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A bioeconomy vision of sustainability…

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Much of the interest in biofuels, bioproducts, and the broader bioeconomy stems from the quest for environmental sustainability. Biological resources are potentially renewable and therefore can form the basis of a sustainable bioeconomy, but only if the economy is deliberately designed for sustainability.[1] A sustainable economy is a tall order. It must use renewable resources as much as possible, assure the supply of food and water, minimize environmental impact, and provide an acceptable quality of life. For all practical purposes, the issues of climate change and sustainability of life cannot be separated from the issues of hunger, poverty, regional development, and quality of life. Production of energy, goods, and services is necessary, but it must be socially, economically, and environmentally sustainable.[1]

Consumption in a bioeconomy will have to be managed within acceptable limits

Mankind once relied exclusively on a primitive bioeconomy. The discovery of fossil fuels offered an easier route to growth, but one that is now known to have terrible consequences. Greenhouse gas emissions associated with fossil fuels are indeed a threat to public health and to our survival. Reducing man-made carbon emissions is essential. Carbon neutral biofuels and other renewable energy sources must largely displace fossil fuels.

Biofuels, unfortunately, have a bad name. Poor analyses, disregard of facts, and pure fantasy have resulted in false starts and outright mistakes in relation to biofuels. Not all existing biofuels are environmentally sustainable or socially desirable. A major limitation of the existing biofuels is their inability to displace petroleum-derived transport fuels to any significant extent,[2,3] but this may change. For example, liquid fuels from microalgae have the potential to substantially displace fossil transport fuels.[2-5] Production of algal fuels remains expensive, but may become affordable in view of the significant developmental effort now being made.[6-8] Algae bioengineered for nitrogen fixation have the potential to provide fuels without requiring nitrogen fertilizers that represent a significant fossil energy input to algae production processes.[9]

Biofuels should produce a net benefit, but not every biofuel type needs to necessarily have a positive net energy balance. For example, the energy consumed in producing a gallon of fossil diesel exceeds the energy it contains.[10] Similarly, as Dale has eloquently argued,[11] a negative net energy balance for a biofuel is not necessarily bad so long as the total carbon footprint of the biofuel is lower than the carbon footprint of the fossil fuel it displaces. Furthermore, the utility of a given quantity of energy from different sources is different[11] and, therefore, equating a megajoule of petroleum energy to a megajoule of bioenergy is an unsatisfactory comparison.[11] For example, 8400 kilojoules worth of food can fuel me for a day, but not the same kilojoules worth of coal. Bioenergy has its own value.

Food fuels us and its sustainable production is important. Availability of food has always controlled animal population in the wild just as it constrained human population for much of our existence. Domestication of crops and animals enhanced the reliability of food supply and continual innovation in agriculture increased productivity so much so that large populations could be supported. Productivity enhancements came from enhanced crop biology, but the use of fossil-fuels-based practices and synthetic nitrogen fertilizers contributed immensely. As a consequence, much of the existing food production is not environmentally sustainable. Sustainable biological alternatives to nitrogen fertilizers need to be found and the carbon footprint of agriculture must be reduced to a minimum.

Unfortunately, we are not likely to be able to replace every carbon-emitting process with a carbon-neutral alternative. Therefore, sustainable methods need to be found to affordably sequester the carbon dioxide that has already accumulated in the environment and that will continue to be emitted to some level in any future sustainable economy. Sequestering methods based on microalgae[12] and biochar[13] seem to offer promising biological options.

A bioeconomy will be powered by the Sun through photosynthesis, an ancient biological process that is the mainstay of nearly all life on Earth. Photosynthesis captures sunlight and converts it to biomass, but has a limited capacity for doing so. Genetic and metabolic engineering have a pivotal role in improving the productivity of crops and other biosystems;[1,2,14-16] for example, by enhancing the efficiency of photosynthesis. Metabolic pathways need to be engineered to allow biosystems to directly produce the desired fuels, chemicals and materials. Production processes can be simplified and made affordable by genetic and metabolic engineering. Engineered biosystems have the potential to greatly enhance the supply of food, biofuels, and other materials without relying on inputs of fossil energy.

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No sustainable economy can provide infinite amounts of goods and services and, therefore, consumption in a bioeconomy will have to be managed within acceptable limits. The necessary transition to a sustainable bioeconomy will not happen overnight and may never happen without supportive governmental policies.[17] Sustainability is a global imperative and demands urgent international action. In principle, a bioeconomy can be environmentally, socially and economically sustainable until of course the Sun fizzles out, or some other natural catastrophe befalls Earth.

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