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 two research programs in the area of renewable energy/biomass.

Professsor Spormann and Professor Bruce Logan at Penn State University are studying the fundamental processes that occur at cathodes during methanogenesis in microbes in a cathodic biofuel. The work involves collaborative design of a cathodic fuel cell, understanding the mechanisms of interaction of the microbes at the cathode and identifying species responsible for methane production. The MEMC technology used will allow for production of CH_4 with high efficiency relative to the electrical input. The technology is currently in the concept stage, with the scientific feasibility shown. The underlying mechanisms of electron transfer from cathodes via intermediates to cells and the stability of the cathodic microbial communities are not fully understood. This work is aimed at understanding these mechanisms and advancing the technology, and has made good progress towards these goals.

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 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. Working independently with different lignin-deficient mutants, the partners have discovered novel genes that mitigate the growth defects [so-called lignin modification-induced dwarfism (LMID)] seen in severely lignin-depleted plants. Revealing the mechanism(s) by which this mitigation occurs is critical to fundamental understanding and useful manipulation of how plants partition carbon and may enable biomass manipulation for carbon sequestration in the future. The goal of these researchers is to determine the causes of, and to reduce the effects of, LMID. To date they have already found a strategy to lessen the effects of LMID in a particular mutant, and discovered novel genes involved in LMID. They have discovered a mutant that partially restores the growth defect of the original line, yet maintains saccharification efficiency. The gene responsible for this trait has been identified, and tests are underway to understand the mechanism behind the LMID reduction. Another mutant screen, in the highly dwarfed *ref8* (*c3h*) background, has identified more than 20 lines that suppress LMID, designated as *growth inhibition relieved (gir)*. Work is ongoing to characterize these and mutants from additional screens. The incorporation of alternative monolignols has also been investigated, as the inclusion of hydroxycinnamaldehydes leads to an increase in saccharification potential. Genes important for the high saccharification of mutants previously identified in *Arabidopsis* have been targeted for implementation in energy crops (barley, poplar). The new CRISPR/Cas9 technology will allow for targeted knock-outs of lignin biosynthesis genes in barley. This will allow for greater effects on plant lignin content and composition.