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Biofuels: Is the cure worse than the disease?

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Summary

Biofuels have been championed as an energy source that can increase security of supply, reduce vehicle emissions and provide a new income stream for farmers. These claims are contested, however. Critics assert that biofuels will increase energy-price volatility, food prices and even life-cycle emissions of greenhouse gases. This paper presents salient facts and figures to shed light on these controversial issues and asks whether biofuels offer a cure that is worse than the disease they seek to heal. The information gathered in this paper gives rise to two fundamental questions:

1. *Do the technical means exist to produce biofuels in ways that enable the world to meet demand for transportation energy in more secure and less harmful ways, on a meaningful scale and without compromising the ability to feed a growing population?*

2. *Do current national and international policies that promote the production of biofuels represent the most cost-effective means of using biomass and the best way forward for the transport sector?*

I. Biofuels: is the cure worse than the disease?

In recent years, biofuels have attracted increasing attention. Their selling points are many: they are made from renewable feedstocks that can be grown by farmers, and substituting them for petroleum products reduces greenhouse gases and dependency on foreign oil. Following Brazil's footsteps, one country after another has launched new programmes to encourage their production and use. The European Union, United States and numerous other countries have set ambitious calendars for their compulsory incorporation at filling stations. Farmers are ready for action, industry is investing, and governments have opened up their treasuries to help biofuels take off.

Unfortunately, the broader picture is not so attractive. A number of concerns are raised by these developments. Without subsidies, most biofuels cannot compete on price with petroleum products in most regions of the world. The surface of cultivable land that they require is significant and has put pressure on food and water prices. A recent OECD/FAO (2007) report expected food prices to rise by between 20% and 50% by 2016. Growing use of cereals, sugar, oilseeds and vegetable oils to satisfy the needs of a rapidly increasing biofuels industry is one of the main drivers, according to the report. Other warnings have come from the CEOs of Cargill and Nestlé, who see food prices set for a period of significant and long-lasting inflation as a result of land being diverted to grow energy crops. Environmental and social impacts are of concern as well, notably the clearing of natural forests or rangeland.

In the light of these concerns, the question must be asked whether the potential "cure" offered by biofuels is worse than the disease. This paper begins with an overview of the potential of biofuels technologies and government subsidies and instruments aimed at increasing their use. Trade in biofuels and the barriers to it are discussed in Section 4. The consequences of current policies on food prices, the environment and energy security are discussed in the following section. We then ask how cost-effective government policies are in reducing carbon emissions and increasing energy security. Finally, practical ways forward while avoiding unintended and harmful consequences of subsidies and targets (such as biofuel certification) are explored.

II. What is the (ultimate) technical potential of biofuels?

Conventional and second-generation biofuels technologies

A wide range of biologically-derived feedstocks can be transformed into liquid fuels. The technologies used to make that transformation are also numerous. The most basic is the chemical transesterification process used to convert oils and fats into fatty-acid methyl ester (FAME), commonly known as biodiesel because of its resemblance to diesel (Fig. 1). Most commercial production of biodiesel is based on vegetable oils such as those obtained from oil palm, rapeseed, sunflower seed, and soybean, but some is made from tallow, used cooking oil and even fish oil.

Ethyl alcohol, or ethanol, can be produced from any feedstock that contains relatively dense quantities of sugar or starchy crops, using nothing more than a flask. The most common feedstocks are sugarcane, sugar beet, maize (corn), wheat and other starchy cereals such as barley, sorghum and rye. Concentrating the ethanol from the 16% or so that exists in the beer to the high level of purity (typically 99.7%) required for use in spark-ignition engines requires distillation and dehydration equipment.

At present, the predominant liquid biofuels in use are ethanol and biodiesel. A much smaller amount of biomass-derived energy is converted into methane gas for use in transport. According to the International Energy Agency's World Energy Outlook 2006, global production of biofuels amounted to 0.8 EJ (or 20 Mtoe or 643 thousand barrels per day) in 2005. This equals roughly 1% of total road transport fuel consumption. Around 85% of this amount came from ethanol, and the remainder from biodiesel.

The global potential of conventional biofuels is limited by the availability of suitable land for crops and the high cost of most conventional technologies. For this reason there is intense interest both in finding ways to use a larger percentage of the plants currently used for fuel production and a much wider range of feedstocks; i.e. using alternative crops such as Jatropha, that do not necessarily need the intensive management and quality soils that food crops require. This is why the hopes of many people are set on developing second-generation biofuels.

The technical challenge that appears at the heart of this strategy is finding ways to convert cellulose (an

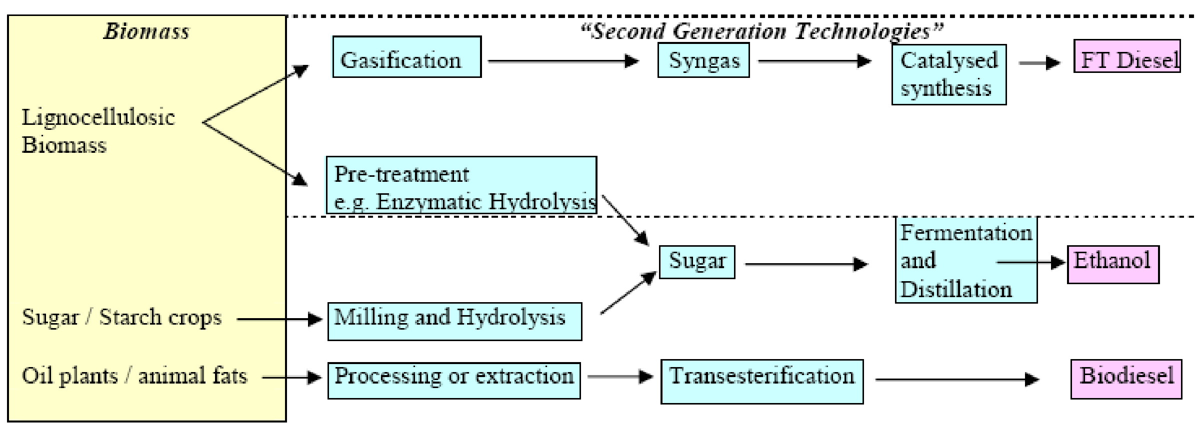


Figure 1. Fuel production pathways
Source: adapted from BMU (2006) and Hamelinck and Faaij (2006)

organic compound) into sugars that can then be converted to ethanol. Cellulose is found in a wide variety of biomass sources, including fast-growing grasses or trees, crop or forest residues, and even paper waste. An important advantage of plants high in cellulose is that they could be grown on marginally productive or degraded land unsuitable for food crop production and that residues of the plant not suitable for food production can be used. Significant technological hurdles remain, however, before ethanol can be produced from ligno-cellulosic feedstocks on a large scale. Breaking down the cellulose molecules into fermentable sugars, and doing it cheaply, is the biggest challenge. One promising method uses enzymes; others use heat or acids.

Second-generation approaches to producing diesel-substitute fuels would provide another possible route. These technologies differ radically from the trans-esterification process. One involves the gasification of biomass and the further transformation of the gas to a liquid. Using this process, wood, straw or other biomass sources can be turned into a syngas before being converted into a liquid fuel by means of the "Fischer-Tropsch Process" (biomass-to-liquids or BTL). In this way the energy of the entire above-ground plant can be utilised -which is not the case for biodiesel production from oilseeds. The most important barrier for biodiesel currently is its higher cost of production compared with ethanol, with few prospects on the horizon for technological breakthroughs that would lead to substantial cost reductions. BTL synthesis looks more promising than biodiesel, but major technological advances would be needed to bring down its cost (IEA, 2006a).

Although second-generation technologies are still in the emerging stage commercially, their basic production pathways have been around for decades. What is giving the technology new impetus is the urgent need to develop transportation fuels with much lower GHG emissions and land use intensity than their fossil-fuel and first-generation biofuel alternatives. What is standing in their way is cost.

The roles and prospects of genetic engineering are worth touching upon briefly. Genetically engineered crops have genes from other species inserted or substituted in their genomes to give the plants different, more favourable characteristics with respect to biomass yields, starch or oil output, fertilizer requirements or improved resistance to pests (IEA, 2005). To avoid the kind of adverse public reaction that frequently accompanies the modification of food crops, plant scientists may focus on altering the genes of dedicated energy crops, such as switchgrass. Research on genetically modifying grasses and trees is less developed than for crops and efforts are focussed on mapping gene sequences and developing ideas for practical applications. In most analyses (IEA, 2005; Fischer and Schrattenholtzer, 2001) an agricultural yield increase of around 1% per annum is assumed possible (leading to a 60% increase in agricultural productivity by 2050 based on extrapolation of slightly lower historical improvement rates). The open question for genetic engineering is; will it allow plant yields to rise faster than this projected 1% annual yield increase, or will it become a necessary tool for sustaining this high improvement rate?

