Government Policies & Drivers of World Biofuels, Sustainability Criteria, Certification Proposals & Their Limitations

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Introduction

Primarily driven by government policies, world ethanol production tripled between 2000 and 2007 (from 17 billion to more than 52 billion liters), while biodiesel expanded eleven-fold (from fewer than 1 billion to almost 11 billion liters) (OECD 2008). These fuels provided 1.8% (~1500 peta joules) of the world's transport fuel by energy value (OECD/FAO 2008). Growing the cereals and vegetable oils used for these fuels used an estimated 20 million hectares (Heimlich 2008), or about 1% of the global agricultural land.

The governments of nearly all the world's major economies have already adopted policies that will continue to boost biofuel production and many are considering still further expansions. At the same time, governments and advocacy groups have grown increasingly concerned about the effects of biofuel production on food prices, social welfare, and the environment. A true accounting for land use effects in particular has raised doubts about whether switching to biofuels actually decreases greenhouse gases – doubts that may negate one of the primary motivations for biofuel policies.

This paper summarizes government and economic drivers of biofuels and both the existing and proposed sustainability criteria for addressing these concerns. Most of these criteria could be easily circumvented and would have little effect because of the displacement of land; however, criteria that would in theory account for the effects of land use change or restrict the types of biofuel feedstocks could have greater significance.

Mandates, Incentives and Economic Drivers of Biofuels

Brazil initiated large-scale biofuel production in the late 1970s after a 1975 law guaranteed price parity for ethanol and gasoline along with a system of tax rebates and subsidies for ethanol construction facilities (Colares 2008; Walter and Cortez 1999). As the price of oil fell in the late 1980's, ethanol production faced

Searchinger, T. 2009. Government policies and drivers of world biofuels, sustainability criteria, certification proposals and their limitations. Pages 37 - 52 in R.W. Howarth and S. Bringezu (eds) Biofuels: Environmental Consequences and Interactions with Changing Land Use. Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008, Gummersbach Germany. Cornell University, Ithaca NY, USA. (http://cip.cornell.edu/biofuels/)

major challenges, which triggered the government to adopt a mandate in 1993 that gasoline include 22% ethanol. Under this authority, the government continues to regulate a blending figure between 20% and 25%, based on supply and demand conditions. In 2005, Brazil added a 2% blending mandate for biodiesel by 2008, which it more recently increased to a 5% blending target by 2013 (Colares 2008; OECD 2008). The government also continues to support biofuels with complex tax incentives. The OECD estimated that those incentives in 2006 provided a subsidy of 0.28 BRL per liter, equal to roughly $0.12 USD at today's exchange rate (OECD 2008). However, the Brazilian sugarcane industry argues that government policies that maintain artificially low gasoline prices discourage the expansion of ethanol in Brazil.

This combined system of mandates, tax credits, and construction incentives has become the norm around the world. The U.S. adopted a preferential tax incentive for ethanol in the Energy Policy Act of 1978, which has varied from $0.13 to $0.16 USD L-1 ($0.50 - $0.60 USD per gallon) over the years (Birur et al. 2007). By 1990, U.S. ethanol production had reached 3.4 billion liters, rising to 5.3 billion liters in 1995. Production retreated slightly throughout 1996 - 1998 as gasoline prices dropped; significant growth was occurred in 2000 after passage of state policies and new federal clean air legislation mandating the phasing out of the petroleum-derived Methyl Tert-Butyl Ether (MTBE) as an oxygenate in gasoline, which was found to cause ground water pollution. The ethanol product, Ethyl Tert-Butyl Ether *(*ETBE) segued as an alternative fuel oxygenate (Birur et al. 2007; Yacobucci 2006). MTBE was largely phased out by 2005 after the U.S. Congress rejected efforts to exempt gasoline companies from pollution liability (Jank et al. 2007). Around the same time, the U.S. Congress passed a mandate calling for wholesalers to incorporate 28.4 billion liters of biofuels into other fuels by 2012. That mandate was met by 2008, and the industry has consistently exceeded the target since due in part to clean air demands; this mandate has probably had its greatest effect in depriving the oil industry of any incentive to develop an alternative to MTBE other than ethanol. These major policies only partially capture the story though, as the U.S. federal and state governments have provided a variety of other special tax credits, incentives, and direct subsidies to the biofuel industry (Koplow 2007). For example, federal tax credits for biofuels directly cost $3.05 billion USD in 2006, but a special provision that exempts the tax credit from taxable income in effect increased that benefit, and therefore the cost to taxpayers, to $4.36 billion USD (Koplow 2007).

