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 six projects in the area of biomass energy.

Investigators Field, Naylor and Asner, from the Carnegie Institution of 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. In addition, they are beginning new projects, one involving quantifying degraded pasture in Brazil.

Professor Chaitan Khosla is developing microbial processes for biodiesel synthesis using Escherichia coli. His program optimizes fermentation conditions for biodiesel production, evaluates the ability of a variety of microbial enzymes to directly produce fatty acid methyl esters in E. coli, and introduces new enzymatic systems into the bacterium.

In the area of biolignin, four projects have begun recently. Professors Clint Chapple and Alan Friedman at the Purdue University are focusing on establishing an enzymatic toolbox for the production of lignin modification molecules (LMMs). They are taking three parallel approaches to the identification and characterization of LMM-synthesizing enzymes and have identified three classes of catalysts that are the focus of their work.

Professors Claire Halpin and Gordon Simpson at the University of Dundee, in collaboration with Professor Wout Boerjan at the University of Ghent, Belgium, and Professor Simon McQueen Mason, of the University of York, UK are identifying and studying novel mutants optimized for lignin, growth and biofuel production via re-mutagenesis. 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.

Professor Wout Boerjan at the University of Gent is working towards new types of degradable lignin. The long term goal of the project is to identify natural products or target molecules that can be biosynthesized in energy crops, translocated through the plasma membrane and cross-coupled with lignin units such that the final lignin polymer is more susceptible to chemical cleavage, or is more hydrophilic, or is less cross-linked with hemicelluloses. Ideally, the structures of the target molecules would be very similar to traditional monolignols so that they can be exported to the wall using the same transport system.

Professors John Ralph, Xuejun Pan and Sara Patterson at the University of Wisconsin-Madison are undertaking a three year 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 bio-mimetic cell wall systems.