Two other general observations regarding the global technical potential of bioenergy to meet future energy demands must be remembered. These concern the low power and energy density of biomass derived fuels as pointed out by Smil (2003). Power density refers to the rate of energy production per unit of the earth's area and is usually expressed in watts per square meter (W/m^2). Biomass has a low energy density that ranges from only 0.01 W/m^2 for burning wood through to a maximum 1.2 W/m^2 for intensively managed tree plantations. By comparison, fossil fuels are commonly produced with power densities of 1000 to 10 000 W/m^2 and hence only small land areas are needed to supply enormous energy flows. Of all renewables the power density from biomass via photosynthesis offers the lowest power density and thus requires the largest areas of land. Harvesting sunlight to produce electricity is for example already an order of magnitude more efficient (10 W/m^2).

Energy density is the amount of energy contained in a unit of fuel. Air-dry crop residues, for example, contain a maximum of 15 megajoules per kilogram

(MJ/kg) whereas the energy of crude oil hovers around 40 MJ/kg. The implication is that to replace 1 unit of fossil fuels, 1.5 units of plant-derived ethanol would be needed, which will have to be reflected in the extent, cost and operations of the needed infrastructure. Both factors, power and energy density, provide permanent physical limits to the extent to which biofuels can replace fossil fuels.

Global biomass potential and biofuels

Several institutions and scientists have tried to assess the global potential for biofuels production. The key questions that are addressed in these studies are: how much land could be made available for energy biomass (given the required rise in food production in the coming decades), how much could agricultural productivity (tonnes per hectare) rise, what other biomass residues and wastes could be used, and what can be expected from increases in conversion efficiency (yield per tonnes of feedstock)? Land available for dedicated crop production in 2050.

Several reports issued over the last couple of years have examined the land requirements for bioenergy in depth. The discussion here draws heavily on the work of the Food and Agriculture Organization of the United Nations (FAO) and the International Institute

	total land surface	land with potential for rainfed cultivation	potential land under forest	land already in use for agriculture (arable land)	additional land needed for food, housing and infrastructure until 2030/50[a]	gross additional land available	additional land potentially available
	(-)	(1)	(2)	(3)	(4)	(5)=(1)-(2)-(3)-(4)	(5) * (1 - % needed for grassland)
North America	2.1	0.4	0.1	0.2	0.0	0.00	0.00 (0%)
South and Central America	2.0	0.9	0.3	0.1	0.1	0.25	0.25 (0%)
Europe and Russia	2.3	0.5	0.1	0.2	0.0	0.08	0.04 (50%)
Africa	3.0	0.9	0.1	0.2	0.1	0.44	0.18 (60%)
Asia	3.1	0.5	0.0	0.6	0.1	-0.07[b]	-0.07 (n/a)
Oceania	0.9	0.1	0.0	0.1	0.0	0.04	0.04 (0%)
World Total	**13.4**	**3.3**	**0.8**[c]	**1.5**[c]	**0.3**	**0.74**	**0.44**

a. Most studies assume that only a small fraction of additional land is needed to feed the world's growing population — from 6.5 billion people at present to 9 billion people in 2050 — and that most of the increase in food requirements will be met by an increase in agricultural productivity.6 Here it is assumed that 0.2 Gha is needed for additional food production (based on Fisher and Schrattenholzer, 2001 where a yearly increase in agricultural productivity of 1.1% is assumed); the remainder (roughly 0.1 Gha) is needed for additional housing and infrastructure.

b. A negative number is shown here as more land is cultivated than potentially available for rain-fed cultivation because of irrigation. The negative land available has not been rounded to zero because food imports are likely to be needed from other region with implications on their land use.

c. Numbers in this column don't add up because of rounding.

Table 1. Potentially available land for energy biomass production in 2050 (in Gha)

for Applied Systems Analysis (IIASA). The IIASA study (Fisher *et al*., 2000) estimates the maximum available area that could be used for rain-fed cultivation (cropland), drawing on an inventory of land resources and their biophysical limitations and potentials. It concludes that less than one-quarter of the global land surface could be used for rain-fed crop cultivation. The other three quarters (10.5 Gha) are either too cold (13%), too dry (27%), too steep (12%), or constrained by unfavourable soil conditions (about 65%).

Table 1 shows the land with cultivation potential by region in Column 1. From the land suitable for rain-fed cultivation is subtracted forested land, land already in use for agriculture, and the increase in land needed to feed and accommodate the world's growing population. The worldwide "gross" available land for dedicated energy crops would then amount to roughly 0.7 Gha (Column 5).

However, it is far too optimistic to assume that 0.7 Gha is available for additional dedicated bioenergy crops (in 2004 only 0.01 Gha was used for the production of biofuels). Currently, virtually all of the Earth's land surface is already in use. From the 13.4 Gha of the global surface 1.5 Gha is used as arable land, 3.5 Gha is used as grass land, 0.2 Gha is used for urban settlements, 3.9 Gha is forest and the remaining 4.2 Gha consists of desert, mountains and otherwise land that is unsuitable for productive use.

Most of the 0.7 Gha that was calculated as potentially available is currently in use as grassland for livestock production. Livestock production remains the world's largest land user, as diet preference trends towards more animal products. As an illustration, if everybody in the world were to eat a western diet of 80 kg of meat per year, then 2.5 Gha of additional cultivated land would be needed to provide sufficient feed crops (Naylor *et al*., 2005). That is half of the 5 Gha of land that is currently under management as arable (1.5 Gha) and grassland (3.5 Gha). On the other side of the ledger there is a trend towards largescale intensive indoor operations fed mainly on bought-in feed from least-cost international markets that might relieve some of the pressure on grasslands. The results of Bouwman *et al*. (2005), as reported in Hoogwijk *et al*. (2005), are used in Table 1 to correct the "gross" estimate for the extensive grassland area that will remain to be needed for cattle grazing in different regions of the world.

The conclusion from this back-of-the-envelope analysis is that 0.44 Gha should be seen as the technical upper limit to what could be made available for dedicated bio-energy crop production in 2050. The potential for expansion is mainly concentrated in Africa and South and Central America. More than 80% of additional cultivable land is located in these two regions, and about half of this land is concentrated in just seven countries – Angola, Democratic Republic of Congo, Sudan, Argentina, Bolivia, Brazil and Colombia (Fischer *et al*., 2006). However, unutilised land in sub-Saharan Africa faces a number of obstacles before it can be profitably brought into production, including poor infrastructure, underdeveloped financial markets, and a hostile investment climate on account of (often inappropriate) government policies (Kojima, 2007). In other regions, the potential is either very limited or negative (dependent on imports). The overall estimate of potential land compares reasonable well with the average of 0.59 Gha calculated from 11 studies (out of a total of 17) reviewed in Berndes *et al*. (2003); and which includes some very optimistic analysis.

These estimates should be viewed with caution. As the FAO (2000) warns, the models used to calculate land availability tend to over-estimate the amount of land that could be used for agriculture and underestimate the area of land that is already in use (by 10-20%). Moreover, in practice it is often extremely difficult to make land that is technically available for agriculture actually available in practice. Other competing demands will exist that put constraints on future changes in land use. Increasing demand for natural fibres and other materials, for foods grown less intensively or using organic production methods, for conservation of ecosystems and biodiversity, and for carbon sequestration, can all be expected to reduce the land available at a given rental cost. In short, competition for arable land among food, fibre, biomaterials and energy production cannot be avoided.

Some analyses (Hoogwijk *et al*, 2003) have suggested high-quality arable land can be reserved for food production, whereas energy crops should be cultivated on land of lower quality, including set-aside land in places like Europe and poorly managed and degraded land elsewhere. However, this option will be severely limited by the shortage of water resources in some regions and the increase of land degradation and desertification. Water supply is already under stress (Brown, 2007). There is a limited potential for the expansion of irrigation onto land unsuited for rainfall cultivation, as large volumes of water are needed and many regions in the dry zones are already experiencing water shortages. The practicality of given priority to food production on high-quality land should also be questioned as land allocation for marketable commodities will (more or less) happen in the way that maximises net private benefits to the land users (WWF, 2006).

Primary energy from dedicated energy crops

After determining the land that could be made available for the growing of bio-energy crops, on the other side of the ledger is determining the agricultural yield on this land that could be achieved. This is an additional reason for the widely diverging projections of the potential for primary energy from biomass as many different yields are used to calculate the tonnes of oven-dry feedstock that can be produced per hectare. They range from 54 GJ/ha/yr to 330 GJ/ha/yr in 2050 or wider.

Actual progress will depend on the development of agricultural productivity influenced by among others technological developments such as genetic engineering and improved harvesting methods. In Europe, annual yields of 20-30 oven-dry tonnes per hectare (odt/ha) are the limit that sunlight, rainfall and climate permit, with adequate water and nutrients. In tropical regions, yields of up to 50 odt/ha can be achieved. Given the large areas of moderately productive land included in the land estimates, and following the IEA, this paper assumes an average yield of 10 odt produced from a hectare with an energy content of 19 GJ/odt -i.e. 190 GJ/ha/yr of primary energy. This results in an estimate of approximately 110 EJ that could potentially be produced from the 0.44 Gha that is available for dedicated bioenergy crop production (Column 1 in Table 2).