Similar types of policies have spurred biofuel production in Europe. A 2003 directive adopted by the European Union required each member country to set targets for minimum shares of biofuels and set a non-binding goal of 5.75% for the end of 2010. In response, European governments have adopted a number of mandates estimated by the OECD to average 3.5% of total EU transport fuel by 2010 (OECD 2008). Member countries have also adopted a broad range of tax concessions, including a complete exemption from fuel taxes in several countries (Doornbush and Steenblik 2007; Jank et al. 2007).

A 2007 study by the OECD, drawing on work by the Global Subsidies Initiative, estimated total OECD subsidies for biofuels in 2006 at $11 billion USD (Steenblick 2007), ranging by major country from $0.08 – $7.0 USD per liter (USD L^{-1}) of fossil fuel saved (OECD 2008). Subsidies are expected to grow to $27 billion USD per year for 2013-17 assuming the same levels of support at predicted levels of production (OECD 2008). The OECD has calculated the cost of subsidies at $960-$1700 USD per ton of CO_2-equivalent saved (OECD 2008). The cost is likely higher, though, as most analyses of greenhouse gas (GHG) savings do not account for land use change, which may substantially increase emissions.

Higher crops prices impose an additional cost to consumers. Once government policies promote increased demand, price signals must be allowed to encourage farmers to increase the supply, but the costs of generating the demand in response to government policy appropriately count as a cost of that policy. The costs from increased crop prices across the world amount to tens of billions of US dollars. The precise estimate depends on the estimate of the effect of biofuels and whether shorter or longer-term prices are counted.

Although government policy has driven most biofuel production, the price of gasoline has begun to play a major role because it interacts with financial subsidies to drive production of ethanol regardless of mandates. For example, Birur et al. (2007) calculated that with today's $0.13 USD L^{-1} tax credit, U.S. corn ethanol is more economical than gasoline at $90 USD per barrel even with a corn price of $5.00 USD per bushel (Birur et al. 2007). A related study found that with oil at $120 USD per barrel and no tax credit, ethanol production would be economical even with corn priced at $5.26 USD per bushel; the U.S. tax credit pushes the break-even price to $6.33 USD per bushel (Abbott et al. 2008). Thus, the price of corn and other biofuel feedstocks is now tied to the price of gasoline. As gasoline prices rise, demand for feedstock will also rise until the feedstock becomes so expensive that further expansion is no longer economical.

Segregating government policies from economics, the OECD has estimated that the elimination of all biofuel subsidies and mandates would reduce U.S. ethanol production by roughly 20% on average compared to the level that ethanol would otherwise average in 2013-17. Canadian and European ethanol and biodiesel would decline by almost 80% (OECD 2008). Latin America, where biodiesel production would expand because of low production costs and the benefit of reduced subsidized competition from other countries, is the exception.

Although high fuel prices can drive significant levels of biofuel production even without government subsidies, such policies will probably play the dominant role in driving new production because biofuel producers face risks from both high and low oil prices. When oil prices are high, demand for biofuels can help drive higher grain prices to a point at which producers can no longer make a profit. This phenomenon occurred in the summer of 2008 as extraordinarily high corn prices forced U.S. ethanol producers to cut back (Peer 2008). On the other hand, U.S. ethanol producers also lost money when ethanol prices dropped in response to collapsing oil prices in the fall of 2008 due to a global recession (Parker 2009). Because these twin price risks imply that expanded biofuel production will be risky, government guaranties of a particular market, which reduce market risk, will probably play a critical role in shaping industry expansion.

Governments are responding by providing these guaranties. In the U.S., the Energy Independence and Security Act of 2007 (EISA) increased the mandate for biofuels to 136 billion liters (36 billion gallons) by 2022, well above projected levels reflected in the OECD analysis reported above. The increase implies a substitution of roughly 13% of the expected 2022 transport energy demand, although the percentage depends on the relative mix of ethanol and biodiesel. The law subdivides this requirement into several categories: no more than 56.8 billion liters (15 billion gallons) can derive from corn ethanol, 3.8 billion liters (1 billion gallons) must derive from biodiesel, and 60.6 billion liters (16 billion gallons) must derive from cellulose. The U.S. Environmental Protection Agency (EPA) can waive requirements annually if supplies of these fuels are not adequate or if economic or environmental effects warrant.

In early 2008, the European Commission proposed a directive requiring that member states, on average, use biofuels for 10% of the energy in transportation fuel by 2020, which would amount to ~ 34 million tons oil equivalent (Mtoe) (Dehue et al. 2007), or roughly 60 billion liters if all biofuels were ethanol. The European Parliament Committee on Industry, External Trade, Research, and Energy voted in July 2008 to open the target to major review in 2015 and to require that 4% of the substitution derive from electricity or biofuels that can not cause indirect land use change. In December of 2008, however, negotiators among the European Parliament, the European Commission and the Council of States, dropped most of these changes. The final directive, passed in December, requires member states to adopt a 10% target - although energy from electrical production may count (Council of European Union 2008). Each country in Europe will have to adopt legislation to achieve this mandate. The legislation is supposed to incorporate 'trajectories' for meeting the final goals, but the final EU directive does not require that countries achieve any specific interim goals.

