Carving Out Policy Space for Sustainability in Biofuel Production

Liz Marshall

Biofuels such as ethanol and biodiesel are increasingly promoted as green alternatives to petroleum-derived transport fuels. Scaling up feedstock production to produce enough biofuel to displace a significant portion of current petroleum demand will put pressure on land and water resources both domestically and internationally, however, and could potentially be accompanied by unacceptable changes in landscape-level land use patterns and provisioning of ecosystem services. Ensuring that feedstock production is sustainable and that biofuels provide the social and environmental benefits that are often attributed to them will require a carefully designed portfolio of agricultural, forestry, energy, and trade policies related to biofuels and feedstock production. Despite the difficulties associated with development and application of such policies, they should be in place before further policy incentive is provided for expansion of biofuel industries.

Key Words: biofuels, sustainability, land use, greenhouse gas accounting

Renewable energy goals in the United States have proliferated since the turn of the millennium. Prompted by volatility in oil markets, a growing realization that fossil fuel combustion contributes to global warming, and an interest in supporting farms and rural communities through stronger agricultural markets, stakeholders from many sectors are eyeing biomass as an alternative energy source. Biomass can be used for energy in several ways: burned directly to generate heat and power, dried and densified into solid fuels such as wood and corn pellets, or converted into liquid or gaseous fuels such as ethanol for use in stationary or mobile source combustion. Because there are other renewable sources of electric power such as solar and wind, however, and no other readily available transport fuel substitutes that work with our current engine technologies, it is this latter category of use that has captured the attention of industry, policymakers, and the public.

The potential benefits of biofuels have been widely discussed and promoted, but the potential costs, and ways to avoid them, are only beginning to receive the attention they require. Potential benefits include increased value of agricultural products and support for farmers and the agricultural sector in both developed and developing countries, potential reductions in greenhouse gas emissions relative to petroleum-based fuels, and improved energy security for countries that grow their own feedstocks. Projected increases in biofuel trade are also considered a potential driver of economic growth for developing countries in the tropics and subtropics, which are likely to hold a comparative advantage in feedstock production due to high biomass productivity.

In an effort to capture these benefits, in many countries the rush to establish national objectives, directives, and policies to stimulate biofuel production has overshadowed the burgeoning debate about the risks and downsides associated with biofuel production. There are, however, significant social and environmental implications associated with scaling up biofuel and biofeedstock production domestically and worldwide; realizing the potential benefits of biofuels will require a concerted effort to design policies that direct the biofuels industry, together with patterns of production and trade, away from paths of expansion that have unacceptable social and environmental impacts. The next wave of biofuel policy efforts

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should therefore focus less on promoting expansion of biofuel production and infrastructure and more on facilitating the emergence of sustainable paths for industry expansion, creating incentives to direct industry and technological development along those paths, and, where necessary, developing safeguards against unintended side effects of biofuel production.

Biofuels in the United States

The term "biofuels" covers a wide range of alternative transport fuels produced from organic materials, such as ethanol, methanol, and biodiesel. The use of biomass-derived fuels is nothing new. When Rudolf Diesel demonstrated the first diesel engine at the 1896 World's Fair in Paris, it was running on peanut oil. Much later, in 1912, he was quoted as saying, "The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal tar products of the present time." Another transport pioneer, Henry Ford, designed his first Model T to run on alcohol, explaining to a New York Times reporter in 1925 that "the fuel of the future is going to come from fruit like that sumac out by the road, or from apples, weeds, sawdust—almost anything. There is fuel in every bit of vegetable matter that can be fermented."

Although held at bay in the United States for nearly a century by the availability of cheap petroleum products, the future envisioned by these men now appears to be back on the horizon. In 2002 the Biomass Research and Development Board—a cabinet-level council co-chaired by the U.S. Department of Agriculture and the U.S. Department of Energy—came out with their "Vision for Bioenergy and Biobased Products in the United States," which included an objective that biomass supply in 2030 an amount of power, fuels, and chemicals roughly equivalent to 30 percent of the country's petroleum consumption in 2003. A follow-up feasibility study found that with projected technological advances, the nation could achieve that goal; the requisite amount of biomass—more than a billion tons per year—is assumed to come from sources including crop and forestry residues, wood and paper processing residue, dedicated energy crops, sustainable forest harvest, and construction and demolition debris (U.S. Department of Agriculture and U.S. Department of Energy 2005a). At roughly the same time, an influential multi-institutional study called "The Role of Biomass in America's Energy Future" concluded that immediate aggressive investments in feedstock and conversion research, combined with extensive efficiency and smart growth measures to reduce demand, could create an ethanol industry capable of virtually eliminating U.S. gasoline demand by 2050 (Greene 2004).

Prompted by these and other calls for movement toward national renewable objectives, legislative action soon followed. To catalyze expansion of renewable fuel markets in the United States, Congress included in the Energy Policy Act of 2005 (EPACT) the first federal mandate for renewable fuels use—a Renewable Fuel Standard (RFS) requiring incremental increases in the amount of renewable fuel blended into the nation's fuel supply, up to 7.5 billion gallons per year by 2012. In subsequent State of the Union addresses, the Administration weighed in on the issue; although the President's mention of "switchgrass" as a renewable energy source was met with collective confusion across the country in 2006, the obscure prairie grass was a household word by the time his 2007 address called for broadening the RFS to require use of 35 billion gallons per year of "alternative" fuels by 2017. Several pieces of biofuel legislation have been introduced in support of this goal and are pending Congressional consideration.

