The Energy-Climate Crisis is Your Business

Part X: "Grassoline"–Biofuels The Right Way[1]

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THE CHALLENGE

Over the last decade, rapid growth in the use of biofuels for powering transportation has been championed globally by politicians and corporate executives as a strategy to 1. Increase income and jobs in rural communities; 2. Reduce dependence on foreign oil; and 3. Address emerging problems due to climate change[2]. Unfortunately, in some countries, for example the U.S., rapid expansion in biofuels production has been driven primarily by special-interest political groups, who seek to generate jobs and stimulate their local economies, and are less concerned with improved economics, environmental benefits, and increased energy efficiency and security. This is an ineffective and untenable approach to addressing energy-climate issues, however in emerging "second-generation" biofuel technologies there is significant promise on the horizon.

Rapid growth in biofuels has contributed to sharp increases in the price of food, grains, and commodities, such as sugar and soybeans. This has created debates as to whether biofuels have a viable future. In the ethanol-from-corn industry, exuberant expansion has been so intense in the U.S. (see **Figure 1**) that now, as we face significant global financial challenges, some ethanol refineries are being closed with the consequent loss of jobs they initially created, and precipitation of a greater negative economic impact than that which they sought to alleviate. Recent studies conclude that the environmental costs of producing corn-based ethanol outweigh its benefits. When the cost contributions from water pollution, loss of wildlife habitat, and decreasing freshwater resources are accounted for, the benefits are questionable[3].

Of equal importance, corn-based ethanol, via conventional fermentation technology provides only a minimal reduction in greenhouse gases (GHG), and current estimates show that the use of this fuel leads to only a 12–18 % reduction in GHG emissions, compared to gasoline. In many instances, corn is grown on carbon-rich land, which results in the release of that carbon into the atmosphere as CO_2, exacerbating global warming. In such cases, environmental benefits completely disappear[4].

It is clearly important that the U.S. and other developed countries foster the growth of a global biofuels industry. However, this transition must focus primarily on "second generation" technologies for the production of bioethanol and biodiesel i.e., not just on bioethanol from annual crops such as corn and soybeans, but from agricultural waste, rapid-growth trees, grasses, and other plants that have little or no food value. Technologies exist to achieve this transition, but in doing so the primary drivers must be improved economics, higher energy efficiency, and increased environmental compatibility and sustainability – not the political forces of special-interest groups.

THE NEAR-TERM SOLUTION

Biofuels such as bioethanol and biodiesel can be produced from anything that currently is, or ever was a living plant. Plants take energy from the sun and through photosynthesis convert atmospheric CO_2, water and soil nutrients into starch, cellulose, hemicellulose – a highly-stable form of cellulose – and lignin – a polymer that gives plants their form, strength, and rigidity. Starch is readily broken down into simple sugars, which then can be fermented by age-old technology to ethanol. Corn and soybeans are rich in starch and therefore are easily converted to ethanol, which is why, based on these readily available feedstocks, there has been rapid growth in ethanol refineries in the U.S. and elsewhere. Currently, in the U.S., 180 are in operation in 22 states. However, in developed countries such as the U.S., there is not enough available farmland to manufacture more than 10–15 % of their liquid-fuel requirements from crops such as corn and soybeans (see **Figure 2**)[5].

Furthermore, the energy and environmental benefits of corn-based bioethanol are questionable, and certainly significantly less than those available from second generation technologies based on cellulose feedstocks. Current corn-to-ethanol technologies can at best yield a product with 25–35% more energy content than the fossil-fuel based energy required in its lifecycle production i.e., from the corn field to the fuel tank in your car. Cellulosic ethanol, on the other hand, can provide 400–900% more energy than the fossil-fuel based energy required to produce it. These substantial energy gains also represent huge benefits in addressing climate change. Current projections show that fueling vehicles with cellulosic ethanol or cellulosic diesel fuel could reduce GHG emissions by 86–94% compared to gasoline and diesel fuel, versus a reduction, at best of 12–18% for corn ethanol[6].