Countries around the world have broadly adopted the pattern of mandates and subsidies, with 10% emerging as the common goal. For example, China has phased in a 10% blending requirement for biofuels by spreading it to more and more cities, while also providing sales tax exemptions and other financial guaranties (Koizumi and Ohga 2007). The existing mandates and goals for OECD and non-OECD countries as of the fall of 2008 are summarized in Tables 2.1 and 2.2, although the European goals must now be modified.

Trade

Because of import tariffs and a range of preferential measures for domestic production, only around 8% of world ethanol, and 12% of biodiesel is traded internationally (OECD 2008). OECD countries apply tariffs at rates of 6% to 50%, including a \$0.14 USD L^{-1} duty on imported ethanol by the U.S., and a € 0.192 per liter denatured ethanol duty imposed by the EU (Doornbush and Steenblik 2007). Developing countries apply their own tariffs between 14% and 50% (Doornbursh and Steenblik 2007). The U.S. waives its tariff for certain countries in the Caribbean Basin, and Europe does the same for Africa, but none of the countries that benefit have significant ethanol industries (Jank et al. 2007).

Other internal production subsidies, including a range of subsidies to establish production facilities, play an important role as well. Most international ethanol trade is made up of Brazilian sugarcane ethanol exports to the U.S., much of which avoids U.S. tariffs by being dehydrated in a country belonging to the U.S. Central American Basin Initiative. Similarly, Malaysia and Indonesia have provided biodiesel exports to Europe, but they have done so by taking advantage of an odd tax provision in U.S. law, which provides a \$0.264 USD L^{-1} tax credit to these biodiesels so long as they are mixed with a small amount of conventional diesel in the U.S. This 'splash and dash' subsidy is the focus of a complaint filed by Europe with the World Trade Organization.

Virtually all economic analyses have calculated that developing countries have major

Table 2.1 Biofuel targets for primary energy and fuels in 2010 for selected countries. (M) indicates mandatory. (adapted from Peterson 2008)

country	substitution in total primary energy	substitution in transport fuel
EU	12%	5.75%
Austria		5.75% (M)
Belgium		5.75%
Cyprus	9%	5.75%
Czech Rep.	5-6%	5.75%
Denmark	20% (2011)	5.75%
Estonia	13%	5.75%
Finland		5.75% (M)
France	10% (2010)	7% (2010), 10% (2015)
Germany	4%	5.75% (M)
Greece		5.75%
Hungary		5.75%
Italy		2.50%
Ireland		NA
Latvia	6%	5.75%
Lithuania	12%	5.75%
Luxembourg		5.75%
Malta		NA
Netherlands	10% (2020)	5.75% (M)
Poland	7.5% (2010), 14% (2020)	5.75%
Portugal		5.75%
Slovak Rep.		5.75%
Slovenia		5% (M)
Spain	12.10%	5.83% (M)(2010)
Sweden		5.75%
UK		5% (M)(2010)
Australia		350 million liters
Canada		5% renewable content in gasoline by 2010; 2% renewable content in diesel by 2012
Japan		50 million liters biofuels, domestic production (2011)
New Zealand	90% of tot. elect	3.4% of tot. transport fuel sales (M) (2012)
USA		136 billion liters (M)(2022)

production advantages for biofuel, with Brazil by far the world's low cost producer (OECD 2008; Jank et al. 2007). Commentators have therefore concluded that freer trade in biofuels would have economic advantages.

Sustainability Criteria Focused on Direct Production Effects

Over the last few years, governments and a range of nongovernmental organizations have grown increasingly concerned about the environmental and social implications of biofuels, and have begun to adopt or propose a range of criteria for determining which biofuels should qualify for subsidies or mandates (Gnansounous et al. 2008; UNCTAD 2008). Advocates view these as "sustainability" criteria although they are not derived from any explicit or quantitative analysis of what would guarantee long-term human well-being or ecosystem health. The goals articulated, though, are sometimes broad and ambitious.