There is, however, a disconnect between the original calls for renewability and the legislative action that has followed. All of the original studies predicate their biofuel objectives on *sustainable* production of biofuel feedstocks. Although non-renewable fossil fuels are used throughout the life cycle of biofuels as raw material for fertilizer, to power tillage and harvest equipment, and to transport feedstock and final product, biofuels are considered renewable in the sense that their primary feedstock can be a number of renewable biomass sources. Biofuels are sustainable only, however, if those feedstocks and fuels are produced and combusted in a way that does not compromise the long-term health and productivity of air, soil, and water resources, or unbalance the social systems that rely on those resources. Nevertheless, requirements for sustainability have not yet been incorporated into U.S.

legislation promoting biofuel development, despite widespread concern about the impacts of scaling up global production to meet future projections for biofuel demand[1] (Figures 1 and 2).

Biofuels and Sustainability

Two key themes have emerged within the burgeoning debate on the sustainability of biofuels: concerns about the sustainability of feedstock production and questions regarding full accounting for the carbon content of biofuels. The two themes are related, as inputs into feedstock production can produce a large portion of the greenhouse gas (GHG) emissions associated with fuels, but are often discussed and handled separately in the policy arena. The first theme recognizes that many of the environmental and social impacts of biofuel production occur as a result of feedstock production and centers around the question of whether biofuel feedstocks can be grown sustainably, and at what scale. Concerns related to feedstock production generally arise and are discussed in policy venues related to agriculture and forest management. The second theme concerns the life-cycle greenhouse gas impacts—or "carbon content"—of biofuels and asks whether, given that biofuels are promoted as a climate-friendly alternative to petroleum fuels, they are in fact effective at displacing greenhouse gas emissions in the transport sector, and to what extent. Fuel carbon content discussions usually surface in the context of energy policy debates. Both discussion threads ultimately lead back to the question of how to identify and quantify the impacts of biofuel production and combustion, and how to incorporate a consideration of such impacts into policies that provide the correct incentive for the evolution of feedstock and fuel production technologies.

Scale concerns related to feedstock production arise largely from the resource requirements for feedstock production. Although biofuel feedstocks vary widely by region, all feedstocks require land and water in some form. The amount of land required depends on the crop productivity (tons per acre) and the conversion efficiency of the feedstock (biofuel yield per ton). As shown in Figure 3, the resulting estimates of land-use efficiency (gallons per acre) vary widely with feedstock and with fuel. A study commissioned by the World Bank found that the most land-efficient way to produce enough biofuels to displace 5 percent of global transport fuel use would be to concentrate production on ethanol from Brazilian sugar cane (an additional 10 million hectares) and biodiesel from Indonesian palm oil (an additional 10.5 million hectares) (Kojima, Mitchell, and Ward 2007). Diversifying feedstocks to include less land-efficient feedstocks, such as corn for ethanol and soybeans for biodiesel, causes the additional land requirements to quintuple, to 100 million hectares worldwide (Kojima 2006).

A comprehensive assessment of the impacts of feedstock production on natural resources requires consideration of two important dimensions of production: the impact of producing feedstocks (i.e., the impacts of *how* feedstocks are grown), and the environmental opportunity cost of removing land from other uses to divert to feedstock production. Production impacts include the water, air, and soil impacts of the production technologies used to grow and harvest the feedstocks, including the erosion impacts of tillage intensity, the water quality implications of nutrient and pesticide use, and the soil productivity implications of removing agricultural residues for use as feedstocks. Land-use efficiency is a possible proxy for estimating the relative magnitude of a feedstock's production impacts, but it does not fully capture the environmental trade-offs that can be generated between land-use intensity and other input intensity when efforts are made to maximize crop productivity. Corn production in the United States, for instance, is relatively land-efficient among available ethanol feedstocks, but much of its crop productivity has been paid for with increased nitrogen intensity. Unintended nutrient runoff from corn production has had adverse implications for surface waterways and coastal ecosystems, and our analysis suggests that, as corn production increases to meet ethanol demand, problems such as erosion and nutrient runoff are likely to increase disproportionately as

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[1] In fact, a shift in attention from the "renewable" fuels standard of 2005 to the "alternative" fuels standard (AFS) proposed in 2007 represents an ominous change in the wrong direction—away from both renewability and sustainability. The AFS broadens the range of fuels that can receive "credit" for displacing gasoline to include alternatives such as coal-to-liquid (CTL), despite the fact that current CTL technology relies on a nonrenewable feedstock and, over the life cycle of the fuel, produces twice the carbon dioxide that gasoline does.

