ENERGY

# Beneficial Biofuels—The Food, Energy, and Environment Trilemma

Exploiting multiple feedstocks, under new policies and accounting rules, to balance biofuel production, food security, and greenhouse-gas reduction.

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Recent analyses of the energy and greenhouse-gas performance of alternative biofuels have ignited a controversy that may be best resolved by applying two simple principles. In a world seeking solutions to its energy, environmental, and food challenges, society cannot afford to miss out on the global greenhouse-gas emission reductions and the local environmental and societal benefits when biofuels are done right. However, society also cannot accept the undesirable impacts of biofuels done wrong.

Biofuels done right can be produced in substantial quantities (*1*). However, they must be derived from feedstocks produced with much lower life-cycle greenhouse-gas emissions than traditional fossil fuels and with little or no competition with food production (see figure, below). Feedstocks in this category include, but may not be limited to, the following:

1) *Perennial plants grown on degraded lands abandoned from agricultural use.* Use of such lands minimizes competition with food crops. This also minimizes the potential for direct and indirect land-clearing associated with biofuel expansion, as well as the resultant creation of long-term carbon debt and biodiversity loss. Moreover, if managed properly, use of degraded lands for biofuels could increase wildlife habitat, improve water quality, and increase carbon sequestration in soils (*1*–*3*). The key to carbon gains is to use land that initially is not storing large quantities of carbon in soils or vegetation and yet is capable of producing an abundant biomass crop (*4*, *5*). Some initial analyses on the global potential of degraded lands suggest that they could meet meaningful amounts of current global demand for liquid transportation fuels (*5*–*7*).

2) *Crop residues.* Crop residues such as corn stover and straw from rice and wheat are produced in abundance. They are rich in elements (C, N, and P) essential for maintaining soil fertility and carbon stores, and they help minimize soil erosion. Recent research suggests that it is to the benefit of farmers to leave substantial quantities of crop residues on the land (*8*), but that, nonetheless, even conservative removal rates can provide a sustainable biomass resource about as large as that from dedicated perennial crops grown on degraded lands (*1*).

3) *Sustainably harvested wood and forest residues.* Another abundant feedstock is residues from forestry operations, which include slash (branches, but not leaves or needles) that currently is left in place, unused residues from mill and pulp operations, and forest "thinnings" removed to reduce fire risk or to allow select trees to attain merchantable sizes more quickly (*9*, *10*).

4) *Double crops and mixed cropping systems.* Double crops grown between the summer growing seasons of conventional row crops and harvested for biofuel production before row crops are planted in the spring are representative of a class of land-use options with potential to produce biofuel feedstocks without decreasing food production and without clearing wild lands (*11*). Mixed cropping systems in which food and energy crops are grown simultaneously present similar opportunities (*12*, *13*).

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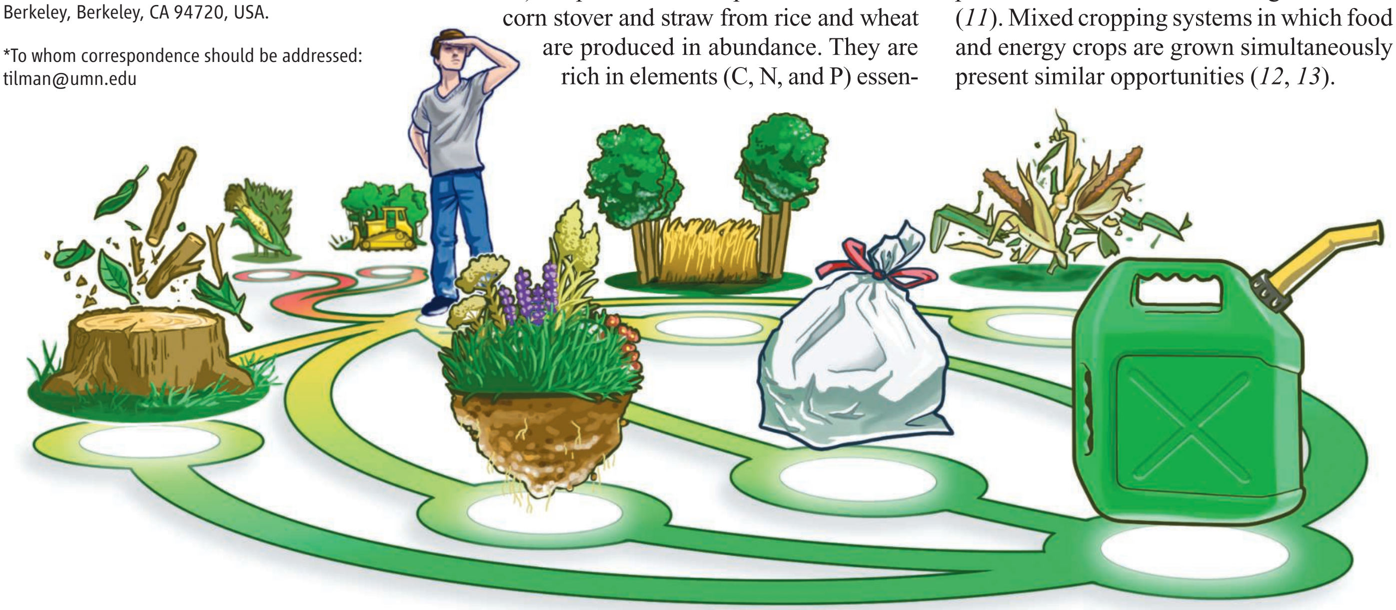

**The best biofuels.** The search for beneficial biofuels should focus on sustainable biomass feedstocks that neither compete with food crops nor directly or indirectly cause land-clearing and that offer advantages in reducing greenhouse-gas emissions. Perennials grown on degraded formerly agricultural land, municipal and industrial sold waste, crop and forestry residues, and double or mixed crops offer great potential. The best biofuels make good substitutes for fossil energy. A recent analysis suggests that more than 500 million tons of such feedstocks could be produced annually in the United States (*1*).