The potential of marginal and degraded land is not explicitly taken into account in the estimation of the biomass potential presented here, as no reliable estimates exist on how much of this land could potentially be used in addition to existing cultivated land. The technical potential might be in the order of 29-39 EJ (based on a review of studies in Hoogwijk *et al*., 2003); however, there may be some double counting with our estimate as reported above.

Bioenergy potential from residues and 'wastes'

The feedstocks for biofuels include not only biomass harvested from dedicated agricultural land and crops but also potentially (with second-generation technologies), agricultural and forest residues, animal, organic and material waste.

The size of useable agricultural residues depends both on the total agricultural area in use as well as the type of production system. Extensive production systems require re-use of residues to provide recycling of nutrients and hence help maintain soil fertility. Because it is assumed that agricultural productivity increases by roughly 1% a year to feed the growing world population, part of this productivity increase is expected to be met by a greater use of plant residues, thus fewer residues will be available for use as energy. Numerous studies have shown that only a fraction — typically 25% to 33% of the technically available crop residues from grasses or corn — can be harvested from the land in a sustainable manner (e.g. Wallace *et al*., 2007). Furthermore, yields from residues will vary among regions depending on the crop, soil quality, climate and water availability. The yields calculated by Fischer and Schrattenholzer (2001) for crop residues by world region are used here.

The sustainable energy potential of the world's forests is uncertain. World demand for wood as a raw material (excluding energy) is projected to grow by 25% between 2005 and 2050. New uses of forest products, including residues -e.g. fibre, fertilizer and even fodder- are constantly being developed (Hoogwijk *et al*., 2005). Where forests are managed sustainably, many of the forest residues are left on the ground -to protect the soil from erosion, to enrich the soil, and to provide habitat for wildlife. Furthermore, the energy potential of wood is restricted to distances of less than 200 km between production and consumption. Fischer and Schrattenholzer (2001) take these factors into account when estimating the potential from wood residues (Table 2).

The cost of collecting animal and organic waste is the most important cost element for these types of feedstocks. At the same time, the technology that is needed to burn and convert these wastes to useable fuel is characterized by significant economies of scale. The economics of the logistical and conversion part of the production of biofuels from this feedstock thus work in opposite directions (decentralization versus centralization). In the words of Exxon Chairman, Rex W. Tillerson, "The bigger challenge [for second generation biofuels] though, again, is the massive amounts of material that you have to gather up. Switchgrass, or whatever you want to use, you've got to collect a lot of material, take it to a central location to be processed -and the amount of material that you have to move around is enormous to generate anything of scale". This inherent difficulty in the use of waste material is the reason for the assumption that biomass waste will only be available in niche markets where material will already be on site or in the direct neighborhood. The global potential in this analysis therefore equals the lower estimates of the global technical potential in other studies summarized in Hoogwijk *et al*. (2003).

Table 2 shows that the primary energy supply for heat, electricity and transport that could technically be produced from the biomass potential is roughly 245 EJ. This is at the lower end of the wide range of 125-760 EJ reported in the IPCC (2007) Fourth Assessment Report and in other studies.

The useable energy in the biomass depends on the efficiency with which it can be converted. This will strongly depend on the technology that is used. Moreira (2006) for example estimates that new, highly efficient combined ethanol and electricity plants in Brazil operating on sugarcane and cellulose can operate with an efficiency of 31% for ethanol

	potential from additional land	crop residues potential	forest residues potential	animal and organic waste	total biomass potential primary energy	total biofuels potential after conversion
	(1)	(2)	(3)	(4)[a]	(5)=(1)+(2)+(3)+(4)	(6)=(5)x0.5x0.35[b]
North America	0.7	5.0	14.3	0.5	20.5	3.6
South and Central America	62.0	4.3	16.8	0.9	84.0	14.7
Europe and Russia	10.1	5.8	16.9	1.1	33.9	5.9
Africa	43.8	6.3	18.2	1.4	69.7	12.2
Asia	-18.6	12.8	20.6	6.0	20.8	3.6
Oceania	11.2	0.6	3.8	0.1	15.7	2.7
World Total	**109.2**	**34.8**	**90.6**	**10.0**	**244.6**	**42.8**

a. As a regional distribution is not available the regional distribution is for practical reasons assumed to be proportional to population figures.

b. Assuming half the biomass is used for biofuels production and a conversion efficiency of 35% as explained in the text.

Table 2. Total (oven-dry) biomass and biofuel potential (in EJ/yr in 2050)

production and 23% for electricity (a net conversion efficiency of 54%). Ideally, such a biorefinery approach that takes advantage of the various components in biomass and maximizes the value derived from it, should be applied widely. The biorefinery concept is important for improving the economics of advanced bio-energy technologies.

Considerable amounts of biomass will be needed for power and heat generation. It is not clear what the most cost-effective allocations of biomass between transport fuel, heat and electricity are likely to be (IEA, 2005). It is unlikely that all biomass available will be used for the production of liquid biofuels. Already such competition is evident in the United States. In June 2007, a company called Green Energy Resources announced that it had recently obtained rights for over 1 million tonnes of standing timber in the south-east United States and had options on storm-damaged wood generated from future hurricanes. This wood will be destined not for production of ethanol, but to supply the 25-30 new wood-fired power plants planned for the New England states by 2010. Green Energy Resources predicts that prices for woodchips, currently between $25-32 per tonne, will reach $50 per tonne by the middle of 2008.

Although cogeneration allows for simultaneous production of biofuels and electricity, it is not always possible. Some will argue that from a strategic point of view, the preferred use of biomass should be for transportation fuel, as clean alternatives for transport fuel are more readily available for electricity generation (wind, nuclear, solar, CCS). This argument is not very convincing, as in almost any conceivable future scenario fossil fuels will still be providing more than 50% of the world's generating capacity in 2050. Using less biomass in electricity generation means using more fossil fuels. The proper economic criteria should be the marginal abatement cost per tonne of CO_2 for either biofuels production, heat or electricity generation that will be determined by the market. Finally, from a biorefinery viewpoint, lingocellulosic feedstock would be split so that roughly one-third to half of the feedstock would be applied to electricity, while the remainder would be put to biofuel production.

A reasonable assumption seems to be that half of the available surplus biomass will be used for electricity and heat, and half for the production of biofuels. Furthermore, we assumed that the conversion efficiency of all biofuel technologies had the high efficiency of ethanol from sugarcane and therefore used 35% as a conversion factor in Table 2. In this way an upper limit for the potential of biofuel in 2050 is calculated, which comes down to around 43 EJ. This would mean biofuels could provide roughly 23% of the 190 EJ demand for liquid fuels in 2050 as foreseen in the IEA's baseline scenario (IEA 2006a). However, that is without taking the economics of biofuels into account.

Climate change mitigation potential

An assessment of the possibilities to reduce GHG emissions via biofuels requires that the performance characteristics throughout the full fuel cycle, from "well-to-wheels", must be taken into account. Research on the net GHG reduction impacts of biofuels is progressing but is far from conclusive. In some cases, emissions may be as high or higher than the net GHG emissions from gasoline vehicles. In other cases they reduce GHG emissions substantially.

The complexity of the assessment is easily understood when reflecting on the many different elements that must be included in the analyses: the type of crop, the amount and type of energy embedded in the fertilizer used to grow the crop and in the water used, emissions from fertilizer production, the resulting crop yield, the energy used in gathering and transporting the feedstock to the biorefinery, alternative land uses, and the energy intensity and fuel types used in the conversion process (IEA 2006b). Nevertheless, the general picture that seems to emerge suggests a certain ranking between the different technologies (Fig. 2).

The best performance is achieved by ethanol from sugarcane in Brazil with the potential to reduce total life-cycle GHG emissions by up to 90% compared with the consumption of an equivalent amount of gasoline. Ethanol from cellulosic feedstocks follows, with typical estimates placing their reduction in the range of 70 to 90% (IEA, 2006a). In some cases, the savings could approach and even exceed 100% with, for example, the cogeneration of electricity that displaces coal-fired electricity from the grid. However, it is important to keep in mind that these estimates mainly come from engineering studies and only a few largescale production facilities from which empirically derived data can be obtained.

Next in line are ethanol from sugar beets and biodiesel, with GHG reductions of roughly 40% to 50%. Finally, ethanol from starchy grains yields the smallest GHG reduction. Farrell *et al*. (2006) compared several reports published on maize (corn) ethanol production in the US and concluded that the "best point estimate" would be a reduction of GHG emissions of only 13% because fossil fuels are used as a fuel in the production process and the energy inputs are almost 80% of the energy output. Even then, to arrive at those ratios one has to assign a "credit" to the major co-product of grain-based ethanol: dried distillers grains with solubles (DDGS). Although ethanol from maize comes in last with respect to its GHG balance, it is expected to take first place in terms of market share in 2007 (around 40%) due to strong US production.

