# Faculty Column

## Addressing Transportation Fuel Challenges

BY ART RAGAUSKAS AND COLLEAGUES
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PHOTO COURTESY OF IMPERIAL COLLEGE LONDON

***ABOVE:*** *This bioreactor contains the bacteria Geobacillus thermoglucosidasius, which researchers metabolically engineerd for improved ethanol production from biomass-derived hexose and pentose sugars.*

Years before today's energy challenges, before Hurricane Katrina, before $70 per barrel oil, several researchers and students at the Georgia Institute of Technology, Imperial College London and the Oak Ridge National Laboratory had already begun to develop research and educational programs that envisaged the energy, environmental and sustainability issues we are now encountering.

With world oil demand growing, supplies dwindling and tension brewing in several oil-rich regions, it is apparent that other types of fuels and technologies are needed to help pick up the slack. It is these challenges that encouraged our multi-institutional consortium — called the the AtlantIC Alliance for BioPower, BioFuels and Biomaterials — to meet and develop a common roadmap from which collaborative research plans and educational opportunities could be developed.

Now, Alliance experts in science, engineering and public policy agree that the cornerstone to addressing our energy challenges is the integrated biorefinery.

### The Technology

In general, the biorefinery integrates biomass conversion processes and equipment to produce fuels, power and chemicals from biomass. The biorefinery works much like a petroleum refinery, which produces multiple fuels and products from petroleum. Its goal is to use all components of biomass to make a range of foods, fuels, chemicals, feeds, materials, heat and power in proportions that maximize economic return.

Our vision is that the biorefinery will complement well-established petroleum refinery processes with some materials and fuels being easier to make from biomass, others from petroleum. But as petroleum resources become more limited, more of these chemicals will be derived from biomass.

A key component of addressing today's energy challenges in a sustainable manner is the systems integration of:

- genomics and biotechnology
- advanced separation science and engineering
- catalysis, nanotechnology and polymer science
- lignin, polysacchride and green chemistry
- process chemistry and engineering
- power generation
- life-cycle analysis

### The Recommendations

Researchers finalized this roadmap last year, and it contained a series of comprehensive research and policy plans

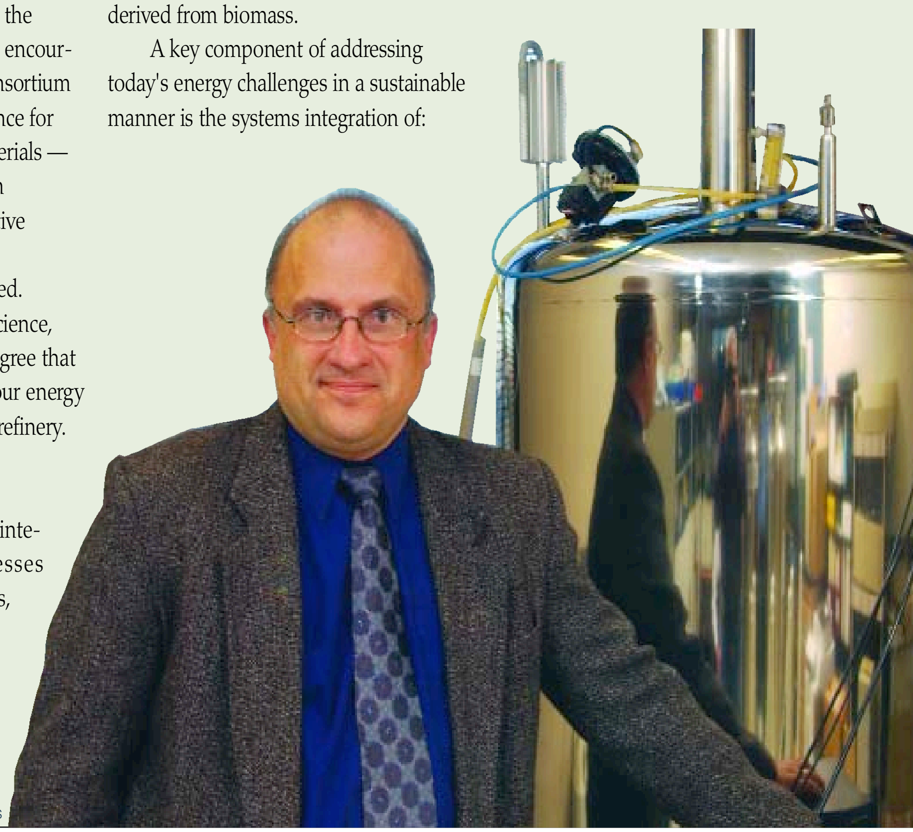

PHOTO COURTESY OF ART RAGAUSKAS

***RIGHT:*** *Associate Professor of Chemistry and Biochemistry Art Ragauskas and his research group use a high-field nuclear magneticresonance spectrometer as the cornerstone of their biomass characterization studies.*