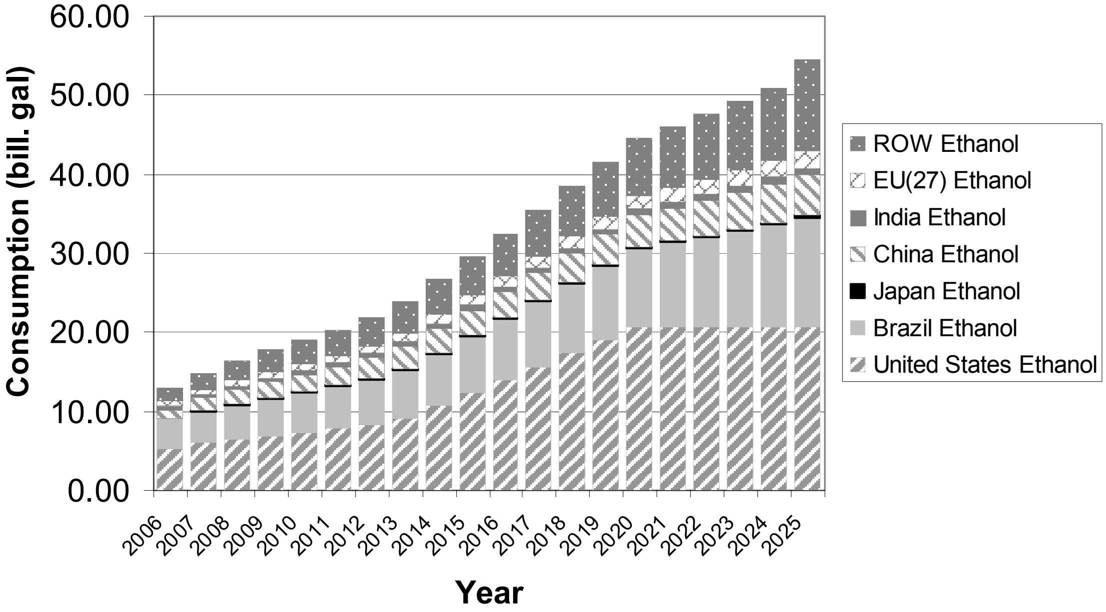

Figure 1. Global Ethanol Demand Projections Developed by the Food and Agriculture Organization (FAO)

Source: Prakash (2007).

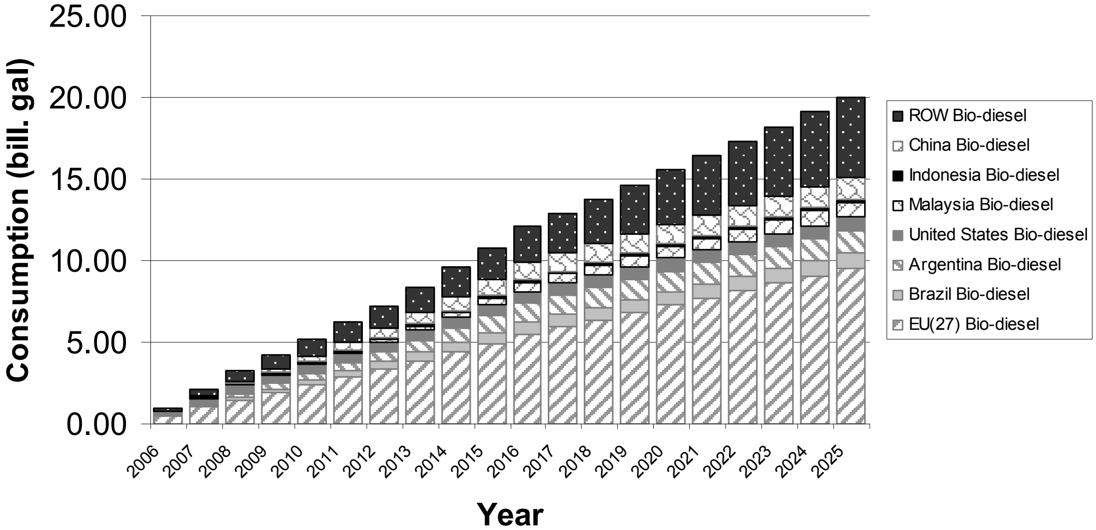

Figure 2. Global Biodiesel Demand Projections Developed by the Food and Agriculture Organization (FAO)

Source: Prakash (2007).

more intensive corn production methods are used on less productive crop lands (Marshall 2007).

Although environmental impacts vary widely by feedstock, it is relatively straightforward to identify the production impacts anticipated from scaling up production of existing agricultural

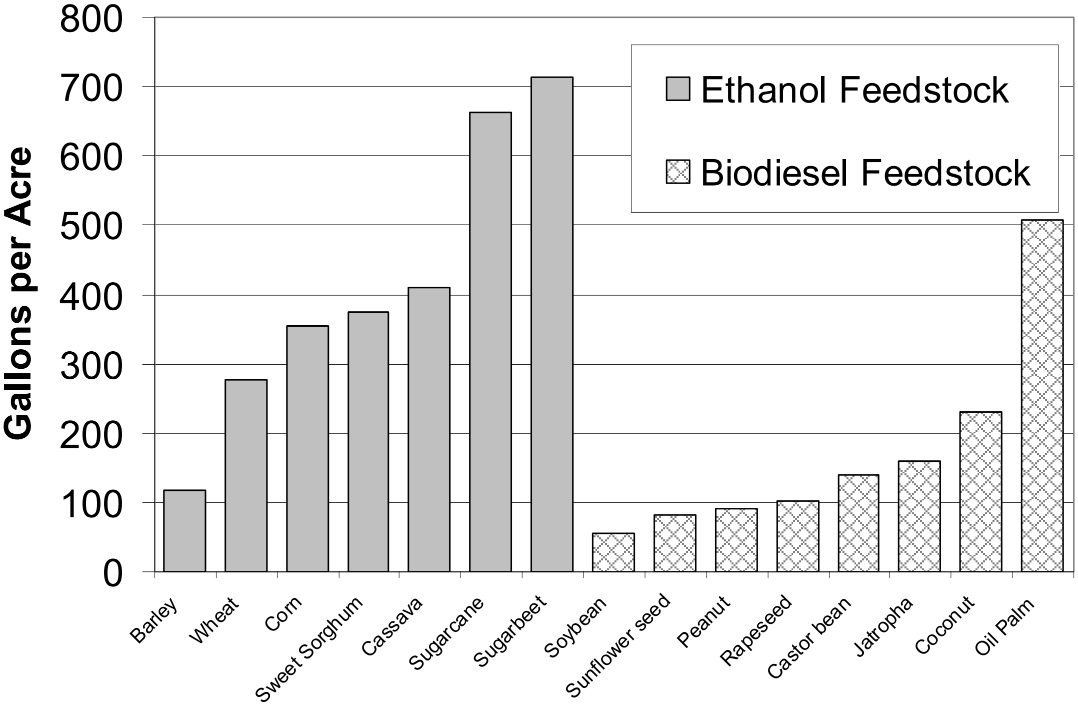

Figure 3. Biofuel Yields of Selected Ethanol and Biodiesel Feedstocks

Source: Adapted from Brown (2006) and Fulton (2006).

