Biomass Movement

By John Deutch
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President Bush has made the welcome point that the U.S. needs "to move beyond a petroleum-based economy," and has lent his support to the need to develop energy from biomass, which refers to all bulk plant material. This is popular with the public and also enjoys significant support in Congress. Unfortunately, congressional subsidies for biomass are driven by farm-state politics rather than by a technology-development effort that might offer a practical liquid fuel alternative to oil. Meanwhile, major oil and chemical companies are evaluating biomass and investors are chasing biomass investment opportunities. But how much of this is practicable?

Biomass can be divided into two classes: food-crop and cellulosic. Natural enzymes can easily break down food-crop biomass such as corn to simple sugars, and ferment these sugars to ethanol. Cellulosic biomass -- which includes agricultural residues from food crops, wood and crops such as switch grass -- cannot easily be "digested" by natural enzymes.

Today, we use corn to produce ethanol in an automobile fuel known as "gasohol" -- 10% ethanol and 90% gasoline. Generous federal and state subsidies, largely in the form of exemption from gasoline taxes for gasohol, explain the growth of its use; in 2005, over four billion gallons of ethanol were used in gasohol out of a total gasoline pool of 120 billion gallons. Politicians from corn-states and other proponents of renewable energy support this federal subsidy, but most energy experts believe using corn to make ethanol is not effective in the long run because the net amount of oil saved by gasohol use is minimal.

In the U.S., cultivation of corn is highly energy-intensive and a significant amount of oil and natural gas is used in growing, fertilizing and harvesting it. Moreover, there is a substantial energy requirement -- much of it supplied by diesel or natural gas -- for the fermentation and distillation process that converts corn to ethanol. These petroleum inputs must be subtracted when calculating the net amount of oil that is displaced by the use of ethanol in gasohol. While there is some quarreling among experts, it is clear that it takes two-thirds of a gallon of oil to make a gallon equivalent of ethanol from corn. Thus one gallon of ethanol used in gasohol displaces perhaps one-third of a gallon of oil or less.

A federal tax credit of 10 cents per gallon on gasohol, therefore, costs the taxpayer a hefty $120 per barrel of oil displaced cost. Surely it is worthwhile to look for cheaper ways to eliminate oil.

The economics are not the same in other countries. Brazil is a well-known example, where sugarcane grows in the tropical climate and conventional fermentation and distillation readily yields ethanol. Ethanol is said to provide 40% of automobile fuel in Brazil and compete with gasoline without government subsidy. Depending on the future world price of sugar and the lessening of trade restrictions on both sugar and sugarderived ethanol, Brazil could become a net exporter of this biofuel.

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The situation in the U.S. is quite different for cellulosic biomass, because much less petroleum is used in its cultivation. There are two paths to convert this material to liquid fuel. In the chemical approach the cellulosic feedstock is gasified with oxygen to produce synthesis gas -- a mixture of hydrogen and carbon monoxide. This "syngas" can be converted by conventional chemical techniques into liquid fuel suitable for transportation use. The cost, although uncertain and dependent upon local production conditions, is in the range of $50 to $70 per barrel of oil, which explains why, until now, it has not attracted a great deal of attention.

The biotech approach, by contrast, seeks to produce new enzymes that will break down the difficult-to-digest cellulosic feedstock into simple sugars that can be fermented into ethanol or other liquid biofuels products. This approach merits genuine enthusiasm, especially as one can imagine engineering an organism to produce enzymes that (a) break down the cellulosic material, as well as (b) more efficiently ferment the sugars into ethanol. Realizing this exciting prospect will not be easy. Many hurdles must be overcome: Biotech experts need to assemble the gene "cassette" and the organisms, and talented engineers need to demonstrate a cost-effective process. Most importantly, an integrated bioengineering effort is required to develop a process that: reduces the harsh pretreatment required to dissolve the solid cellulosic feedstock; increases the concentration of ethanol that is tolerated by the enzymes; and achieves an efficient process to separate the ethanol from the product liquor.

Success will require a sustained research effort; it is too early to estimate the production costs of this method, because process conditions are unknown. However, the expected fossil energy inputs for cellulosic biomass will be much less than that of gasohol, because the energy cost for cultivation is less, and because the portion of the cellulosic material not converted to ethanol can be burned to provide process heat -- thus substantially lowering the implied cost of federal tax subsidies per barrel of oil displaced.
I will be astonished, but delighted, if the cost of ethanol or other biomass-derived chemicals proves to be less than $40 per barrel of its oil equivalent, and if large-scale production can be accomplished in six years.

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Critics of biomass argue that the conversion of sunlight into plant material is "inefficient," and that impractically large amounts of land would be required to produce significant amounts of transportation fuel. Both arguments are overstated. We should be humble about calling natural photosynthesis "inefficient" -- especially since we clever chemists cannot accomplish any artificial photosynthesis in the lab. At present, artificial photosynthesis is not an option, but it is an important basic research goal.

As for the land required to support significant biofuel production from a dedicated energy crop, switch grass offers a basis for estimation. It grows rapidly, with an expected harvest one or two years after planting. Ignoring crop rotation, an acre under cultivation will produce five to 10 tons of switch grass annually, which in turn provides 50 to 100 gallons of ethanol per ton of biomass. Thus the land requirement needed to displace one million barrels of oil per day (about 10% of U.S. oil imports projected by 2025), is 25 million acres (or 39,000 square miles). This is roughly 3% of the crop, range and pasture land that the Department of Agriculture classifies as available in the U.S. I conclude that we can produce ethanol from cellulosic biomass sufficient to displace one to two million barrels of oil per day in the next couple of decades, but not much more. This is a significant contribution, but not a long-term solution to our oil problem.

Rising real prices of oil and natural gas reflect in part the progressive decline in low-cost reserves, and signal the wisdom of preparing now for a long transition from our petroleum-based economy. Almost certainly, future economies will exploit all possible technology options for replacing petroleum-based liquid fuels, especially technologies that do not produce net carbon dioxide, the major greenhouse gas. Biomass should, properly, be considered along with nuclear power and coal conversion with carbon capture and sequestration as important options for future energy supply.

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