Biofuels Research at the University of Virginia: Conversion of Biomass to Fuels, Chemicals and Power

A White Paper submitted to the SURA Bioenergy Summit February 27-28, 2007

The US faces significant scientific and technical challenges to alleviate its growing demand for petroleum and petroleum-derived products. It is now well-recognized that world-wide production of petroleum will peak in this century, and could actually occur within the next 50 years. Moreover, the scientific consensus is that use of fossil fuels over the past century has significantly increased the level of carbon dioxide in the atmosphere thus facilitating global climate change.

The Integrated Biorefinery

One strategy that has the potential of diminishing our reliance on oil while decreasing the environmental impact of fossil fuel processing involves the creation of integrated biorefineries that produce both fuels and chemicals. Because the price of oil is predicted to remain high in the foreseeable future, the previous economic barrier to large-scale adoption of alternative feedstocks has decreased significantly. The challenge now is to efficiently convert biorenewable feedstocks to useful materials.

Since carbohydrates are the most abundant organic material on earth and represent roughly 95% of the annually regrowing biomass, they have many of the attributes required of a primary feedstock for the fuels and chemicals industries. Some carbohydrates such as starch, cellulose, lactose, chitin and sucrose are produced in relatively pure form using well-established methods and are commercially available in quantities of tens of thousands of tons per year. In addition, a growing demand for biodiesel fuel in the US, which is produced by transesterification of plant oils with methanol or ethanol, will result in an expanding inventory of co-product glycerol. The utilization of glycerol as a fuel or chemical feedstock will significantly influence the future economics of biodiesel synthesis. The production of biodiesel illustrates a critical need for a systems approach to biomass utilization.

The integrated biorefinery concept will succeed only when the various processing routes are discovered and optimized. A biorefinery will most likely use a combination of biocatalysis for raw material conversion to various building blocks followed by heterogeneous catalysis for secondary transformation of those building blocks to high value fuels and chemicals. However, the molecules derived from biomass are very different than those obtained from petroleum. For example, bio-derived molecules tend to be highly-oxygenated, thermally-unstable, water-soluble and fairly non-volatile. Heterogeneous catalysts and catalyst supports that have been developed for petroleum processing will often be ineffective for biomass processing. Therefore, new research on the catalytic conversion of biorenewable feedstocks to fuels and chemicals in aqueous environments at moderate temperatures is needed.

Current Research at the University of Virginia

Two faculty members in the Department of Chemical Engineering (R. Davis and M. Neurock) are currently working on the catalytic conversion of biorenewable feedstocks to fuels and chemicals. In addition, Davis and Neurock have initiated a new study on the direct conversion of biomass-derived synthesis gas ($CO + H_2$) to light alcohols such as ethanol. In a separate effort, I. Harrison

(Chemistry) is exploring the catalytic conversion of biologically-derived ethanol and methane. Another aspect of research on biofuels at UVa involves their direct utilization for electric power generation. S. McIntosh (Chemical Engineering) and H. Chelliah (Mechanical and Aerospace Engineering) are studying solid oxide fuel cells and microturbines, respectively, for production of electrical power from biofuels.

Future Plans

The University of Virginia is planning to host an energy summit in the fall of 2007 on the broad theme of policy, business and technology solutions for the energy equation of the 21st century. One goal of the summit is to involve the expertise of the various professional schools such as Engineering, Business, Law and Architecture in a high-level discussion of energy-related issues, including the biofuel options.

The University will continue to foster research in biofuel-related topics. Individual investigators and groups of investigators have submitted research proposals for additional federal research funding in bioenergy-related topics, and more submissions are planned in the near future. At least two of these proposals will involve collaborative partnerships with international institutions.

Finally, the University recognizes the need to add faculty in targeted research areas, with energy being a major focus. In particular, the Chemical Engineering department is very interested in hiring a new faculty member in the area of metabolomics, with a focus on optimized production of biofuels from plant sources.