Here it is assumed that biofuels being produced in 2050 will reduce GHG by 90% over their total life cycle compared with gasoline (arguably an overambitious assumption given that all biofuels should in that case come from sugarcane and cellulosic ethanol). This, together with a market share of biofuels in the transportation sector of 24% (as calculated in section 2.2), gives a potential for biofuels to reduce global energy-related CO_2 emissions in 2050 by roughly 4.5% or 2.5 Gt of CO_2. Limiting global warming to 2-3º C would require a reduction of annual global energy-related CO_2-equivalent emissions of roughly 39 Gt of CO_2 in 2050 (Stern, 2006; IEA, 2006a).

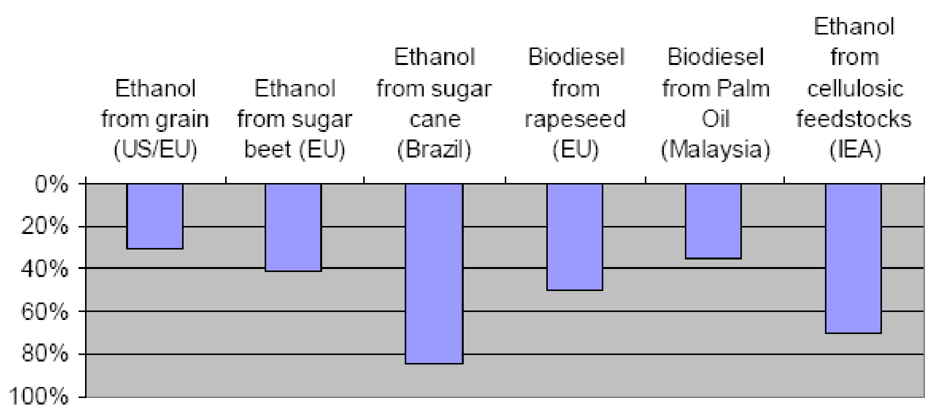


Figure 2. Range of estimated GHG Reductions from Biofuels compared with gasoline and mineral diesel

Source: IEA, 2005 and EMPA (biodiesel from Palm oil)

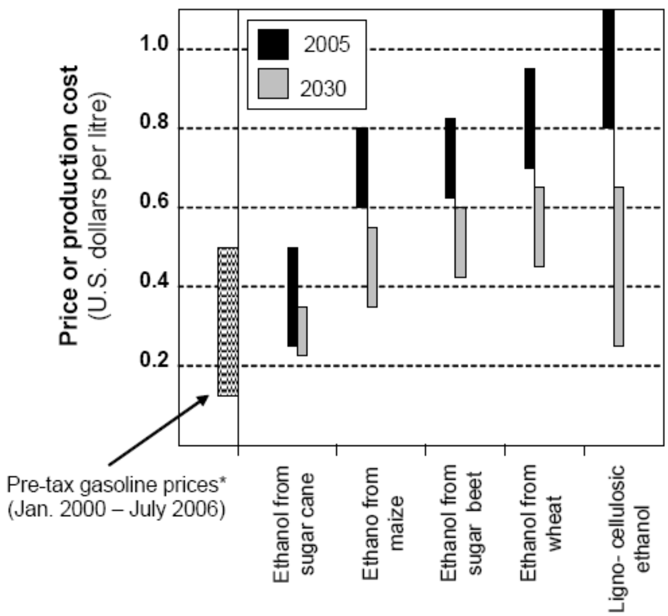
Note: Reduction in well-to-wheels CO_2-equivalent GHG emissions per kilometer

III. The economic potential for biofuels

Up to this point in the discussion, questions of costs and prices have been largely ignored. With the exception of Brazil, biofuels are not competitive with oil prices around $70 per barrel without extensive government support. Moreover, the factors that limit their technical potential also strongly influence the long-term economics of biofuels. More than half of the production cost of biofuels is determined by the price of the feedstock. Given the enormous requirements for land and the competition with food and fibre, feedstock prices may not decline as much as is often assumed. This could perhaps already be seen in Brazil, a country with -relatively- ample space for agricultural production, where prices for land and feedstocks have gone up in response to the increased demand for biofuels.

Costs of ethanol

Current and projected future costs of producing ethanol from different feedstocks were calculated by the IEA (2006b) (Fig. 3). Brazil's costs, at $0.20 per litre ($0.30 per litre of gasoline equivalent) for ethanol produced in new plants, are the lowest in the world. Even before the recent rise in maize prices in the United States, grain-based ethanol cost some 50% more to produce than cane-based ethanol in Brazil, and 100% more than in the EU. These costs do not include the costs of transporting, splash blending and



* Based on monthly average import prices for crude oil into the IEA region, crude oil import prices varied between $20 and $70 per barrel in this period.

Figure 3. Current and projected future ethanol production costs, compared with recent (pre-tax) gasoline prices / litre of gasoline equivalent
Source: Adapted from IEA (2006), Figure 14.7.
Note: Cost estimates exclude from consideration subsidies to crops or to the biofuel itself

distributing ethanol, however, which can easily add another $0.20 per litre at the pump.

According to the IEA (2006b), "further incremental cost reductions can be expected, particularly through large-scale processing plants, but no breakthroughs in technology that would bring costs down dramatically are likely." They foresee such technological improvements helping to reduce costs by one third between 2005 and 2030, in part driven by reductions in the costs of feedstocks. Whereas they project feedstock costs declining by around one-quarter in the EU, and one-third in Brazil, they assume that net feedstock costs will shrink by more than half in the United States. In all cases, the IEA assumed current rates of subsidies to crops and ethanol production remain in place.

Expecting feedstock costs in the EU to fall over the next 25 years is not an unreasonable assumption, given changes in policies (notably the elimination of export subsidies for sugar) and improvements in plant genetics that could put downward pressure on costs. Yet with pressure on commodities to feed a growing world population, uncertain changes in yields caused by global climate change, and increased demand for biomass for fuels, relative prices for feedstocks could well rise significantly. Already between 2005 and May 2007 prices for key ethanol feedstocks rose by between 6% and 68% in nominal terms (Table 3), with the largest proportional increase being observed for maize. Certainly spot prices can be expected to remain volatile. At its peak in February 2006, for example, the reference price for sugar was more than twice its lowest value only nine months earlier.

It bears stressing that while the cash costs of producing sugar in Brazil, maize in the United States or wheat in Argentina or Canada will be lower than the international prices shown in Table 3, what matters is the opportunity cost of diverting these feedstocks to ethanol production, as opposed to selling them to other buyers. Studies of the costs of producing biofuels must make assumptions about the price of the feedstock biomass as well as the price that the fuel will fetch in the market.

Cost of Biodiesel

In OECD countries, some plants using the transesterfication process to produce biodiesel have used low-value oils, such as used cooking oil (also known as "yellow grease"), fish oil or tallow. Because of the limited nature of the supply of yellow grease, these plants rarely exceed annual capacities of 30 million litres, and most have capacities of 5 million litres per year or less. As low-cost supplies of these fats are exhausted, additional capacity has to be based on virgin oils. Over the long run, it is the cost of procur-

commodity	average price for 2005 (USD/tonne)	peak price since May 2005 (USD/tonne and week ending)	peak price since May 2005 (USD/tonne and week ending)	percentage change, nominal terms, 2005 to mid-May 2007
sugar[1]	218	406 (03.02.06)	231	6%
maize[2]	109	203 (23.02.07)	183	68%
wheat[3]	150	229 (20.10.06)	191	27%

1 Based on weekly averages of International Sugar Organization (ISO) daily price, expressed in US cents per pound.

2 US No.2, Yellow, price at US Gulf ports (Friday quotations), expressed in $per short ton.

3 US No.2, Soft Red Winter Wheat , price at US Gulf ports (Tuesday quotations).

Table 3. Reference international commodity prices for sugar, maize and wheat, 2005-2007
Source: Data from Food and Agricultural Organization of the United Nations, "International Commodity Prices".
http://www.fao.org/es/esc/prices (accessed on 22 May 2007)

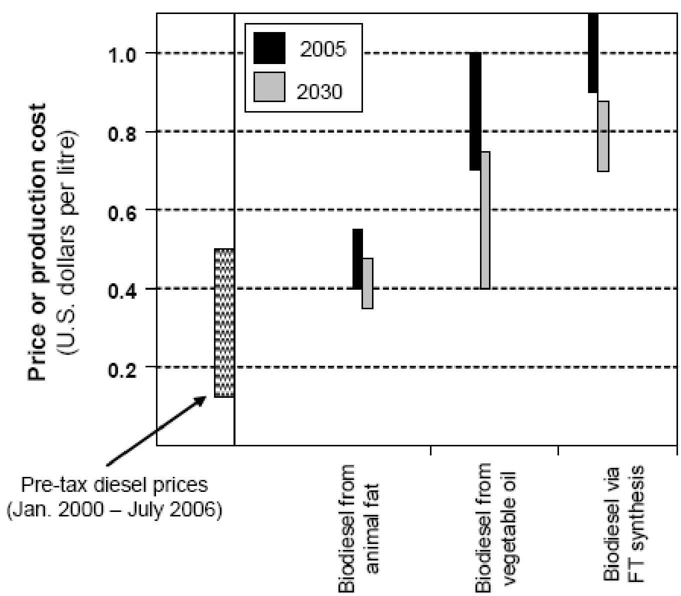
ing virgin vegetable oils that largely determines the cost of producing biodiesel. Generally biodiesel made from palm oil costs less to produce than from soybean oil or rapeseed oil, defining respectively the two ends of the range of costs shown in Fig. 4.