Cellulosic biofuels can be produced from hundreds of feedstock sources, including wood waste, agricultural residues such as cornstalks and wheat straw, and numerous fast-growing grass "weeds" such as switch grass. These feedstocks are cheap – with a fully-loaded cost of $10–40 per barrel of oil energy equivalent. They are abundant, and do not conflict with food production. Furthermore, most of these feedstocks, such as switch grass can be grown on fallow land, and some grasses, such as willow coppice, actually decontaminate land that has been polluted by toxic waste water and heavy metals – so-called phytoremediation[7]. The potential for cellulosic biofuels far exceeds that for food crops, such as corn and soybeans (see **Figure 2**).

A recent study by the U.S. Department of Agriculture and the U.S. Department of Energy concludes that the

Figure 1 – U.S. Corn Used in Ethanol Production, 1980–2008 (2)

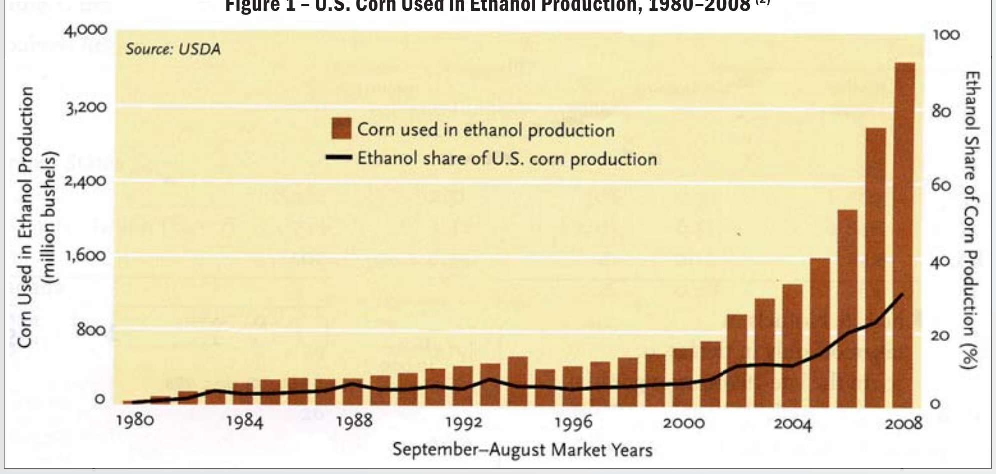

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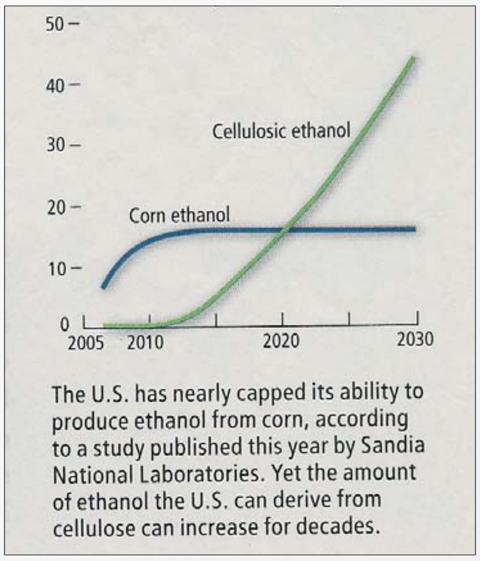
Figure 2 – Amount of Ethanol The U.S. Can Produce (Billions of Gallons)[(5)]



U.S. can produce annually, a minimum of 1.4 billion dry tons of cellulosic biomass without decreasing the level of crops available for food, animal feed and exports (see **Figures 3**)[8]. As shown in **Figure 4**, the U.S. could easily produce the equivalent of 50 % of its current petroleum requirements from biofuels. Based on these and similar figures, projections estimate that the annual global supply of cellulosic biomass feedstocks has an energy content that is equivalent to between 34 and 160 billion barrels of oil per year, depending upon whether one assumes a conservative or optimistic scenario, respectively. This level of biofuels production significantly exceeds the current annual global consumption of petroleum of 30 billion barrels. Also, as has been demonstrated at the pilot-plant level, cellulosic feedstocks can be converted to essentially any of our current or projected fuel requirements – ethanol, gasoline, diesel, and jet fuel. For example, cellulose can be converted via enzymatic catalysis to glucose, which can then be fermented to ethanol. Ethanol is then readily transformed over molecular-sieve zeolite catalysts to your choice of gasoline, diesel fuel or jet fuel, simply by modifying the design of the catalyst and the process conditions. In the U.S., in April 2009, there were 25 cellulosic ethanol demonstration or pilot plants and two cellulosic diesel plants in operation[9].

