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 currently supports three research programs in the area of renewable energy/biomass.

Professor Alfred Spormann of 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. Over the past year these researchers have discovered that the dominant microbial species is Methanoarchaeon 1.1, but when platinum is present the dominant species becomes Methanoarchaeon 1.2. This makes sense since platinum is a hydrogen evolution catalyst and Methanoarchaeon 1.2, is a typical hydrogenotrophic methanogen.

The four PIs previously funded on separate projects in the lignin management area were successful in their proposal for a combined project that targets an important and unsolved issue in plants with modified lignin content. This new project led by Clint Chapple, Wout Boerjan, Claire Halpin, John Ralph, and Xu “Sirius” Li, entitled “Lignin Management: Optimizing Yield in Lignin-Modified Plants”, is aimed at overcoming the dwarfism and yield penalty associated with plants with modified lignin. The success of the first projects by the four original GCEP PI’s, involvement of Professor Li, and the key issue of focus in this project could lead to very exciting results. In this short first partial year, these researchers have made good progress including identifying more than 20 lines that suppress lignin-modification-induced dwarfism, (LMID) in the highly dwarfed ref8 (c3h gene) lignin mutants, and have started to map the suppressor genes. To support this work, the next step in semi-automated metabolite profiling has been developed. The Candidate Substrate Product Pair (CSPP) algorithm searches for pairs of m/z features (UHPLC-HRMS peaks characterized by a particular retention time and m/z value) for which the mass differences correspond with those expected for well-known enzymatic reactions. At the same time, NMR assignment methods continue to be improved, and were validated in the analysis of triple mutant lines that have their lignins derived almost entirely from the typically minor monolignol, p-coumaryl alcohol. The lignins are therefore unlike anything seen before in nature, and the agronomic resurrection of these lines suggests that lignin composition may be pushed beyond previously held compositional bounds.