products based on observation of existing production practices and impacts. The environmental impacts of diverting land from other uses are much harder to project, though in some cases they may swamp the magnitude of feedstock production's environmental impacts, particularly when both the direct and indirect components of land-use change are fully considered. The direct component quantifies changes in the provision of on-site ecosystem services that occur when the pre-existing land use is lost. The indirect environmental impact of land-use change quantifies changes in the provision of off-site ecosystem services that occur when land uses displaced by feedstock production pack up and move elsewhere.

The net direct impacts of land-use change for feedstock production are not necessarily negative; much attention has been paid to the potential for perennial, herbaceous grasses harvested for biofuel production to rehabilitate degraded and abandoned lands, for instance. It would be naïve, however, to assume that land for feedstock production will be drawn solely from the pool of available marginal land. In most developed countries, for instance, there is not a significant amount of "idle" marginal land, so incremental feedstock acreage is likely to be pulled from one of two primary land uses: food production or environmental preservation (Sexton et al. 2007).

Analysis performed at the World Resources Institute suggests that in the United States, lands withdrawn from the Conservation Reserve Program (CRP) could account for 25–40 percent of the new land required for agricultural production by 2012 to meet burgeoning demand for corn. That constitutes a loss, over just five years, of 3–4.7 million acres from a program that has been highly successful at eliminating soil, nitrogen, and phosphorus losses from, and increasing soil organic matter on, the nation's most vulnerable soils (Food and Agricultural Policy Research Institute 2007). A similar analysis performed for the state of Iowa projected that, at a corn price of $3.00 per bushel, one million acres of CRP land in that state alone would move back into production (Secchi and Babcock 2007).

A similar land supply dynamic is playing out in the European Union, which has dedicated a great deal of acreage to feedstock production to meet a non-binding biofuel objective of 5.75 percent of liquid transport fuels by 2010. Given the resulting shortage of agricultural production land, the EU is now considering weakening its mandatory 10 percent set-aside requirement for agricultural land to combat rising food prices. At their July meeting, Farm Ministers agreed to set the 2008 compulsory set-aside level at 0 percent, and the EU Commission is expected to confirm this proposal (Smith 2007). Environmental organizations are concerned about the impact such a move would have on insect and bird species that rely upon the set-aside land for food and breeding sites (Biofuelwatch, Ecological Internet and Rainforest Rescue 2007).

Even in developing countries where "marginal" or "idle" land is purported to be in greater supply, feedstock production does not necessarily migrate to low-value transitional or abandoned lands. In Indonesia, media attention has focused on the highly destructive practice of burning peat swamp forests, which are extremely valuable as habitat and carbon sinks, to plant palm plantations that provide palm oil for the biodiesel market (Rosenthal 2007). Although the value of habitat and carbon sequestration services is rarely internalized in either public or private decisions resulting in land-use change, quantifying the loss of such services is critical to a true assessment of the environmental and economic impacts of feedstock production.

Measuring the indirect impacts of land-use change for biofuel production, which represent the landscape-wide repercussions of increased pressure for land, has proven to be both a conceptual and quantitative challenge for life-cycle sustainability accounting. This geographical displacement of environmental impact outside of the boundaries of the biofuel system (called "leakage") broadens the range and magnitude of potential impacts associated with feedstock production. In a recent assessment of the sustainability of Brazilian bioethanol production, Smeets et al. (2006) give a generally positive account of the potential for Brazilian ethanol to meet a set of sustainability criteria developed by the Dutch government. The study acknowledges, however, that although sugar cane production generally replaces pasture and food crops and takes place far from Brazil's most diverse biomes, the fact that those other land uses are then pushing into high diversity biomes is significant: "… the direct impact from land use for cane production on biodiversity is limited, but the indirect impacts could be substantial" (Smeets et al. 2006, p. 35).

The significance of indirect land-use impacts becomes particularly problematic in the evaluation of the life-cycle carbon content of biofuels. Some research suggests that forests are more effective at sequestering carbon over a given time period than biofuels are at displacing petroleum-related GHG emissions, and that proponents of emission reductions should therefore press for forest protection and reforestation efforts rather than expansion of biofuels (Righelato and Spracklen 2007). The magnitude of the GHG impacts of land-use conversion resulting from expanded feedstock production, either directly or indirectly, is therefore a critical, albeit difficult-to-measure, component of any biofuel carbon content measure. Development of the methodologies necessary to identify and quantify such life-cycle measures of the impacts of biofuels produced from a variety of feedstocks is an active area of research that requires significantly increased public investment. Such information will be critical to the design of effective markets and policies to advance sustainability principles in biofuel production.