The vast bulk of sustainability criteria focus on the environmental and social effects of direct

Table 2.2 Biofuel targets from selected non-OECD countries. T = target; M = mandatory. * indicates enhanced OECD engagement; ** indicates OECD ascension candidate. (adapted from Peterson 2008)

country	type	Quality & Blending Share
Argentina	T/M	5% ethanol share (2010) 5% biodiesel share (2010)
Bolivia	T/M	20% ethanol share (2015)
Brazil*	M	25% ethanol blend (2007) 5% biodiesel blend (2013)
China*	T	15% transport fuel demand (2020)
Columbia	T/M	10% ethanol share (2007) 5% biodiesel share (2015)
Dominican Rep.	T/M	5% ethanol share (2015) 2% biodiesel share (2015)
India*	M	10% ethanol blend (2008-09) 5% biodiesel blend (2012)
Indonesia*	T	10% biofuel share (2010)
Malaysia	M	5% biodiesel blend in public vehicle
Paraguay	T/M	5% biodiesel share (2009)
Peru	T/M	7.8% ethanol share (2010) 5% biodiesel share (2010)
Philippines	T	10% ethanol share (2011) 2% biodiesel blend (2010)
Thailand	T	5% biodiesel share (2011)
Uruguay	T/M	5% ethanol share (2014) 5% biodiesel share (2012)

biofuel production with criteria governing the particular lands and production processes used. Germany, the United Kingdom, Switzerland, and the United States have all legislated criteria that focus heavily on direct land use. SEKAB, a major biofuel producer in Sweden, has reached an agreement with Brazil with similar standards (SEKAB 2008). Influential, broader recommendations include those established by the Dutch government and adopted by the Cramer Commission in 2006 and the draft criteria circulated for comment in August of 2008 by the Roundtable on Sustainable Biofuels (RSB), an organization that brings together biofuel producers and environmental organizations from across the world. The most common features of sustainability criteria (i.e. GHG emissions, biodiversity, farm practices, and social impacts) are discussed in below

GHG emissions: Since reducing greenhouse gases is a prominent goal for biofuel policies, existing criteria, not surprisingly, require variable levels of GHG reductions based on lifecycle analysis of the production processes. For example, the UK policy requires that fuels reduce GHG emissions by 40% in 2008, rising to 60% in 2010 (Gnansounou et al. 2008). The U.S. energy law (EISA) requires 60% reductions in greenhouse gas reductions for 61 billion liters of cellulosic biofuels and 50% reductions for the remaining 19 billion liters of other required "advanced biofuels." Additionally, the law, in theory, requires a 20% reduction for the 57 billion liters of biofuels that may be "conventional." Nonetheless, the U.S. law contains a grandfather provision for biofuels from existing production facilities anywhere in the world, which should easily fill up the 57 billion liters regardless of the calculated GHG impact. Although the European Parliament sought to require immediate GHG reductions for biofuels of 45% and 60% by 2015, the final directive required only a 35% immediate decrease, rising to 50% by 2017 (Council of the European Union 2008; Secretariat General 2008). These requirements may supercede tougher national requirements.

Many criteria also attempt to safeguard GHG gains by barring biofuels produced on some newly converted lands that today have high carbon content. As discussed below, EISA contains much tougher criteria than the proposed EU directive, but the proposed EU directive would create a disincentive to direct conversion by accounting for emissions from direct land use change amortized over twenty years, with specific emissions specified for different potential types of land conversion (Council of the European Union 2008, Annex 7 par. C).

Biodiversity: The broader recommendations of the Cramer Commission and the RSB would require that biofuels avoid areas of high biodiversity. The proposed directive by the European Commission has a weaker version that focuses on relatively pristine habitats; it would only preclude direct conversion of forests either undisturbed or regrown to "natural species composition", legally protected areas, and "highly biodiverse grassland" (i.e grassland that is species-rich, not fertilized and not degraded). UK rules use an alternative approach that relies on rankings of high biodiversity based on global systems. The European Commission provisions would also prohibit conversion of wetlands to non-wetlands, and forest to other biofuel uses, but would permit harvest of forest or conversion of those unmanaged forests that do not meet standards for native vegetation to tree plantations. In addition, many standards require protection of riparian areas, including the UK standards and those of the RSB.

EISA contains by far the toughest restrictions on land conversion by largely prohibiting any new clearing of natural areas for biofuel production. It does so by limiting the direct sources of biofuel feedstocks to existing actively managed or fallow agricultural lands and privately owned tree plantations, as well as wastes and residuals. EISA also prohibits plowing up natural grazing lands, although the status of grazing lands previously converted from forest is ambiguous[1].

In addition, some standards would impose criteria on the country wishing to produce the biofuel. For example, the EU directive would require that countries comply with treaties governing the trade of endangered species and protection of nationally designated important wetlands.