Newer technologies are now at the pilot-plant stage for converting the hemicellulose in plants to glucose, and separating the lignin for use as fuel for the distillation step, subsequent to fermentation. These improvements provide a large increase in overall energy efficiency and process economics.

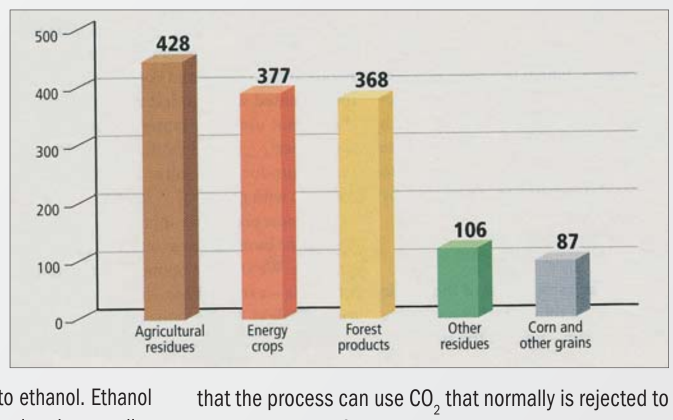
In alternate high-temperature “thermolysis” processes (~500 °C), highly-stable biomass feedstocks can be converted to “biocrude” oil, analogous to petroleum crude oil. This biocrude can then be processed to transportation fuels in existing petroleum refineries. At higher temperatures (>700 °C), synthesis gas – a mixture of carbon monoxide and hydrogen – can be produced. Using Fischer-Tropsch technology, developed in Germany during World War II, and optimized since then by Shell, ExxonMobil and other oil companies, as well in South Africa by the SASOL refinery, the synthesis gas can be converted to existing fuel products such as gasoline, diesel and jet fuel. A modern Fischer-Tropsch plant was built in 2006 in Qatar in cooperation with ExxonMobil to convert that country’s large stores of natural gas to liquid fuels, which are much less costly and safer to transport.

Favorable economics for various biofuels technologies vary, but nearly all require oil at a price of more than $50 per barrel to be cost competitive with current petroleum technology. For the foreseeable future, this does not appear to be a hurdle. In fact, it is likely that the current approximate $70 per barrel price of petroleum will increase significantly over the next 18 months to more than $100 per barrel. The economics for at least one process, called the AFEX Process can produce cellulosic bioethanol for $1 per gallon of equivalent gasoline energy content, and this biofuel would likely sell for less than $2 per gallon at the pump[10].

THE FUTURE

As research continues in biofuels, perhaps the most promising technology in these “third generation” biofuels is that based on microalgae. Microalgae are single-cell organisms produced in water via solar photosynthesis of CO_2 and nutrients. These organisms grow rapidly – often doubling their mass in 24 hours – and are rich in natural oils that can be used as biodiesel and other transportation fuels. This means that it would be possible to produce more than 100 times more oil per acre than standard biodiesel crops, such as soybeans. An additional benefit is that the process can use CO_2 that normally is rejected to the atmosphere from power plants and other emitting sources.