The IEA (2006b) is less bullish on further incremental cost reductions in the conventional, noting that there "remains some scope for reducing the unit cost of conventional biodiesel production by building bigger plants. But technological breakthroughs on the standard transesterfication process, leading to substantial cost reductions in the future, are unlikely." They foresee production costs falling by up to 37% between 2005 and 2030 in the United States (to around $0.33 per litre of diesel equivalent), and by up to 32% in the EU. Again, these projections assume net costs of feedstocks falling by around one-third in real terms over the projection period.

As with feedstocks for ethanol production, the prices of feedstocks for biodiesel production have been heading in the opposite direction since the IEA's cost estimates were produced. Between 2005 and February 2007, international reference prices for rapeseed oil, soybean oil, and crude palm oil rose, respectively, by 19%, 29% and 43% in nominal terms (Table 4). The price rises have been more monotonic, exhibiting less volatility than the prices for sugars and grains over the same period.

Second-generation biofuels

For the reasons discussed above, an explicit assumption behind government plans for large-scale displacement of petroleum fuels by biofuels must be



* Based on monthly average import prices for crude oil into the IEA region, crude oil import prices varied between $20 and $70 per barrel in this period.

Figure 4. Current and projected future biodiesel production costs, compared with recent (pre-tax) gasoline prices
Source: Adapted from IEA (2006), Figure 14.7.
Note: Cost estimates exclude from consideration subsidies to crops or to the biofuel itself

that the expansion of biofuels derived from starch, sugars or plant oils will hit a limit within the next decade or so. Any increase in supplies beyond that will have to come from second-generation technologies and feedstocks.

Demonstration plants have already been built to produce ethanol from ligno-cellulosic materials, but production costs are high, generally around $1.00 per litre on a gasoline-equivalent basis (Fig. 3). Hundreds of millions of dollars have already been spent by both governments and private industry on research to bring down those costs. Most of these efforts are focussing on the front end of the process, the breaking down (through enzymes or microbes) of lignin, cellulose or hemi-cellulose (the building blocks of ligno-cellulosic biomass) into a form that can then be fermented, and increasing the ethanol contented in the fermented broth, so as to reduce the energy needed in the distillation stage.

Because of the rapid pace of technological developments, and uncertainty over the long-run costs of feedstock, projections of the probable future costs of producing ethanol from ligno-cellulosic materials vary widely. The IEA (2006a) notes that its costs are expected to fall in the long term to $0.50 per litre of gasoline equivalent, due to achievement of better ethanol concentrations before the distillation, lower costs for enhanced enzymes (resulting from biotechnological research) and improved separation techniques. All of these advances need technological breakthroughs. However, some pioneer companies and researchers claim progress might follow a quicker pace. In May 2007, Dedini SA, Brazil's leading manufacturer of sugar and biofuel equipment, announced for example that it had developed a way to produce cellulosic ethanol on an industrial scale from bagasse (Biopact team, 2007) at a cash cost of below $0.41 per litre on a gasoline equivalent basis. Others expect an improved competitiveness from successful biorefinery of lingo-cellulosic feedstock that would have an associated array of valuable co-products that could reduce feedstock costs.

As with cellulosic ethanol, a considerable amount of research is being devoted to reduce the costs of producing diesel from biomass, using the Fischer-Tropsch process. The focus is on breaking down biomass into gas with heat or chemicals rather than with microbes. The Fischer-Tropsch process allows higher yields per hectare than biodiesel based on oil-seed crops. Production cost for large-scale plants are estimated to be around $0.9 per litre of diesel equivalent, declining to $0.7-0.8 in the medium term (IEA 2006a). Thermo-chemical production of ethanol is also being evaluated at the commercial scale.

In addition to favorable technological breakthroughs, cost reductions are also expected from the scaling up of production facilities. However, large manufacturing plants imply procuring biomass from over a wide

commodity	average price for 2005 (USD/tonne)	peak price since May 2005 (USD/tonne and month)	average price, January-February 2007 (USD/tonne)	percentage change, nominal terms, 2005 to avg.-2007 to date
rapeseed oil[1]	669	856 (12.06)	800	19%
soybean oil[2]	545	714 (02.07)	706	29%
crude palm oil[3]	422	605 (02.07)	602	43%

1 Monthly averages of ex-mill price (f.o.b.), Netherlands.

2 Monthly averages of ex-mill price (f.o.b.), Netherlands.

3 Monthly averages of import price (c.i.f.), north-west Europe.

Table 4. Reference international commodity prices for rapeseed oil, soybean oil and crude palm oil, 2005-2007
Source: Data from Food and Agricultural Organization of the United Nations, "International Commodity Prices".
http://www.fao.org/es/esc/prices (accessed on 22 May 2007)

area — as noted earlier, a logistical and economic challenge. Moreover, most analyses of the procurement cost of the biomass feedstock undertaken to date focus on actual production costs, either without taking into account the rental value of the land or assuming a low value for it.

A long term perspective on biofuels

In the IEA business-as-usual (reference) scenario (IEA, 2006b), energy demand in the transport sector grows strongly, by 136% between 2005 and 2050 to almost 190 EJ (4.500 Mtoe). The share of the transportation sector in total emissions remains at around 20% of total energy-related CO_2 emissions, however, and biofuels contribute in this scenario 3% of the total transport fuel demand.

In the IEA's alternative "policy rich" scenario, biofuels are assumed to supply 7% of road-fuel use in 2030. The most important assumption underlying this relatively favourable development is the decreasing cost relative to fossil fuel alternatives and consistent government support in the form of subsidies and mandatory targets. Because of the significant challenges that remain for second-generation technologies to become commercially viable the IEA does not expect these to come on stream before 2030. However, if this were to happen, biofuels could play a bigger role than foreseen.

The IEA has also investigated the potential of second-generation technologies in an aggressive CO_2 reduction MAP scenario out to 2050 (IEA, 2006a). It considers that biofuels could meet up to 13% of transport fuel demand in 2050. If that target could be met, the avoided CO_2 reduction from increased biofuels would be almost 1.8 Gt (or 3% of energy related CO_2 emissions in a business-as-usual scenario). Though ambitious, this estimate is lower than the one contained in Section 2.3 (2.5 Gt of CO_2 emissions avoided, as economic factors have not been taken into account). To reach the IEA's estimate, virtually all biofuels must come from second-generation ethanol sources and sugarcane. All other first-generation technologies are assumed to have been phased out.

But biofuels will not be competing alone with traditional petroleum products. Liquid fuels from alternative sources, such as oil from tar sands and coal-to-liquid fuels, will also be vying for market share. Investments in both technologies have been growing quickly in recent years, and can already match the price of petroleum products when the oil price exceeds, respectively, USD 25 or USD 40 per barrel. Furthermore, they are also competing for the same subsidies and tax breaks in the United States. Despite strong opposition from environmental groups, several bills put before the US Congress in 2007 proposed support for major coal-to-liquid plants -e.g. a tax credit of $0.14 per litre and automatic subsidies if oil prices were to drop below $40 per barrel.

The analysis up to this point suggests that biofuels can make a modest but useful part in mitigating climate change. However, this conclusion is based on several assumptions that need further analysis to be sustained:

- fierce competition with agricultural and food production can be avoided in a sense that feedstock prices will be able to further decline;
- trade in biofuels will be liberalised, allowing production technologies in terms of cost and GHG balance; and
- that the assumed net environmental benefits for biofuels can be confirmed.

Before examining these assumptions in more detail, those government policies that presently influence biofuel production are outlined.

IV. What government policies influence biofuels production and prices?

Government policies play a large role in the financial attractiveness of biofuels production and trade. Quantifying and assessing these policies is not an easy task because of the huge array of different policies in place that influence biofuel costs and prices. While subsidies are most commonly thought of as cash payments to a particular person or corporation, this definition misses most of the ways that governments transfer value to private entities. A wide range of policies, including special reductions, commonly required payments (such as tax breaks) or risk internalisation (such as unrealistically low insurance requirements) are used to provide benefits to specific groups (OECD, 2007). The Global Subsidies Initiative has applied a framework to analyse support levels at different points in the supply chain for biofuels, from production of feedstock crops to final consumers (Fig. 5).