Farm Practices: Some proposed standards attempt to protect water quantity and quality. The RSB proposals would require broadly that biofuel production "shall not deplete water resources" and shall maintain water quality to its "optimal level under local conditions." EISA has no related criteria, but the EU directive requires that agricultural producers meet existing EU environmental directives. The U.K. standards would require annual documentation of applied good agricultural practices for efficient water usage and responsible use of chemicals. Whether the various standards could meet the high goals of the RSB statements is doubtful. For example, the EU as a whole has quantitative nutrient application limits only for manure application, not synthetic fertilizer (EEC 1991). More fundamentally, because agriculture is an inherently thirsty and leaky system, best agricultural practices tend to reduce, but do not eliminate, adverse impacts on water quality and quantity (Wiebe and Gollehon 2006).

Social Criteria: In addition to environmental criteria, a number of sustainability systems would impose labor, human rights, and rural development criteria. The RSB proposals would prohibit child and slave labor, guarantee the right of workers to organize, and require producers to abide by all laws and meet "internationally recognized" conditions of health and safety. The UK criteria are comparable, and include limitations on working hours. EISA contains no such criteria and the principal requirement in the proposed EU directive is for compliance with existing law.

Implementation and Enforcement Challenges

Implementing certification systems presents great challenges. As illustrated by the system put in place by the U.K., most certification systems contemplate placing the point of regulation on the biofuel facility, which then becomes responsible for tracking and guaranteeing that its fuel sources meet land use criteria. Tracking each facility's production process should prove relatively easy, but tracking production of the feedstock is challenging. To date, organic food certification provides a potentially successful model. In the United States, for example, each certified organic producer must have a third party inspector who certifies that the producer complies with nationally set standards. While the nature of those standards has been controversial on some points, there have been few publicized examples of products falsely claiming to meet the standards. However, recent reports exposing that much exported Italian olive oil was neither Italian nor even olive oil, and that much 'wild' salmon sold in New York supermarkets was in fact farm-raised (Consumer Reports 2007; Mueller 2007) highlight the potential for abuse.

The nature of sustainability criteria influences the ease of enforcement. The vaguer and more general the criteria, the harder they will be to enforce. Examples of problematic criteria highlighted by UNCTAD (2008) include criteria that workers not be "unnecessarily exposed to hazardous substances," or that the biofuel "should contribute to strengthening and diversifying the local economy." Other examples include those in the July 17, 2008 draft criteria of the RSB urging that biofuels should give "preference to waste, residues, and non-staple crops" (RSB 2008). Even for objective criteria, those that govern production processes that become invisible further down the supply chain will be hard to enforce. For example, it would be easier to enforce criteria distinguishing between corn stover and corn grain as a feedstock by inspecting a production facility than to differentiate acceptable from unacceptable corn based on the fertilizer application techniques employed to grow the corn.

Some reports also emphasize the importance of creating a certification system that avoids excessive costs, particularly to avoid placing special burdens on small farmers in developing countries. The Cramer Commission estimated the potential costs of a certification scheme focused on land management at 20% of production costs (UNCTAD 2008). To avoid an unmanageable multiplicity of standards, virtually all commentators and countries have agreed on the need to try to synthesize different standards, and some have proposed that biofuel sustainability criteria build on existing certification systems, like those of the Sustainable Forestry Initiative (Meyer 2007).

Limitations of Conventional Certification Approaches

Certification schemes of the kind proposed have the potential to achieve some goals if enforced. For example, criteria on GHG emissions governing the direct production of biofuels could have the effect of encouraging producers to use the most energy-efficient refining technologies[2]. Criteria governing farm production practices, including wage conditions, could also have real effect if properly enforced. Even so, there are important complications[3].

Unfortunately, traditional certification criteria that focus on direct production processes are probably incapable of protecting biodiversity, guaranteeing overall greenhouse gas benefits, or avoiding at least some additional contributions to the burdens on the world's water availability and quality. Such impacts derive from the simple fact that biofuel production increases the total world demand for intensively managed land. Nearly all the available literature on sustainability criteria acknowledge the challenge, but many pass it over too quickly and fail to appreciate its fundamental significance.

As a practical matter, biofuel industries can easily circumvent land use criteria such as requirements to avoid lands with high carbon content or high biodiversity. All of the crops now used for biofuels are also abundantly used in food production, which is not held to the same land use conversion limitations. Thus, a biofuel producer can easily avoid using newly converted lands for biofuels simply by using crops from existing croplands for biofuels. Once existing food acreage is diverted to biofuels, new production to replace the lost food crops can still permissibly move into the most carbon rich, biodiverse lands. Producers of new bioenergy feedstocks (e.g. *Miscanthus*) can similarly use existing cropland, while they or other producers clear new land to replace the food.

More broadly, the distinction between direct and indirect land use change is economically inappropriate. Biofuels create new demands for a feedstock, leading to its expanded production. Subject to land use rules, that expansion will occur on the lands where it can be most economically produced and utilized, which are likely to include a mixture of land types: some biologically diverse or carbon rich, and others not. The true land use costs of biofuels represent an average of the different land use types used to expand the feedstock regardless of whether the particular lands from which any particular feedstock originates are high carbon, low carbon or existing croplands.