Advancing Sustainability in U.S. Biofuel Use

An important prerequisite to U.S. achievement of sustainable biofuel policy will be to keep biofuels' potential contribution to our domestic transport energy supply in perspective. Hill et al. (2006) note that devoting the entire U.S. soybean and corn harvest in 2005 to biodiesel and ethanol production would have produced sufficient biofuel to displace 6 percent and 12 percent of our domestic diesel and gasoline demand, respectively. Sexton et al. (2007) calculate that, at a global scale, converting the entire global production of sugar cane, corn, wheat, sorghum, sugar beet, and cassava to ethanol would require 449 million hectares and would displace 50 percent of today's global gasoline demand. The Natural Resources Defense Council proposes an almost complete displacement of domestic gasoline demand with ethanol, but only after significant improvement to fuel efficiency and altered development patterns have reduced projected gasoline demand by more than 50 percent, and only once aggressive investments in ethanol research and development have produced higher-efficiency conversion technologies and improved crop yields (Greene 2004). Biofuels are therefore only part of the solution to our transport fuel dilemma, and policies to promote them must be embedded within a larger strategy to substantially reduce domestic oil demand; only then will it be reasonable to expect biofuels to sustainably capture a significant share of the market for liquid transportation fuels.

Addressing both aspects of biofuel sustainability described here—the environmental impacts associated with biofuel feedstock production and the net carbon content of the fuel—will require several distinct types of policy intervention. Some of these policies are described below, including policies that influence farmer decisions about what, where, and how feedstocks will be grown; broader land-use policies that reflect the value of the ecosystem services provided by land in such a way that leakage of environmental impacts beyond the biofuel system boundary are minimized and remain consistent with national priorities for balancing production of food, fuel, and ecosystem services; and trade policies that mitigate the extent to which developed countries are able to export the environmental impact of their energy demand.

Promote Biofuel Technologies with Improved Environmental Performance

The "Beyond Corn" movement has picked up momentum in the United States. Some advocates are motivated by concerns about the environmental impacts and energy intensity of corn ethanol production, others by the livestock sector, food price, and export implications of large-scale diversion of corn for ethanol use, and others simply by the impact that increased corn prices have had on ethanol profit margins. Replicating corn-to-ethanol yields with other small grains such as barley and wheat has not been easy, however; these alternate feedstocks have varying starch contents, require a greater volume of feedstock input and additional fermentation enzymes, and have greater up-front investment costs (McElroy 2006). From an environmental perspective, although these other crops use fewer nutrients per acre, their crop productivity per acre is much lower than that of corn. Large additional land requirements, and increased potential for indirect land use impacts, would therefore accompany any significant movement away from corn toward other small grains.

Researchers are also exploring the use of more land-efficient, sugar-rich crops such as sugar cane and sugar beets as ethanol feedstocks in the United States. There are significant logistical problems associated with harvesting and transporting these bulky feedstocks, but they would greatly reduce the land requirements for ethanol production. Sugar cane has additional energy use efficiencies because the fibrous bagasse that remains once the sugar has been extracted from the cane can be burned to provide the energy used to drive the conversion process, thereby displacing coal or natural gas (which are generally used to power corn-to-ethanol processing facilities) and greatly reducing the energy- and GHG-intensity of the production process. Use of such feedstocks becomes profitable when ethanol prices exceed \$2.35–\$2.40/gallon (USDA 2006); in the highly volatile ethanol market, futures and cash prices have exceeded \$2.50/gallon at several points over the last two years, but they are currently hovering closer to \$2.00/gallon. Additionally, at current feedstock prices, the use of sugar feedstocks is not cost-competitive with corn in the United States (Table 1).

Increasingly, attention within the biofuels community is turning toward the potential for cellulosic conversion technologies in ethanol production to deliver us from our dependence on corn. Current production technologies convert simple sugars, or loosely bound complex sugars such as starch, into ethanol, but much of a plant's sugar is bound tightly into complex sugars called cellulose and hemicellulose, which are inaccessible for fermentation by conventional methods. Because cellulose and hemicellulose comprise roughly two-thirds of a plant's dry weight, conversion technologies that unlock these sugar components would allow a much greater portion of biomass to

Table 1. Summary of Estimated Ethanol Production Costs (dollars per gallon)[a]

Cost Item	U.S. Corn Wet Milling	U.S. Corn Dry Milling	U.S. Sugar Cane	U.S. Sugar Beets	U.S. Molasses[b]	U.S. Raw Sugar[b]	U.S. Refined Sugar[b]	Brazil Sugar Cane[c]	EU Sugar Beets[c]
Feedstock costs[d]	0.40	0.53	1.48	1.58	0.91	3.12	3.61	0.30	0.97
Processing costs	0.63	0.52	0.92	0.77	0.36	0.36	0.36	0.51	1.92
Total cost	1.03	1.05	2.40	2.35	1.27	3.48	3.97	0.81	2.89

[a] Excludes capital costs.
[b] Feedstock costs for U.S. corn wet and dry milling are net feedstock costs; feedstock costs for U.S. sugar cane and sugar beets are gross feedstock costs.
[c] Excludes transportation costs.
[d] Average of published estimates.

be converted to ethanol, resulting in significantly higher land-use efficiency in ethanol production. It would also greatly broaden the variety of feedstocks that could be used for ethanol production, as conversion would no longer be limited to crops that are rich in starches and simple sugars; cellulosic ethanol technology would allow the conversion of biomass feedstocks such as stalks, leaves, perennial grasses, trees, and even wood waste into ethanol.