At the beginning of the supply chain are subsidies to what economists call "intermediate inputs" -goods and services that are consumed in the production process. The largest of these are subsidies to producers of feedstock crops used to make biofuels. In some countries, the crop subsidies are small enough that they are only wealth transfers and do not materially affect supply or prices. In others, border protection raises the domestic prices of the crops above international prices, thereby effectively taxing consumers of those crops, including biofuel producers. Some countries compensate for these "taxes" on the input feed-

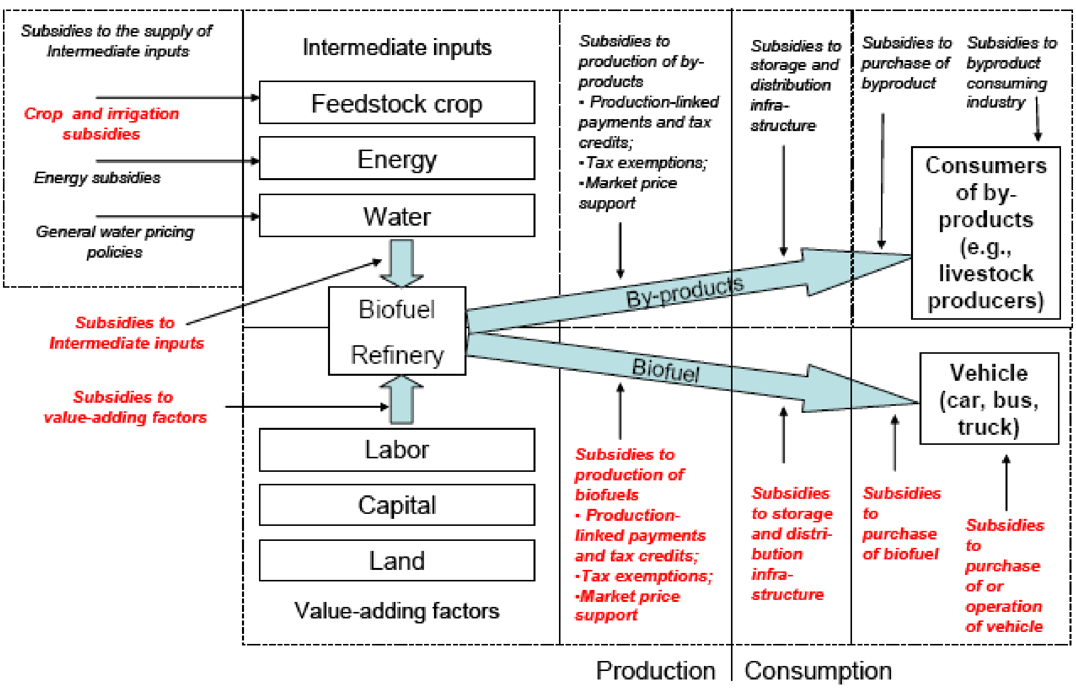


Figure 5. Subsidies provided at different points in the biofuel supply chain
Source: Global Subsidies Initiative. Steenblik and Simón (2007).

stocks by providing countervailing subsidies to biofuel producers.

Subsidies to intermediate inputs are often complemented by subsidies to value-adding factors -capital goods, labor employed directly in the production process, and land. These may take the form of grants, or reduced-cost credit, for the building of ethanol refineries and biodiesel manufacturing plants. Some localities are providing land for biofuel plants for free or at below market prices as well. These types of subsidies lower both the fixed costs and the investor risks of new plants, improving the return on investment.

Further down the chain are subsidies directly linked to output. Output-linked support includes the protection from foreign competition provided by import tariffs on ethanol and biodiesel; exemptions from fuel-excise taxes; and grants or tax credits related to the volume produced, sold or blended. Although, in a few cases, tax exemptions and subsidies have been used to actually depress biofuel (mainly ethanol) prices below the energy-equivalent cost of competing petroleum fuels, mainly they have enabled biofuels to be sold at retail prices that are roughly at parity with their (taxed) fossil-fuel counterparts.

Support to the downstream side of the biofuels market has generally been provided in one of five ways: credit to help reduce the cost of storing biofuels in between the production seasons; grants, tax credits and loans to build dedicated infrastructure for the wholesale distribution and retailing of biofuels; grants to demonstrate the feasibility of using biofuels in particular vehicle fleets (e.g. biodiesel in municipal buses); measures to reduce the cost of purchasing biofuel-capable fleets; and government procurement programmes that give preference to the purchase of biofuels.

Generally, policies that directly bear on the level of production are considered to have the greatest level of distortion on production decisions, followed by subsidies to intermediate inputs and subsidies to value-adding factors. Because quantitative information regarding the latter two is largely unavailable and output-linked support is the most important, only output linked support is discussed here.

Current output-linked support for ethanol and biodiesel

Domestic production of biofuels is directly supported by governments through two main instruments: border protection (chiefly import tariffs) and production subsidies. Regulations mandating usage or blending percentages and fuel-tax preferences stimulate production directly as well. But whether that production occurs within a country's borders or elsewhere depends in part on the level of border protection.

The leading OECD countries producing bio-ethanol apply a most-favoured nation (MFN) tariff that adds at least 25%, or $0.14 per litre, to the cost of imported ethanol. This will be enough in most cases (Fig. 3) to keep cheaper foreign produced ethanol from the domestic market. The United States charges a 2.5% ad valorem tariff plus an additional, $ 0.143 per litre "secondary" duty on ethanol intended to be used as a fuel (by distinguishing between fuel ethanol and ethanol destined for beverages and other end uses). The EU applies a much lower MFN tariff of € 0.00192 per litre on undenaturised ethanol and € 0.00102 per litre on denaturised ethanol.

Taxes and subsidies can also be used to discriminate between foreign and domestic production. The AUD 0.38143 ($0.27) per litre excise duty on ethanol applied by Australia for example is set at the same level as the federal fuel excise tax on petrol (making the effective tariff on imported ethanol one of the highest in the OECD). However, domestically-produced ethanol can qualify for a countervailing grant that completely offsets that tax. Biodiesel is subject to much lower import tariffs than ethanol; these tariffs range from 0% in Switzerland to 6.5% in the EU.

Various exemptions from the MFN tariff and tariff-rate quotas apply. Biofuels are often charged at zero or reduced duty when imported from countries with which the importing country has signed a freetrade agreement, or which are covered by their General System of Preferences (GSP).

In addition to providing border protection, several countries and sub-national governments provide direct, production-related subsidies. The leading country in the use of these subsidies is the United States, which grants a $0.13 per litre ($0.51 per gallon) tax credit to blenders according to the amount of pure ethanol they blend with gasoline (petrol). The US federal government also grants a similar, but higher tax credit to companies that blend biodiesel with petroleum diesel. Several US states provide their own volumetric subsidies to support in-state production of ethanol or biodiesel at rates equivalent to $0.05 per liter ($0.20 per pure biofuel gallon) or more. In a few cases, these subsidies are contingent on the use of feedstock produced in the same state. Biofuels subsidies continue to grow rapidly in scope and scale and are expected to soon reach $8.3-$11 billion a year in the United States (Koplow, 2006).

The production of biofuels in the EU is also heavily subsidized. Different tax rates apply in different Member states; taxation on biofuels compared to excise taxes applied to fossil fuels varies from 0% to 45%. Spain and Sweden, for example, exclude biofuels from excise taxes. In other countries, such as France and The Netherlands, this is only the case up to a certain amount. Feedstocks for biofuels production also receive support under the 2003 reform of the Common Agricultural Policy. However, agricultural raw materials used for biofuel production also benefit from the more substantial support granted to traditional food crops: around $1.6 billion for oil seed producers and around $15 billion for cereal producers in 2004 (Jank *et al*., 2007).

Most other countries (and some sub-national governments) support biofuel use (and therefore production, where border protection is effective) through tax preferences tied to fuel-excise taxes or sales taxes. These most commonly take the form of reductions in, or exemptions from, per-liter excise taxes normally charged on transport fuels.

Complementing many of the aforementioned production-related support measures are various targets and mandated requirements for the amount or share of designated “renewable fuels” consumed as compo-

(Continúa en la página 82)

country	type	quantity or blending share	comment
Australia	**T**	**350 million litres by 2010**	
Victoria	T	5% by 2010	Is currently considering whether to make target mandatory
EU	**T**	**2% by 2005; 5.75% by 2010; 10% by 2020**	**2020 target still under discussion**
Austria	T	2.5% by 2006	
France	T	7% by 2010; 10% by 2015	
Japan	**T**	**6 billion litres by 2020**	
USA (federal)	**M**	**2.78% by volume of gasoline consumption in 2006 (4 billion gallons , or 15 GL); 7.5 billion gallons (28 GL) by 2012**	**Of which 0.25 billion gallons (0.95 GL) must be cellulosic ethanol in 2013. Credit rate varies by feedstock.**
Iowa	T	10% by 2009; 25% by 2020	

Table 5. a Use and blending share targets (T) and mandates (M) for liquid biofuels that can be met by either ethanol or biodiesel
Source: Global Subsidies Initiative based on various sources

country	ethanol			biodiesel		
	type	quantity or blending share	year	type	quantity or blending share	year
Australia						
New South Wales	M	2%	2007	-	-	-
New South Wales	M	10%	2011	-	-	-
Queensland	M	10%	2011	-	-	-
Brazil (federal)	**M**	**4.5%**	**1977**	**M**	**2%**	**2008**
	M	20-25%	~1985	M	5%	2013
Canada (federal)	**M**	**5%**	**2010**	**M**	**2%**	**2012**
Ontario	M	5%	2007	-	none	-
Ontario	T	10%	2010	-	none	-
EU						
Czech Republic	M	2%	2008	M	2%	2007
Germany	M	3.6%	2010	M	4.4%	2007
Hungary	M	-	-	M	4.4%	2007
Netherlands	M	-	-	M	2%	2007
Romania	M					
USA						
Hawaii	M	85% of gasoline must contain ≥ 10% ethanol	2006	-	none	-
Louisiana	M	2%[1]	2006	M	2%[2]	2006
Minnesota	M	20%	2013	M	2%	2005
Missouri	M	10%	2008	-	none	-
Montana	M	10%[3]	2005	-	none	-
Oregon (Portland)	M	10%	2007	M	2% (10%)	2007 (2010)
Washington[4]	M	2%	2008	M	2%	2008

1 Requirement starts to apply within six months after monthly production of denatured ethanol, produced in the state, equals or exceeds an annual production volume of at least 50 million US gallons (189.25 million liters). To qualify, the ethanol must be produced from domestically grown feedstock.