The Nature of Displacement

Most economic analyses assume that if cellulosic biofuels emerge, the first installments will utilize non-food agricultural and forestry residues, and therefore not displace other land uses. However, any biofuel that diverts the productive capacity of land will cause some kind of displacement. Biofuels grown on forest or grasslands displace carbon storage, and potentially forest products or forage for livestock. After accounting for the food value of biofuel byproducts, biofuels grown on existing croplands result in three possible effects:

1. the food is not replaced because people consume less, which could modestly increase consumer efficiency in developed countries but also increase hunger for many of the world's poorest people

2. farmers plow up new forest or grassland, which releases carbon dioxide and may reduce biodiversity

3. the food is replaced on other existing agricultural lands because farmers intensify production in response to the diversion.

The third is the most attractive option, although it too will lead overall to expanded fertilizer and pesticide use, and greater water consumption.

Some studies hypothesize that biofuels could utilize existing or future abandoned agricultural land without cost (Fehrenbach et al. 2008; Field et al. 2008), but abandoned agricultural land commonly reverts to forest or grassland. So using that land for biofuels will still sacrifice ongoing carbon sequestration and potential biodiversity. The basic principle, particularly in an age of climate change that values carbon storage by land, is that productive land provides valuable benefits, and the world cannot use such land for biofuels without sacrificing some other benefits.

To a large extent, the decision to produce biofuels is therefore a land use decision. The fundamental policy question is whether the benefits of devoting land to biofuels exceed those of leaving that land in its existing use, or potentially improving its existing use in other ways. Limiting the focus to climate change, the basic question is whether the use of biofuels, and thus the use of land for feedstock production, saves more GHG emissions by displacing fossil fuel than that saved by leaving land in its existing use even while continuing to use fossil fuels.

The magnitude and potential consequences of the three effects of diverting cropland to biofuels obviously vary based on a range of factors, including the type of biofuel and the land on which it is produced. Nevertheless, biofuel production communicates to the market through a price signal, which reverberates worldwide. Once this signal is sent, economic factors will dictate the response within the confines of different laws. Economic models are therefore required to predict the balance of responses.

These models face large uncertainties and challenges. To date, one interesting result is that different economic modeling results are generating similar responses. For example, Searchinger et al. (2008) and the OECD (2008) used two very different modeling approaches and analyzed different mixes of biofuels, but Searchinger et al. predicted that cropland would expand at a rate of 373,000 hectares per Mtoe (ha $Mtoe^{-1}$) of corn ethanol while the OECD predicted 318,000 ha $Mtoe^{-1}$ for a mixture of biofuels. These results are even closer than they appear because the scenario used in the OECD analysis incorporates large quantities of ethanol from sugarcane, which produces more ethanol per hectare than corn ethanol.

These two results imply 65 to 76 Mha of additional cropland to provide 10% of the world's total transport fuel in 2020, which implies a net increase in world cropland of roughly 5% to provide 10% of the world's transport fuel. This percentage does not fully convey land use impacts because the world's cropland is of widely varying quality, and crop-based biofuels would tend to use many of the most productive lands. In 2007, although biofuel production used a little more than 5.5% of the world's cropland (Heimlich 2008), it used 6% of the world's cereal production and 8% of the world's vegetable oil (OECD/FAO 2008).

Many other modeling efforts are underway, and all tend to show significant land use change (e.g. Gurgel et al. 2007; Banse et al 2008; Hertel et al. 2008), although the analyses do not typically present results in ways that permit a quantitative analysis as described above. The land figures extrapolated here from Searchinger et al. (2008) and OECD (2008) are on the low end of many analyses, at least in part because they estimated that higher prices will drive down demand and, thus, some food will not be replaced. That reduction in demand should be viewed as an additional cost of biofuels. Other calculations summarized by Kampman et al. (2008) estimate that a 10% world biofuel target for transport fuel would use 73-276 Mha. The different estimates depend on such important assumptions as the types of feedstocks that will supply the biofuels and on such methodological differences as the treatment of byproducts.

Regional analyses reveal the significance of these assumptions and methods. For example, the IEA estimated in 2004 that replacing 10% of gasoline and diesel in the U.S. and Europe would require 43% of the cropland in the U.S. and 38% in the EU (IEA, 2004). This analysis, however, did not account for byproducts and assumed that food consumption would otherwise remain unchanged. By contrast, the European Commission, in assessments of its proposed biofuel directive, has predicted that biofuel production would use only 15% of European arable land and cause virtually no displacement of existing cropland (EC 2007a, 2007b; Dehue et al. 2008). This projection assumes substantial production of biofuels from waste biomass that use no land and assumes that all new European crops are planted on reserve lands or croplands that would otherwise become abandoned. That prediction seems dubious, as many European reserve lands have already been converted, and even if the assumptions are valid, reserve and abandoned croplands would sequester carbon and provide other benefits if not used for biofuels. Most importantly, that analysis ignores the expansion of cropland abroad to replace European food exports.