There are additional environmental and GHG-related advantages to cellulosic conversion. Once all the cellulose and hemicellulose in biomass has been broken down, the residue remaining is called lignin; it is the biomass component that provides plants' structural support. Although lignin does not contain sugars that can be made available for fermentation, it plays an important role in cellulosic ethanol production because it, like bagasse, can be burned to generate process energy. Cellulosic biorefineries are designed to generate their own power by burning non-fermentable lignin from their cellulosic feedstocks, thereby considerably reducing their dependence on fossil fuels for ethanol production.

Cellulosic technology therefore promises to deliver transport fuel with a smaller environmental footprint, but there is considerable debate about how close to commercialization cellulosic conversion technologies actually are. The barriers to commercialization that remain include technical barriers such as the design of efficient and low-cost enzymes for the breakdown of complex sugars (U.S. Department of Energy 2006), as well as non-technical barriers such as the high cost of financing plants constructed using untested technology (Greene and Mugica 2005). Small-scale pilot cellulosic plants are in operation in Canada (using wheat straw), China (using corn stover), and Japan (using wood waste). To expedite commercialization in the United States, in early 2007 the U.S. Department of Energy awarded 6 grants to companies interested in constructing medium-scale biorefineries (10–40 mmgy) utilizing a number of different cellulosic feedstocks including wheat straw, wood chips, and orange peels. These biorefineries are expected to begin construction within two years.

Despite the enthusiasm for cellulose as a potential feedstock, it is critical to remember that all cellulose is not created equal—feedstocks will have widely varying environmental footprints that must be understood and acknowledged within biofuel policy. Projections from the billion-ton biomass feasibility study, for instance, rely heavily on corn stover (the residue that remains when corn cobs have been harvested) as a feedstock for future ethanol markets (U.S. Department of Agriculture and U.S. Department of Energy 2005a). However, relatively little is known about the long-term soil and water impacts of removing residues that have in the past been left on the fields to build soil organic content. On the basis of per-acre production impact comparisons, perennial herbaceous crops such as switchgrass may turn out to be a more environmentally friendly alternative cellulose source, but such comparisons do not take into account the direct and indirect land conversion impacts that could emerge from introducing an entirely new market product that, unlike corn stover, is incompatible with production of current market products and therefore may vastly increase the land required to meet feedstock needs. Public R&D dollars will play a key role in supporting the type of long-term, integrated analysis that will be required to make credible and substantive projections about such impacts, and such information will be critical to the success of any sustainable biofuel policy.

Increase Capacity and Credibility of Policies Providing Support for Ecosystem Services

The aggregate environmental impacts of biofuel use increase drastically when land is converted from high-valued environmental uses, such as old-growth forests and native grasslands, to agricultural production. Even in the absence of full conversion, significant environmental impacts may occur if biomass harvest entails changes in management, such as an increase in the frequency of harvest on set-aside grasslands, or an increase in the density of residues removed from forestlands. These types of environmental impacts are not unique to feedstock production, however; feedstock production is embedded within broader agricultural and silvicultural systems that have provided our food, livestock feeds, and forest products for decades and yet chronically manifest problems with environmental impact and unsustainability.

Addressing the sustainability issue for biofuel production therefore fits snugly within a broader discussion of promoting sustainable land use more generally. Sustainable land uses are uses that maintain an ecosystem's ability to provide the services required to maintain human welfare. Ecosystem services are defined as "components of nature directly enjoyed, consumed, or used to yield human well-being" (Boyd and Banzhaf 2006) and include products, or provisioning services, such as food and fuel, as well as regulating services such as water purification and cultural services such as aesthetic and recreational benefits (Millennium Ecosystem Assessment 2003) (Figure 4). Economists recognize the non-market products as the "external benefits" associated with various land uses and have long argued that a failure to value such benefits will result in under-provision of those land uses, and of the services they provide, and overly rapid land conversion in favor of those uses that provide market benefits. The Millennium Ecosystem Assessment substantiated that argument, finding that, in general, human management of lands to increase the food and fiber provisioning services that are supported by markets has degraded the ability of ecosystems to provide other, regulating and cultural services not supported by the market (World Resources Institute et al. 2005).

Environmental groups are increasingly calling for promotion of sustainable land use through policies designed to reward land-management decisions that maintain non-market ecosystem services. Some groups envision such "payments for ecosystem services" as replacing more traditional forms of farm support, such as indirect payments, counter-cyclical payments, and loan deficiency payments, which are tied more closely to production of those ecosystem services that the market already supports—commodity production. Such "green payment" programs can be either practice-based or performance-based. Practice-based programs reward farmers for engaging in land management practices that are presumed to have associated ecosystem services benefits; examples of practice-based programs already exist within our farm support toolbox and include working lands programs such as the Conservation Security Program and the Environmental Quality Incentives Program, as well as the Conservation Reserve Program.

Despite the enormous popularity of these programs, serious questions have been raised about the effectiveness with which they allocate conservation dollars to achievement of environmental

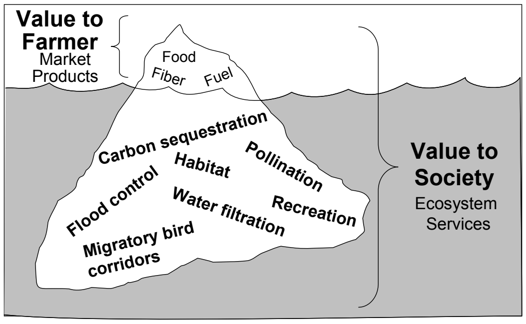

Figure 4. Ecosystem Services from Agricultural Land

Source: World Resources Institute.

benefits (Soil and Water Conservation Service and Environmental Defense 2007a, 2007b). Truly cost-effective achievement of environmental goals requires the ability to allocate payments based on measures of the magnitude of ecosystem service provided; policies that allocate payments in this way are called performance-based, and they include tools such as nutrient markets and reverse auctions, which provide ecosystem services payments on a per-unit basis (such as per pound of nutrient reduced). The quantification and implementation difficulties associated with establishing credible performance-based policies have historically limited their on-the-ground application, but recent developments in computation and improved access to biophysical data are accelerating experimentation with pilot performance-based programs such as those mentioned above.