Figure 3 – Amount of Biofuel Feedstock the U.S. Can Sustainably Produce[(5)]

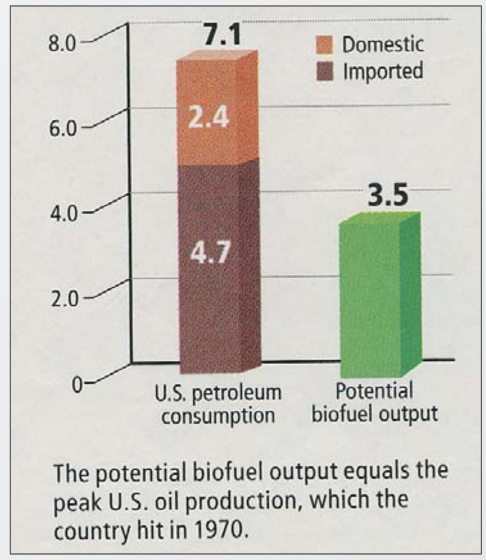


Craig Venter, who led the Celera Genomics effort that was the first group to determine the human genome, is now head of Synthetic Genomics, a firm based in San Diego, California. Venter is using genomics to develop a commercial process that will produce microalgae that have been genetically engineered to yield the desired final biofuels directly, without the requirement of refinery processing. The credibility of his technology can perhaps be viewed by the fact that Synthetic Genomics recently signed a $600 million agreement with Synthetic Genomics to develop and commercialize Venter’s technology[11].

THE PROMISE

Earlier this year, U.S. President, Barak Obama signed into law a stimulus bill for clean sustainable energy, which contains $800 million in funding for the U.S. Department of Energy’s Biomass Program. This should accelerate biofuels research and development, and also the bill provides up to $6 billion in loan guarantees for “leading edge” biofuels projects that will initiate construction by October 2011. If the U.S. maintains this momentum and level of commitment, it could become a world leader in next generation biofuels production. In doing so, it would help lead a global transition away from petroleum to a new era where energy security is no longer an issue, and hopefully the current consequences of climate change are diminished.

Figure 4 – Current Oil Consumption And Potential Biofuel Production (Billion Barrels of Oil Equivalent) [(5)]



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[1] *Parts I and II of this series outline the Global Energy Security and Climate Change issues, respectively; Part III provides a summary of a workable solution; Part IV presents an analysis of nuclear power; Parts V and VI describes the role of vehicular transportation with a focus on hybrid, electric and fuel-cell cars; Part VII details the potential of wind power; Part VIII treats the potential impact of solar energy, and Part IX addresses the future of global oil prices. See www.LeadersMagazine.Cz, volumes 2, 3, 4, 5, 2008 and 1, 2, 3, and 4, 2009.*
[2] *F.O. Licht, World Ethanol and Biofuels Report, March 26, 2009.*
[3] *Jane Early and Alice McKeown, “Red, White, and Green: Transforming U.S. Biofuels,” Worldwatch Report 180, Worldwatch Institute, Washington, D.C. 2009, p. 5.*
[4] *Ibid*
[5] *George W. Huber and Bruce E. Dale, “Grassoline at the Pump,” Scientific American, July 2009, p. 40.*
[6] *Jane Early and Alice McKeown, Op. cit., p. 17–18.*
[7] *Ibid, p. 42.*
[8] *U.S. Department of Energy Biomass Program Website: http// eere.Energy.Gov/Biomass*
[9] *Jane Early and Alice McKeown, Op. cit., pp. 19–20.*
[10] *George W. Huber and Bruce E. Dale, Op. cit., p. 47.*
[11] *The Economist, July 18, 2009, pp. 74–75.*

About the Author: James A. Cusumano is Chairman and owner of Chateau Mcely (www.ChateauMcely.Com), chosen in 2007 by the European Union as the only “Green” 5-star luxury hotel in Central and Eastern Europe and in 2008 by the World Travel Awards as the Leading Green Hotel in the World. He is a former Research Director for Exxon, and subsequently founded two public companies in Silicon Valley, one in clean power generation, the other in pharmaceuticals manufacture via environmentally-benign, low-cost, catalytic technologies. While he was Chairman and CEO, the latter – Catalytica Pharmaceuticals, Inc. – grew in less than 5 years, to a $1 billion enterprise with 2,000 employees. He is co-author of “Freedom from Mid-East Oil,” recently released by World Business Academy Press (www.WorldBusiness.Org) and can be reached at Jim@ChateauMcely.Com.