LIGNOCELLULOSIC BIOMASS: A POTENTIAL FEEDSTOCK TO REPLACE PETROLEUM

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Sustainability considerations for product and energy production in a future US economy can be met with lignocellulosic biomass. The age of petroleum as the key resource to meet the US economy requirements is rapidly dwindling, given the limited resources of petroleum, the growing global population, and concurrent detrimental effects on environmental safety. The use of natural and renewable feedstocks such as trees and switchgrass is becoming more attractive; indeed, lignocellulosic biomass is becoming a logical alternative to petroleum in light of looming oil shortages, increases in oil prices, and environmental sustainability considerations. This editorial aims at providing a broad overview of the considerations for replacing the US petroleum economy with one based on lignocellulosic biomass.

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The US Chemical industry generates a large amount of hazardous waste that is released at a staggering rate of nearly 1.5 billion pounds annually, while the US fossil fuels industries (petroleum, natural gas, coal) likewise produce roughly 1.6 GT of greenhouse gases emissions (primarily CO_2) annually. Outspoken critics have suggested that one way to offset such environmental pollution is to explore utilizing the most abundant feedstocks on the planet, *viz.*, carbohydrates and lignin. These polymers are present in a collective matrix known as lignocellulosics (e.g., trees, switchgrass, bagasse, but not corn) represent a vast amount of biomass (in the range of hundreds of billions of tons), *of which only 3% is used by humans.*

As opposed to synthetic chemicals and fossil fuels, these polymers are readily renewable, inexpensive, and environmentally benign. Interestingly, the systematic exploitation of this vast resource is still in its infancy and has only been recently been given a jump start by rising fuel prices. Since clean air pressures are mounting, while the availability of cheap and abundant fossil fuel becomes increasingly questionable as seen in the current climate, it is likely that any economic advantages for a petrochemical-based economy will evaporate within the next fifty years.

Yet, can such feedstocks really replace our current petro-chemicals and fossil fuels? In short, at least in the short term with respect to products, the answer is a resounding yes! However, the inertia with respect to products and energy for such a broad paradigm shift in the way the US does business has been based on simple economics. Oil has always been cheaper than any other commodity product, hence delaying the implementation of a bio-based economy that was predicted by Henry Ford in the early part of the 19th century as a logical and necessary choice for the growth of any civilization. But now, given that the prices of a barrel of oil are well over US $140, the competitive price advantage fossil fuels have enjoyed for the last century have disappeared. From a global perspective, rising populations and the need for cheap energy/resources to maintain continued growth have only exacerbated the need for fossil fuels. But maintaining a global dependence on fossil fuels does not make any sense, especially given the well-known environmental, geo-political, and economic (local) problems such dependence causes!

It behooves us to investigate rational methodologies to get chemical and fuel value from our natural lignocellulosic resources. For example, one of our major companies, DuPont, has already determined that an extractive from plants, tulipalin (A–α-methylenebutyrolactone), is competitive with its major commercial analogue, methyl methacrylate, for polymer applications. Also, the pharmaceuticals industry continuously engages in a variety of organic chemical manipulations with environmental risks, the most significant being toxicity and disposal of reaction by-products and solvents. As a consequence of these problems, the scientific community has paid considerable attention to alternative solvents, including water, fluorinated solvents, supercritical fluids, and ionic liquids.

An early example of a bio-based "green" solvent is a new class of chiral ionic liquids that can be derived from α-pinene, an extractive from pine trees. Ionic liquids are salts that are liquid at or near room temperature. As such, they are composed of an anion and a cation, like any salt, but they do not have the high melting points typical of salts. Since the combination of organic cations and anions is virtually limitless, several classes of ionic liquids have actually been reported with more and more such systems discovered continuously.

Finally, one of the unifying themes in all biomass work is the development of "biorefinery," i.e., a conceptualized site that provides materials, chemicals, and energy from renewable resources. The biorefinery concept describes the ability to convert traditional feedstock into usable energy and products. Currently, the biorefinery concept is receiving a lot of impetus to explore the conversion of our most abundant lignocellulosic biomass, wood → ethanol, to replace gasoline as a motor fuel source. It is not feasible to use a non-lignocellulosic, corn, to make a significant dent in our national or global demands.

Lignocellulosic biomass is therefore a potential source of starting materials for many industrial processes. The advantage of this biomaterial is that its processing is or will shortly become less expensive than petroleum, it will not affect food supplies, and all chemicals derived from it will have a lower environmental impact than petrochemicals. Additionally, it is considered carbon dioxide-neutral because burning it with coal in power plants doesn't add carbon to the environment beyond what was required for the process of growth. Five percent of all global chemical sales relate to "green" products such as ethanol, pharmaceutical intermediates, citric acid, and amino acids. This market share may go as high as 20% by 2010 and may reach as high as 2/3 of the total global economy, if low-cost enzymes and new recombinant technologies to make more efficient enzymes become available.

The future of extracting chemical, material, and energy values from lignocellulosic biomass appears to be bright. It promises to be brighter with the current attention and high potential to reduce US dependence on fossil fuels and thereby develop a renewable resource-based economy.