As we advance development of a conservation framework based on the concept of ecosystem services, it is critical that the science of impact assessment keep pace with our computational capacity and the creativity with which we design policy. We need to know, and be able to demonstrate, that the best management practices that performance-based policies are promoting have the impacts that we think they have. As evidenced by recent debates about the effectiveness of conservation tillage at increasing soil carbon sequestration (Baker et al. 2007), considerable uncertainty persists within the basic science of impact assessment. For example, to credibly provide the level of precision required for performance-based policies for nutrient reduction, and to improve the targeting precision of practice-based policies, we need a better understanding of temporal nutrient fluxes, better ability to account for transport processes from field to stream, including improved documentation of tile drain extent in critical watersheds, and better understanding of nutrient processes in freshwater and coastal wetlands. Advances such as these will require a concerted investment in more sophisticated and extensive water- and soil-quality monitoring and assessment and improved modeling and quantification methodologies calibrated to collected data.

The effort to make biofuels more sustainable is therefore inextricably linked to the effort to make agricultural production, and land use more broadly, more sustainable. Such efforts will require more attention to both the effectiveness and the cost-effectiveness of land-management policy, as well as greater investment in the basic science necessary to support the most cost-effective forms of conservation policy. Fortunately, these investments will have the added advantage of supporting other policies designed specifically to address biofuel sustainability, such as certification programs and performance-based fuel mandates; such policies require an enormous amount of information for effective implementation, and will be only as successful as the precision of their underlying science can make them.

Tie Fuel Incentive Policies to Life-Cycle Measures of Performance Criteria Rather Than to Fuel Type

In January 2007, California Governor Schwarzenegger signed into law a pathbreaking executive order called the "Low Carbon Fuel Standard," which mandates a 10 percent reduction in the carbon content of California's transport fuels by 2020. Unlike the Renewable Fuel Standard (RFS), which mandates a volumetric blending of certain types of biofuels, regardless of their environmental impact, the Low Carbon Fuel Standard (LCFS) mandates the desired environmental outcome, but leaves flexible the fuel pathways with which to get there. Subsequent technical feasibility analysis describes this objective as "ambitious but attainable" using a number of possible technologies, including plug-in hybrid vehicles, battery electric vehicles, and biofuels with various levels of GHG reductions (Farrell et al. 2007b).

The difference in the incentives provided by these two policy approaches is critical in influencing how the industry evolves. The RFS stimulates production of an alternative fuel, but does not provide incentives for type of production to move in a way that encourages improved environmental performance (with the exception of indirect support for cellulosic ethanol, which receives 2.5 times the renewable fuel credit that grain-based ethanol does). In fact, ethanol that is produced in such a way that life-cycle GHG emissions actually increase relative to gasoline also qualifies to receive RFS credits; such fuels may further national objectives related to farm support and domestic energy security, but they do so at the expense of the environment. To ensure that environmental objectives are met as well, the fuel support incentives should be tied explicitly to the environmental performance of the fuel, as they are with the LCFS. Such policies also provide continuing incentives to develop new technologies with improved environmental performance, whereas technology-based policies such as the RFS can entrench current technologies and disadvantage emerging technologies that didn't exist when the technologies qualifying for support were determined. The Natural Resources Defense Council (NRDC) describes these desirable fuel policies as "technology neutral and performance based" (NRDC 2007).

The downside of such policies arises because, whereas gross categories of fuel technologies are easy to observe, document, and reward, the life-cycle environmental performance associated with those fuel technologies is not. There are significant problems associated with identifying and measuring impacts (such as the impacts of removing stover on soil quality or of displacing cattle ranching that pushes farther into the Amazon), which are then compounded by the logistical difficulties associated with tracing and aggregating such impacts through the supply chain to ensure that markets and policymakers can differentiate between "green" and "brown" biofuels, and reward producers and suppliers accordingly.

To establish a consistent methodology for tracking and reporting such impact numbers, reporting standards for biofuel sustainability and carbon content are being developed and ground-tested for the UK's Renewable Transport Fuel Obligation (RTFO): "Reporting is seen as a 'stepping-stone' towards a mandatory assurance scheme that would reward biofuels based upon their carbon intensity and penalise those that came from feedstocks produced unsustainably" (UK Department of Transportation 2007). Carbon reporting and accounting standards have also been developed for California's LCFS, and draw largely from the UK framework (Farrell et al. 2007a).

Develop Internationally Accepted Sustainability Criteria and Certification Programs for Biofuels

To advance development of the biofuels industry in a sustainable direction, several groups have convened to identify and establish sustainability criteria for biofuel production and to advocate for their expanded application in national and international policy (UN-Energy 2007, Global Bioenergy Partnership 2005, Roundtable on Sustainable Biofuels 2007). In the United States, a coalition of environmental groups has called for establishment of an independent certification process for feedstock production, much like the Forest Stewardship Council's certification for sustainable forest practice or the independent organic certification process administered by the USDA. Establishment of sustainability criteria, followed by a certification process to verify achievement of those criteria, would set the stage both for mandatory policies that tie eligibility for support programs to achievement of those criteria and, when combined with product labeling, for niche markets that even in the absence of mandatory policies would allow consumers to selectively participate in and support "green" biofuel markets.