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5) *Municipal and industrial wastes.* Solid waste streams, which are frequently rich in organic matter, including paper, cardboard, yard wastes, and plastics, can be converted to liquid fuels (*14*, *15*).

As global population and standards of living increase during the coming decades, both the urgency to lower greenhouse-gas emissions and the demand for transportation and meat may increase. Nonetheless, the five biomass sources discussed above—in combination with large reductions in fuel demand, achieved through increased efficiency, and large increases in both food and biomass productivity on existing farmland—could produce enough biofuels to meet a substantial portion of future energy demand for transportation (*1*).

However, looming over the future of biofuels are several wrong options. Sometimes, the most profitable way to get land for biofuels is to clear the land of its native ecosystem, be it rainforest, savanna, or grassland. The resulting release of carbon dioxide from burning or decomposing biomass and oxidizing humus can negate any greenhouse-gas benefits of biofuels for decades to centuries (*16*–*20*). Decisions regarding land for biofuels can have adverse consequences far beyond the land directly in question. For example, if fertile land now used for food crops (such as corn, soybeans, palm nuts, or rapeseed) is used to produce bioenergy, this could lead, elsewhere in the world, to farmers clearing wild lands to meet displaced demand for crops. In this way, indirect land-use effects of biofuels can lead to extra greenhouse-gas emissions, biodiversity loss, and higher food prices (*21*, *22*).

**Dramatic improvements in policy and technology are needed to ... meet global demand for both food and biofuel feedstocks.**

Dramatic improvements in policy and technology are needed to reconfigure agriculture and land use to gracefully meet global demand for both food and biofuel feedstocks. Good public policy will ensure that biofuel production optimizes a bundle of benefits, including real energy gains, greenhouse-gas reductions, preservation of biodiversity, and maintenance of food security. Present legislation in the United States takes partial steps in the right direction by specifying minimally acceptable greenhouse benefits for certain types of biofuels. Notably, the U.S. 2007 Energy Independence and Security Act states that cellulosic biofuels (such as ethanol made from cellulose) must, when both direct and indirect emission are taken into account, offer at least a 60% life-cycle greenhouse-gas reduction relative to conventional gasoline (*23*).

The biofuels industry is positioned to undergo rapid growth. The attendant policy should anticipate and provide for a biofuels industry that meaningfully and positively addresses pressing sustainability and security challenges. Biofuels should receive policy support as substitutes for fossil energy only when they make a positive impact on four important objectives: energy security, greenhouse-gas emissions, biodiversity, and the sustainability of the food supply. Performance-based policies are needed that provide incentives proportional to the benefits delivered. Legislation that is vague could allow significant portions of the biofuels industry to develop along counterproductive pathways. Complementary policies must directly target related goals, such as land- and water-efficient food production, reduced agricultural greenhouse-gas emissions, and the prevention of habitat loss from land-clearing (*24*, *25*).

The recent biofuels policy dialogue in the United States is troubling. It has become increasingly polarized, and political influence seems to be trumping science. The best available science, continually updated, should be used to evaluate the extent to which various biofuels achieve their multiple objectives, and policy should reward achievement. Three steps should be taken: meaningful science-based environmental safeguards should be adopted, a robust biofuels industry should be enabled, and those who have invested in first-generation biofuels should have a viable path forward.

In support of such policy, rigorous accounting rules will need to be developed that measure the impacts of biofuels on the efficiency of the global food system, greenhouse-gas emissions, soil fertility, water and air quality, and biodiversity (*26*). Accounting rules should consider the full life cycle of biofuels production, transformation, and combustion.

Unless new technologies and life-styles are adopted globally over the coming decades, the massive projected increases in global energy and food consumption will greatly elevate atmospheric greenhouse-gas levels from fossil fuel combustion, land-clearing, and livestock production and will create immense biodiversity loss from habitat destruction and climate change. The quality of human life will be compromised. A central issue for the coming decades, then, is how the environmental impacts and potential benefits associated with meeting the global demand for food and energy can be internalized into our economic systems (*27*). This is a complex question that cannot be addressed with simplistic solutions and sound bites. It needs a new collaboration between environmentalists, economists, technologists, the agricultural community, engaged citizens, and governments around the world.

**References and Notes**


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28. Individuals whose backgrounds span a broad range of perspectives gathered in Princeton, NJ, to exchange views about the sustainability of biofuels, food, and the environment. After considerable back-and-forth, we arrived at the consensus presented above. We are hopeful that colleagues charged with developing biofuels policies, who are likely to span a similarly broad range of views, will benefit from our deliberations. We thank the Carbon Mitigation Initiative at the Princeton Environmental Institute, supported by BP and Ford, for funding the workshop.

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