IMAGE COURTESY OF ISTOCKPHOTO.COM

to increase the practicality of using biofuels and biomaterials as a supplement to petroleum. A condensed version was summarized as a review article, called "The Path Forward for Biofuels and Biomaterials," which appeared in the Jan. 27, 2006 issue of *Science*. (See **www.chemistry.gatech.edu/faculty/Ragauskas/**)

We can readily address, with research, a third of current transportation fuel needs. But reaching that goal will require five to 10 years and significant policy and technical effort.

While many think of ethanol made from corn when they think of biofuels, our research group recommends a much broader spectrum of possible materials, including: agricultural wastes, such as corn stovers and wheat stalks; fast-growing trees, such as poplar and willow; and several perennial energy crops, such as switchgrass.

In addition, the group also recommends some changes to the plants themselves using techniques such as accelerated domestication to make them more efficient energy crops. But doubling the productivity of energy crops will mean identifying constraints and engineering-enhanced pathways with genomic tools.

To make biofuels a truly practical alternative to petroleum, we believe there will need to be significant improvements in how biofuel is processed. Thus, we recommend the biorefinery.

Associate Professor Sam Shelton, director of Georgia Tech's Strategic Energy Institute, says, "The integrated biorefinery offers great long-term potential utilization of biomass and dovetails nicely with Georgia Tech's near-term development of southern pine-to-ethanol technology using the existing southeastern pine pulpwood resource, infrastructure and technology."

## The Research

Our group based its recommendations on research studies of: the development of rapid-growth, high-energy-content trees and perennials; novel environmentally friendly biomass extraction technologies; innovative catalysts for the conversion of agricultural and wood residues to bioethanol/diesel and hydrogen; and biofuel cells and next-generation green plastics and materials derived from functionalized feedstocks prepared from sustainable sources such as plants, sunlight and wastes.

The response to our review article in *Science* has been fantastic. The authors have been interviewed by numerous news agencies, including Fox, National Public Radio and the BBC. At last count, more than 450 newspapers, Web sites and other news outlets had referenced this article. It has provided a touchstone from which students are being engaged in science and engineering, faculty are pursuing energy-related research programs, and inventors and industrialists are pursuing new technologies to help develop integrated biorefineries.

Researchers from Georgia Tech, Imperial College and ORNL have initiated new biofuel, biopower and biomaterial projects to help solve some of the major research issues surrounding the biorefinery. These include unique, green solvent-extraction systems to recover value-added chemicals from biomass, and the development of catalytic systems to reform biomass carbohydrates to biogasoline and biodiesel precursors.

But, just as energy is a pervasive societal issue, the solutions will undoubtedly come from many sources. The Alliance encourages a strong dialogue and interactions with its partner institutions' alumni and the communities the institutions serve. By working together and leveraging our skills, knowledge and synergies, we will provide a sustainable path to renewable biofuels, biopower and biomaterials to address today's and tomorrow's energy challenges.

*The team leaders of this project are Charlotte Williams and Richard Murphy from Imperial College London, Brian Davidson from Oak Ridge National Laboratory and Art Ragauskas from Georgia Tech. Other key collaborators are: John Cairney, Carol Carmichael, Chuck Eckert, James Frederick, Charles Liotta, Jason Hallett, John Muzzy and Robert Synder from Georgia Tech; Richard Templer, David Leak, George Britovsek, Tom Welton, Sergei Kazarian, Sandro Macchietto, Ausilio Bauen, Jeremy Woods, Alex Taylor, Tariq Ali and Michiyo Shima from Imperial College London; and Timothy Tschaplinski, Jonathan Mielenz and Lee Riedinger at Oak Ridge National Laboratory. The authors acknowledge the National Science Foundation, U.S. Department of Agriculture and U.S. Department of Energy for their support of the research represented in the Science paper.*

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***LEFT:*** *Georgia Tech is helping develop southern pine-to-ethanol technology, and it would dovetail with future planas for an integrated biorefinery, researchers say.*