Steven E. Koonin is chief scientist for BP, London, UK. He is a theoretical physicist from the California Institute of Technology, Pasadena, CA, USA, where he also served as provost from 1995 to 2004. E-mail: Steven.Koonin@uk.bp.com

Getting Serious About Biofuels

ALTHOUGH RUDOLF DIESEL IMAGINED THAT HIS EPONYMOUS ENGINE WOULD BE FUELED BY VEGETABLE oils, the widespread availability of inexpensive petroleum during the 20th century determined otherwise. The world is now seriously revisiting Diesel's vision, driven by surging global oil demand, the geographical concentration of known petroleum reserves, the increasing costs of finding and producing new reserves, and growing concerns about atmospheric greenhouse gas (GHG) concentrations.

Liquid hydrocarbons are well suited for transport uses because of their high energy density and handling convenience. Although fossil fuels will be required and available for many decades, producing supplementary fuels from biomass can simultaneously address three important societal concerns without requiring substantial modification of existing vehicles or of the fuel distribution infrastructure: security of supply (biofuels can be produced locally in sustainable systems), lower net GHG emissions (biofuels recycle carbon dioxide that was extracted from the atmosphere in producing biomass), and support for agriculture.

The 2% of today's transportation fuels derived from biomass and blended with fossil fuels are produced either by the fermentation to ethanol of food-derived carbohydrates (such as cane sugar or cornstarch) or by the processing of plant oils to produce biodiesel. Unfortunately, current practices based on food production models do not maximize energy or GHG benefits (because they use fossil fuels) and are not economically competitive with fossil fuels at today's energy prices.* Nevertheless, many nations (including the United States, European Union, and India) are expecting that some 5% of their road fuels will be bioderived within the next 5 years.

Credible studies show that with plausible technology developments, biofuels could supply some 30% of global demand in an environmentally responsible manner without affecting food production. To realize that goal, so-called advanced biofuels must be developed from dedicated energy crops, separately and distinctly from food. This is a multidisciplinary task in which biologists, agronomists, chemical engineers, fuel specialists, and social scientists must work to integrate and optimize several currently disjoint activities.

There are major technological challenges in realizing these goals. Genetic improvement of energy crops such as switchgrass, poplar, and jatropha has barely begun. It will be important to increase the yield and environmental range of energy crops while reducing agricultural inputs. Plant development, chemical composition, tolerance of biotic and abiotic stresses, and nutrient requirements are important traits to be manipulated. The combination of modern breeding and transgenic techniques should result in achievements greater than those of the Green Revolution in food crops, and in far less time.

The cost of biomass transport determines the supply area of a biofuels processing facility and thus its scale and economics. But unlike most food crops, there is no need to keep biomass intact. That means that in-field densification, pelletization, drying, and pyrolysis are among the technology opportunities to reduce transport costs. Fuel production from the lignocellulosic component of biomass will be a very important improvement. Its particular challenges of chemical recalcitrance and utilization of the constituent sugars to produce optimal fuel molecules and co-products are not intractable to current biotechnology. Similarly, process integration comparable to that of a modern petroleum refinery is a plausible chemical engineering goal.

Intertwined with the technology of large-scale biofuels production are the social and policy issues. The balances between natural vegetation and cultivation, arable and marginal land use, mechanized agriculture and employment opportunities, and food and energy crops will be important matters of discussion in many different forums. Whatever the outcomes, technologies will have to be sufficiently robust to accommodate a diversity of needs around the globe.

There is substantial technology "headroom" for advanced biofuels to enhance energy security, reduce GHG emissions, and provide economical transport. It exists largely because the world's scientific and engineering skills have not yet been focused coherently on the challenges involved. It is now time to do that through a coordination of government, university, and industrial R&D efforts, facilitated by responsible public policies. In the jargon of the petroleum industry, the "size of the prize" is too large to ignore.

—Steven E. Koonin

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*Brazil is a singular counterexample, where favorable agricultural conditions and a flexible processing infrastructure allow the majority of the country's road transport to be powered economically with cane-derived ethanol.

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