2 Requirement starts to apply within six months after monthly production of biodiesel produced in the state equals or exceeds an annual production volume of 10 million US gallons (37.85 million liters). To qualify, the biodiesel must be produced from domestically grown feedstock.

3 Requirement starts to apply within one year after the Montana Department of Transportation has certified that the state has produced 40 million US gallons (151.4 million liters) of ethanol and has maintained that level of production on an annualized basis for at least 3 months.

4 Requirement could apply earlier if a positive determination is made by the Director of the State Department of Ecology that feedstock grown in Washington State can satisfy a 2% fuel blend requirement. The biodiesel requirement would increase to 5% once in-state feedstocks and oilseed crushing capacity can meet a 3% requirement.

Table 5.b Use and blending share targets and mandates specifically for ethanol or biodiesel
Sources: Brazil (F.O.Licht); Canada (Litman, 2007, forthcoming); EU (Kutas and Lindberg, 2007, forthcoming)
US (US Department of Energy, http://www.eere.energy.gov/afdc/progs/reg_matrx.cgi)

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nents of ethanol-petrol or biodiesel-diesel blends. Some of these targets and mandates do not discriminate by biofuel (Table 5a). Many others are specific to either ethanol or biodiesel. Tables 5.a and 5.b provide an overview.

California's Low Carbon Fuel Standard (LCFS), established through an executive order issued by that State's Governor in January, does not specify "renewable fuels", but rather requires that the carbon intensity of transportation fuels sold in California be reduced by at least 10% by 2020. The plan would rely on developing an agreed method for measuring the full fuel-cycle carbon output of alternative fuels and a system of certification of the life-cycle carbon emissions of fuels, including biofuels.

A mandatory blending, volumetric or market-share target for consumption of a biofuel operates as a support mechanism when prices for petroleum fuels are cheaper than for biofuels, as it makes demand below the mandated volume inelastic. Their logic is derived from many of those used to justify other import-replacement policies -an argument that generally has little validity in an era of floating exchange rates. In most cases, biofuel mandates do not distinguish among biofuels according to their feedstocks or production methods, despite wide differences in environmental costs and benefits. The perceived advantage of portfolio targets is that they provide a stable and predictable market for a product, without touching public budgets. However, they impose costs on society as a whole, as discussed in section 6.

Subsidies to biofuels are not an isolated phenomenon, of course. They are widely spread in the energy sector and subsidies to fossil fuels are in many countries higher than those to renewable energy and nuclear power. Unfortunately, estimates of support to energy consumption and production are either incomplete or very approximate. The International Energy Agency (IEA, 2006b) recently estimated that consumption subsidies -i.e. those manifest through end-user prices for hydrocarbon fuels, coal and electricity that are lower than the reference price- are on the order of $250 billion a year globally: around 75% for petroleum products and natural gas, and most of the remainder for electricity.

More solid data are available for the United States (Table 6) where more than 50% of the total benefits the oil and gas sectors. Nuclear power is the next largest beneficiary at 12% for a range of subsidies aimed at new plant construction. Subsidization of ethanol is on par to support for all other renewables combined (at roughly $6.5 billion/year), though this may be in part due to the better data availability of ethanol subsidies (Koplow, 2006).

	USD billions per year (avg. of high and low estimates)	% share
oil and gas	39	52.4
coal	8	10.5
fossil, mixed	2	3.3
total fossil	**49**	**66.2**
nuclear	9	12.4
ethanol	6	7.6
other renewables	6	7.5
conservation	2	2.1
mixed resources other	3	4.2
total	**74**	**100.0**

Table 6. Distribution of US Federal Energy Subsidies, 2006
Source: http://www.earthtrack.net as reported in OECD (2007)

V. What are the opportunities and barriers to international trade in biofuels (feedstock)?

Current trade in biofuels and biomass feedstock is modest compared with total production. Trade statistics must be treated with some care, but a reasonable estimate is that in 2005 trade covered about 10% of the world's biofuel consumption (Walter *et al.*, 2007). In 2005, the US, Europe and Brasil accounted for 95% of biofuels production. Canada, China and India produced most of the rest (IEA, 2006b).

With the creation of renewable-fuel targets in an increasing number of countries, biofuel trade is expected to grow for the simple reason that it is impossible to reach the ambitious targets in many countries by domestic production alone. Biofuels produced in tropical regions from sugarcane and palm oil have a considerable comparative advantage over those derived from agricultural crops in temperate zones. When water is not the limiting factor, tropical countries have two to three times higher productivity (Girard and Fallot, 2006). Tropical and subtropical countries not only have land and climatic conditions more suitable for efficient crop production, but also their labor costs are lower than in most OECD countries. Biofuel and biomass wood chips and pellets shipping costs are small as a proportion of the total energy value of the fuel itself (IEA 2006b). The difference between production potential and demand is high in South America and to a lesser extent Africa, as these countries that have the potential to export to North America, Europe and Asia (Fig. 6). However, trade barriers and subsidies currently prevent large-scale trade from taking place.

The preference of large consumer countries to produce biofuels domestically may be prompted by a desire to provide additional opportunities for national agricultural producers or for reasons of energy security. This will in many cases seriously compromise the cost effectiveness and environmental sustainability of biofuel production. Corn and rapeseed in the US and EU will be favored despite the fact that the cost of production is significantly higher and energy return on investment lower for these annual crops than for perennial crops such as palm oil and sugarcane. International trade in biofuels would enhance economic efficiency by directing production to the

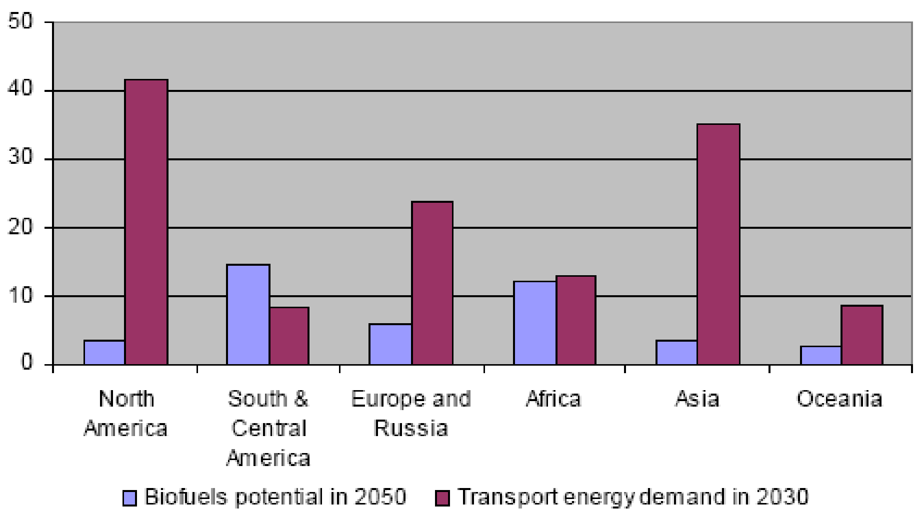

Figure 6. Technical potential of biofuels (2050) and energy demand for the transport sector in 2030
Source: IEA (2006b) for energy demand in transport sector. Biofuel potential as shown in Table 2.

most efficient locations, while at the same time taking the environmental impacts of biofuels production into account.

Trade barriers for biofuels

The barriers to trade in biofuels and biomass feedstocks can be classified under two traditional headings: tariff barriers and non-tariff barriers.

Tariff barriers

As stated earlier, for ethanol MFN tariffs range from roughly 6% to 50% in the OECD, and up to 186% in the case of India. Bound and applied tariffs on biodiesel in OECD economies are relatively low, varying between 0% and 7%. Tariffs applied by developing countries are generally between 14% and 50% (Steenblik, 2006).