Although global trade in biofuels has been quite small, it is expected to increase substantially in the coming years, with import demand in countries such as the United States, the EU, and Japan likely to be met with exports from more tropical countries in Latin America, sub-Saharan Africa, and Southeast Asia, which have climates suitable for high crop productivity and more land available for feedstock production (Kojima, Mitchell, and Ward 2007). In the United States, for instance, ethanol imports have increased dramatically since 2002, despite a $0.54/gallon import tariff, with more than 50 percent of imports coming from Brazil. International trade, and trade policy, will therefore play a critical role in determining the pattern and magnitude of impacts from biofuel use (Dufey 2007). To avoid international displacement of significant environmental impacts, importing countries must proactively engage in the development of sustainability standards for biofuel products and trade-compliant methods of applying them.

The draft UK reporting guidelines for biofuel sustainability attempt to lay the groundwork for practical application of such criteria. To determine "qualifying standards" of sustainability for the RTFO, the guidelines benchmark the criteria being developed by groups such as those listed above against the following "meta-standards" that the UK government report has identified as relevant criteria for sustainability (UK Department of Transportation 2007):

- Biomass production will not destroy or damage large above- or below-ground carbon stocks.
- Biomass production will not lead to the destruction of or damage to high biodiversity areas.
- Biomass production does not lead to soil degradation.
- Biomass production does not lead to the contamination or depletion of water resources.
- Biomass production does not lead to air pollution.
- Biomass production does not adversely affect worker's rights and working relationships.
- Biomass production does not adversely affect existing land rights and community relations.

Validation of carbon and sustainability claims throughout the life cycle of the fuel will be critical to the effectiveness of any policy premised on performance. The UK reporting guidelines call for suppliers to engage independent auditors to verify the veracity of their carbon and sustainability reports. An independent international certification body could perform the same function if participating suppliers agreed on the validity of its conclusions.

Although individual countries have free rein to tie their domestic policies to these sorts of sustainability criteria for biofuels and biofeedstocks produced domestically, linking a "green index" for biofuels to trade policy may not be as straightforward. There are restrictions on the types of standards that can be imposed on international trade agreements and remain WTO-compliant (Turner et al. 2007). WTO countries can adopt domestic policies related to trade as long as those policies do not directly or indirectly discriminate between imported and domestically produced "like" products, or between "like" products imported from different countries; any standard perceived as creating an unfair barrier to trade is subject to challenge under the WTO (Lancaster 2006).

For an illustration of the complexities of designing and imposing WTO-compliant environmental standards, one need look no further than the "dolphin-safe" tuna and shrimp/turtle disputes. Twice in the 1990s the U.S. policy of prohibiting tuna imports from countries that allowed purse seining (which increases dolphin mortality) was challenged and found to be GATT-incompliant, with the GATT panels arguing that standards cannot discriminate among "like" products on the basis of non-product-related production methods (International Centre for Trade and Sustainable Development 2000). This finding was never adopted, and the argument was essentially overturned in subsequent WTO Appellate Body rulings responding to a 1999 challenge of the U.S. policy of prohibiting import of shrimp from countries that do not engage in turtle conservation efforts that are comparable to those of the United States. The WTO found the U.S. policy to be in violation of trade policy, not because a unilateral standard imposing PPM (production process and methods) criteria on imported products was inherently out of compliance, as the GATT panel had found in the earlier tuna dispute, but because those standards had been imposed unfairly on exporting nations. The process of negotiating each export country's compliance or non-compliance with the standard and subsequently establishing an embargo was found to lack transparency, flexibility, and equity, and as a result to impose a greater burden on some exporting countries than others (Chang 2000). The United States and the WTO were able to settle the dispute, leaving the standard largely intact, by individually addressing the issues singled out above.

The process of establishing WTO-compliant import standards for biofuels and biofeedstock production is likely to be at least as complex as these cases; there is a wide variety of possible crops that qualify as feedstocks, many have multiple uses, and for many of the crops there is little information on the types of practices that are likely to be used for large-scale production or on the best management practices available to producers. Establishing comparable standards for such a wide variety of feedstocks, which come from a wide variety of regions and with a spectrum of social and environmental impacts, will require a vastly improved understanding of regionally appropriate feedstocks, likely and potential production methods, and their impacts. The institutional process used to evaluate and negotiate export countries' compliance with those standards will be equally difficult to design and establish, but, as history has demonstrated, equally important in determining the compatibility of subsequent regulations with the existing trade policy regime.

Concluding Thoughts

Biofuels are not necessarily "green," especially at the scales of production that have been promoted by those looking to substantially shift our transport energy dependence from petro- to carbo-fuels. If advanced correctly, however, they do have the potential to provide the benefits that are so often attributed to them. The industry is evolving and expanding rapidly; to avoid the types of large-scale environmental impacts that could scuttle an over-exuberant industry, and permanently banish the opportunity to realize its benefits, we must have guiding sustainability principles in place *before* significant expansion occurs. Domestic policy needs to stop pushing expansion of the biofuels market *per se*, and instead focus on identifying and creating the conditions necessary for the emergence of a credibly green biofuels market both domestically and internationally. Only then should we explore the limits of scaling up biofuel production.

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