Alternative Environmental Criteria to Address Land Use

Two different environmental approaches have emerged to address land use demands. One requires that life cycle GHG calculations assess indirect land use change. For example, the EISA requires that 80 of its 136 billion liters of mandated biofuels achieve roughly 50% or 60%

reductions in greenhouse gases (depending on type) after accounting for emissions from indirect land use change. The California Air Resources Board is developing regulations for a low carbon fuel standard that would similarly assign greenhouse gas levels to different biofuels that incorporate land use change, and require that the total mix of fuels sold in California reduce greenhouse gas emissions overall.

The European Union Parliament proposed similar measures incorporating a method for calculating greenhouse gas emissions for indirect land use change and a set default emission factor of 40 gCO_2 equivalent (Secretariat General 2008), enough to cause most crop-based biofuels to fail the EU's greenhouse gas requirements. EU legislation, however, must receive the approval not only of the parliament but also the Council of States and the European Commission. In final negotiations, the Parliament backed down from the requirement to calculate indirect land use change because of opposition from the European Commission and, especially, France, which occupied the rotational Presidency of the Council at the time. The compromise still requires the European Commission to propose a "concrete methodology" for calculating "emissions from carbon stock changes caused by indirect land use change" to the Parliament "where appropriate."

Precise reliance on a GHG accounting approach presents at least two major challenges. First, because this approach uses only GHG accounting to measure land use change, it ignores other potential environmental effects. In other words, it implies that substantial indirect conversion of the world's forests due to biofuels is acceptable so long as the GHG benefit from the production side of biofuels is large enough. This approach also rewards biofuels for hunger effects: to the extent that food diverted to biofuels is not replaced, biofuels do not cause greenhouse gas emissions from land use change and can therefore become acceptable. That perverse approach is not merely theoretical: it is reflected in an analysis underway by the EPA to implement EISA. Second, this accounting approach requires specific calculations of emissions from land use change for biofuels from many different feedstocks produced in different locations despite inherent uncertainty in the model results. Key variables with high uncertainty because of fundamental methodological constraints include the likely balance between expansion of cropland (extensification) and more production on existing cropland (intensification). Precise model predictions will probably also vary with the level and types of biofuels demanded, not only in one country, but in all countries.

More broadly, the precise response of the world's farmers depends on many unknowable, government responses. Much of the world's best potential cropland is tropical forest and wetlands, which has high carbon content. In the face of food shortages and higher prices, governments may build infrastructure to encourage production in these areas, but global warming concerns could also motivate governments to enact and truly enforce policies to inhibit use of those areas. In light of these uncertainties, quantitative estimates are probably best used for making qualitative judgments. In reality, any system of greenhouse gas accounting that relies on precise estimates for indirect land use change could be based on a false precision.

Because of these modeling uncertainties, some biofuel advocates argue that GHG calculations should ignore land use change (Simmons et al. 2008). These advocates in effect argue the untenable position that GHG calculations should incorporate the benefits of using land to make biofuels while ignoring the cost. They would still credit biofuels with all the carbon taken up by plants incorporated into the biofuel while ignoring the fact that the land used to produce these plants would still be growing plants and therefore taking up carbon anyway. Such an analysis would present the gross benefit of using land for biofuels rather than a net benefit (if there indeed is any), which is equivalent to counting the economics of making biofuels while assuming that using land is free.

In addition, while the precise emissions associated with indirect land use change are uncertain, it is quite clear that they are high. Searchinger et al. (2008) calculated emissions from indirect land use change for U.S. corn ethanol at roughly 100 gram CO2 per megajoule (g MJ^{-1}) using a 30-year amortization period for land use change. Similarly, if 25% of palm oil biodiesel derives directly or indirectly from new palm plantation on peat lands, the emissions from these drained soils alone imply 378 g MJ^{-1} according to figures used by the Joint Research Centre of the European Commission (De Santi et al. 2008). Replacing rapeseed or soybean biodiesel in part through palm oil similarly implies high emissions. Indeed, direct payback periods calculated by Gibbs et al. (2008), Fargione et al. (2008) and the Gallagher Report all imply high emissions from land use change unless only an extremely small percentage of land diverted to biofuel production is replaced elsewhere.

