and utilized in a similar manner to fossil fuels with lower net emissions of CO_2.

Biomass energy conversion could take advantage of many existing waste streams, but would also likely involve the cultivation and conversion of dedicated energy crops. The naturally low efficiency conversion of solar energy to biomass leads to large requirements of land, water and nutrients. Lifecycle cost, energy, and greenhouse gas emission considerations such as fertilizer production, harvesting, and feedstock transportation are barriers to the widespread use of energy crops. Increases in the yield of energy crops for given energy, water, and nutrient inputs would decrease the associated lifecycle costs. Research utilizing modern biotechnology could increase efficiency with respect to each of these inputs.

Research enabling more efficient and lower cost conversion methods could also benefit biomass energy. Thermochemical conversion systems designed for fossil fuels could be adapted to accommodate biomass feedstock, or new systems designed to take advantage of the unique properties of biomass could be explored. Biological conversion systems have the potential for higher efficiency and lower cost as our understanding and control of these organisms increase.

GCEP supports five research programs in the area of biomass/bioenergy.

In the area of lignin management, two programs have ended and two are coming to an end this year. The two projects that have ended are by Professors Clint Chapple and Alan Friedman, at Purdue University, and Professor Wout Boerjan at the University of Gent. More details about these can be found in the final reports section of this document.

Of the continuing projects in the lignin management area one is by Professors Claire Halpin and Gordon Simpson at the University of Dundee and the other is by Professors John Ralph, Xuejun Pan and Sara Patterson at the University of Wisconsin-Madison.

Professors Halpin and Simpson's project is aimed at identifying and studying novel mutants optimized for lignin, growth and biofuel production via remutagenesis. Their work involves the use of a saccharification screen to identify mutants in the model plant Arabidopsis thaliana that are more easily processed to biofuels and determining the underlying genetics of these to enable transfer of knowledge to biofuels crops. Recent exciting findings from both Halpin and Boerjan's research have prompted the request for a patent filing on a gene family that when knocked out in plants has a marked increase in the sugar release from the plants under mild processing conditions.

Professors John Ralph, Xuejun Pan and Sara Patterson at the University of Wisconsin-Madison are undertaking a plan to delineate a set of approaches for successfully altering lignin structure, in a way that allows plant cell wall breakdown to produce biofuels in a more energy-efficient manner, by providing alternative plant compatible monomers to the lignification process. This approach differs from that of Professors Boerjan and Chapple in that chemical as opposed to biological synthesis will be used to create various classes of novel plant compatible monomer substitutes. Their ability to incorporate into lignins, and effects on biomass processing will be tested in biomimetic cell wall systems.

Professors Field, Lobell, Naylor and Asner, from the Carnegie Institution for Science and Stanford University are working in the area of biomass energy. They are focusing on five main areas: defining the sustainable domain for biomass energy production; comparing the transportation services from biomass processed to provide ethanol versus bioelectricity; understanding the carbon consequences of biomass agriculture in Brazil; the velocity of climate change; and quantifying the climate consequences of albedo changes related to biomass agriculture.

Professor Alfred Spormann of from Stanford University began a project in 2010 studying the synthesis of biofuels on bioelectrodes. This work is aimed at a technology that will allow electricity to be stored as chemical fuels. The fundamental science to be studied will encompass microbial communities, their interaction with electrodes and the processes that allow efficient electron uptake, transfer and synthesis of fuels and fuel precursors such as methane, acetic acid, and hydrogen.

Professsor Spormann and Professor Bruce Logan at Penn State University began a project in 2011 studying the fundamental processes that occur at cathodes during methanogenesis in microbes in a cathodic biofuel. The work involves collaborative design of the cathodic fuel cell, understanding the mechanisms of interaction of the microbes at the cathode and identifying species responsible for methane production. The ultimate goal is to be able to store electrons from intermittent sources in a usable fuel such as methane.