An alternative approach is suggested by proposed Swiss criteria and by the Gallagher Report of the U.K. government. The Swiss approach starts by barring biofuels derived from palm oil, corn, and soybeans (Steenblik 2008). It then distinguishes between biofuels from waste products, which are automatically acceptable, and biofuels from any agricultural product, which have to pass an evaluation of social and environmental criteria by the Swiss Ministry of Environment. These criteria are supposed to evaluate if the cultivation is jeopardizing rainforests or other carbon sinks, whether the biofuel generates a 60% GHG savings compared to fossil fuels, and whether the biofuel is at least a 25% improvement on fossil fuels using a total ecological indicator. How the Swiss will evaluate impacts on indirect land use change, however, is not yet clear, and the exemption of rapeseed biodiesel from the bans seems arbitrary if for no other reason than that market experience to date indicates that palm oil in the tropics will partially replace rapeseed oil as a biodiesel feedstock in Europe (Jank et al. 2007).

The Gallagher Report proposes more simply that, in addition to the UK's existing certification criteria, future policies (i.e. criteria applied only to biofuels in excess of an already adopted 5% UK target for transport fuels) should only support biofuels that avoid indirect land use change altogether (Gallagher 2008). According to the report, acceptable biofuels would be those generated from waste products, and those produced on 'idle' and 'marginal land'. The report acknowledges the challenge of defining these terms, but indicates such lands must not now produce food, should be of low carbon stock and biodiversity value, and yet be capable of high productivity if rehabilitated for biofuels. This recommendation followed the conclusion that using productive land for biofuels creates an unacceptable risk of directly or indirectly competing with food, harming biodiversity and increasing greenhouse gases.

This approach, which seeks to avoid competition with other valuable land uses, is also the approach explicitly or implicitly recommended by a broad host of international technical agencies including the Food and Agricultural Organization of the UN (FAO), the

International Energy Association (IEA), the Joint Research Centre of the European Commission (JRC), and the European Economic and Social Committee (Searchinger 2008). It implies, significantly, that a certification system must not merely prohibit some types of lands but must affirmatively require use of waste products or other types of marginal lands.

Conclusion

Though high oil prices could become an independent driver, expensive biofuel subsidies and mandates have driven and will probably continue to control the expansion of biofuel production. Because those mandates seek public benefits in general and GHG reduction in particular, governments have begun to impose different sets of sustainability criteria, all of which would require some kind of certification system.

All certification approaches raise major administrative challenges, but conventional approaches do have the potential to influence production processes, agricultural conservation, and labor practices. Yet, most criteria that aim to protect biodiversity or assure GHG benefits are likely to be unsuccessful. Barring direct production of biofuel feedstocks on lands that presently have high value for carbon storage will have little effect because farmers can simply supply feedstocks from existing cropland while replacing food-crops on newly converted forests, wetlands, or other high value lands.

To avoid these effects, some approaches, particularly that of the U.S. through EISA, seek to require large GHG savings that take into account indirect land use change. In reality, estimating such change and emissions is only possible within a broad range of uncertainty. However, virtually every technical agency that has looked into the question, has concluded that incorporating indirect land use change will eliminate or greatly reduce potential GHG savings (Searchinger 2008). This kind of effort also ironically awards biofuels to the extent they reduce food consumption and generate hunger.

A promising alternative approach, recommended but not yet tried, would require use of feedstocks that inherently avoid significant land use change; i.e., biofuels from waste products and 'idle' and 'marginal' lands. This policy recognizes that biofuel production systems that divert the productive capacity of land inherently compete with other valuable land uses (e.g. food, fiber, or timber production and carbon storage and sequestration). The basic question now confronting the world involves the trade-offs in using land to meet energy needs rather than other needs.

Notes

[1] These criteria are incorporated into the definition of "renewable fuel." The use of grazing lands that were once forest may actually be allowed because the definition permits cropping for biofuels of land previously "cleared" even if not used for crop purposes as of December, 2007.

[2] For example, some lifecycle analyses would distinguish production facilities based on the extent to which they use natural gas or coal as a fuel source. But if natural gas supplies are limited, using them for biofuel production would probably mainly cause other energy-consumers to use coal. Life-cycle analysis presents serious boundary problems.

[3] Criteria that require riparian buffers, fertilizer best management practices, or compliance with minimum wage laws, if enforced, would assure that the biofuel production itself complies with certain minimum practice criteria. Even so, that does not guarantee any environmental improvement. To the extent some feedstocks are already produced in compliance with these criteria, certification could simply mean that

the most benignly produced portions of existing crops are diverted to biofuels, without changing overall farm practices. Over the long run, the benefits of these sustainability criteria may depend on the emergence of a price premium for the desired forms of production that encourage more farmers to adopt the preferred production techniques.

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