The differential application of tariffs due to bilateral and regional trade arrangements and general systems of preferences can be trade-diverting. For example, prior to 1 July 2005, Pakistan benefited from Special Arrangements for Combating Drug Production and Trafficking under the EU's Generalized System of Preferences (GSP) anti-drug regime. Able to export its ethanol to the EU at zero tariff, it became the EU's second-leading foreign supplier of ethanol (Bendz, 2005). Subsequently, Pakistan was brought under the General Regime, and then as of 1 January 2006, ethanol was withdrawn from the scope of this Regime, meaning that Pakistan lost all preferences on its ethanol exports. As a result, Pakistan reported that the loss of trade had led to the closing of two of its seven operating distilleries, and that another five new distilleries would probably abandon plans to begin operations due to uncertainties in the market situation (Bendz, 2005).

A similar fate could one day befall ethanol exporters in Caribbean Basin nations, which currently benefit from a special 1983 concession that grants them tariff-free access to the US market on volumes up to 7% of US domestic consumption. Rather than produce ethanol themselves, most dehydrate ethanol imported from Brazil, a value-adding step that meets the US requirement that products qualifying under the tariff quota be "substantially transformed" if they do not originate from the countries themselves. In the past, Caribbean Basin nations have consistently been under quota. But the prospect of exporting up to 9.3 billion liters of ethanol to the United States tariff-free (while still benefiting from the tax credit) -should President Bush's goal of using 35 billion gallons (132.5 billion liters) of alternative fuels by 2017 become mandated- is now attracting a flurry of new investment in dehydrating capacity (Etter and Millman, 2007). Almost all of this capacity would become redundant should the US Congress not renew the secondary tariff on ethanol when it expires at the end of 2008, or if it were to revoke the tariff rate quota.

Non-tariff barriers

Many non-tariff barriers, such as regulations relating to public health and safety, are recognized by the trade-policy community as essential. Other barriers, such as long delays in clearing customs because of over-bureaucratic customs and administrative-entry procedures, are regarded as generally worth streamlining. Of special interest in relation to biofuels are: government participation in trade and restrictive practices tolerated by governments, sanitary and phytosanitary measures, and technical barriers to trade.

Biofuel feedstocks, final products and vehicles designed to run on biofuels often face sanitary and phytosanitary (SPS) measures or technical regulations applied at borders. SPS measures mainly affect feedstocks which, because of their biological origin, can carry pests or pathogens (a biological infectious agent). One of the most common forms of SPS measures is a limit on pesticide residues. Even though pesticide residues are regulated mainly to ensure the safety of food and beverages, and are much less of a problem in biomass feedstocks that will undergo thermal or chemical processing, customs agents nonetheless may have no other choice than to apply the same regulations to vegetative biomass feedstocks as to crops destined for human or animal consumption, especially if they have no way of determining the product's end use. Meeting pesticide residue limits is usually not difficult, but on occasion has led to the rejection of imported shipments of crop products, especially from developing countries (OECD, 2005).

In WTO parlance, technical regulations generally refer to mandatory requirements not covered by the SPS Agreement. In the area of biofuels, these concern the chemical and physical characteristics of the final product as well as to regulations pertaining to how the biofuels or their feedstocks were produced and processed.

Regulations pertaining to the technical characteristics of liquid transport fuels, including biofuels, exist in all countries. These have been established in large part to ensure the safety of the fuels and to protect consumers from being sold fuels that could cause costly damage to vehicle engines. In this respect, fuel characteristics are less of an issue for ethanol than for biodiesel that has more variable and quality sensitive characteristics.

Increasingly more significant to biofuels trade are requirements imposed or under consideration on either feedstocks (such as palm oil) or final products that relate to non-product-related processes or production methods (PPMs) to ensure the sustainability of their production method. These are summarized as sustainability standards and regulations and will be discussed in more detail in Section 7.

Discrimination in trade on the basis of production method is highly contentious, and has been the nub of several precedent-setting trade disputes at the WTO. In relation to trade the proliferation of different standards is a cause for concern, as exporters will face increasing cost of certification and bureaucratic complexity. Fortunately, the fact that countries and non-governmental organizations seem to have acknowledged these types of potential problems early suggests that some of the barriers created by national regulation of organic standards (see OECD, 2005) may be avoided in the case of biofuels. Encouragingly, the EU, for one, has expressed its intention to apply its proposed system of certificates in a nondiscriminatory way to domestically produced biofuels and imports. Nevertheless, the growth of sustainability standards and regulations is a continuing challenge to fair and indiscriminate trade that should be confronted with great care and a healthy wariness.

How to develop international trade in biofuels?

The European Commissioner for Trade, Mr. Peter Mandelson, stated that Europe should be open to accepting that it will need to import a large part of its biofuel supplies. Europe should, in his opinion, not favour EU production of biofuels with a weak carbon performance if it can import cheaper, cleaner, biofuels. This would argue for unilateral removal of trade barriers by the EU.

Others have argued that biofuels could be used to unlock the Doha Round trade negotiations. Production of biofuels, it is assumed, by absorbing surplus production will allow developing countries either to sell more of the commodities to the industrial North, or transform more of their commodities, such as sugar and sweet sorghum, into biofuels, for own use or for export.

Though there may be some enthusiasm that biofuels could breathe new life into the Doha Round of multilateral trade negotiations, there are major differences of opinion on the desired outcome. One scenario envisages a WTO deal on agriculture that legitimizes current and future subsidies to domestic production of ethanol and biodiesel; the other envisages reducing or bringing down barriers to trade in biofuels, including trade-distorting subsidies.

Of course, subsidies and tariffs benefiting crops used as inputs to biofuels (sugar beets, maize, wheat and oilseeds) are not the only contentious ones in the WTO. Agreement needs to be reached on how to treat continuing high levels of support for cotton, rice and livestock products (particularly dairy products). Indeed, as feed prices are driven up by diversion of crops to biofuel production, livestock producers are finding themselves in a cost-price squeeze. It would not be surprising if they were to start demanding off-setting subsidies as well.

For the time being the obstacles for biofuels trade to expand are high, and therefore the prospects for the costs of biofuels to drop, and their potential for oil displacement (on a global basis) to increase substantially are limited.

VI. What are the consequences of current government policies?

In the sections above the potential of biofuels and government policies influencing their development have been assessed. This section will take a closer look at the consequences of described policies on agricultural markets and food prices, environmental sustainability and energy security.

Agricultural market impacts

Agricultural feedstock dominates the production costs of liquid biofuels. As a result, the market for biofuels and agricultural products are strongly entangled. Because of crop substitutability, world biofuels markets will also be related to crop markets that are not used as an input for biofuel production per se (Kojima *et al*., 2007). All crops tend to compete for the same inputs, land, fertilizers and water (where irrigation is necessary), to find the best return on investment.

Because of these many links it is not sufficient simply to compare the cost of ethanol from sugarcane to the cost of ethanol from maize. Over time, relative positions might change. For example, when the demand for maize in the food and the animal feed market is low at the same time the demand for sugar is high, ethanol produced from maize can be less costly than ethanol from sugarcane. This happened in June 2000 when sugar prices in Brazil reached their peak. The World Bank (Kojima *et al*., 2007) compares ethanol prices with world gasoline prices given prevailing sugar prices from January 1990 to April 2007. The results show that even in Brazil -the most cost-effective ethanol producer in the world- for most of this period turning sugar into ethanol was a lower-value use of the sugar than selling it on the world market would have been. Despite very high world petroleum prices, soaring world sugar prices made it difficult, for example, for ethanol to be more profitable than sugar during 2006.

The augmentation of the biofuels market will tend to increase the impact of the oil price on the agricultural market. Higher oil prices in general will have two effects: they will increase production costs in agriculture and as such also make the production of biofuels more expensive. At the same time, rising oil prices create incentives for biofuel production, stimulating demand for feedstock production and probably more than counter weighting the negative effect on demand from the higher production costs. The exact outcome is difficult to predict, but it will further increase the pressure on the agricultural sector.

The rapid growth of the global biofuels industry is likely to keep farm commodity prices high through the next decade as demand rises for grains, oilseeds and sugar from 2007 to 2016 (OECD/FAO, 2007). At the same time, it is likely that the prices of commodities and products that compete with the byproducts of biofuel production will decline. The OECD considers the bioenergy industry to become a key factor in the functioning of agricultural markets. Food prices are expected to rise between 20% and 50% over the next decade. This projection seems to be consistent with the development of food prices in recent years that have gone up sharply in reaction to increased biofuel production in Brazil (the world's largest sugar exporter), China, the EU and the United States (the world's largest maize exporter). However, it is opposite to the price developments projected in the models of the IEA's World Energy Outlook 2006 (IEA 2006b), which assumed a further declining price of agricultural feedstocks because of increased productivity. The reason for this discrepancy may be that the feedback effects between the agricultural and biofuels market are not modeled in the IEA's models but agricultural prices are taken exogenously. In reality, however, increased biofuels production to the target levels assumed for the EU, US, Brazil and others will instead lead to upward pressure on feedstock prices.

Furthermore, the entanglement of agricultural and biofuels markets gives further nuance to the assumption in the calculations of the long term technical potential of biomass that assume the food supply should be secured before agricultural land can be dedicated to biofuels production. The assumption behind these calculations is that competition between food and biofuels can be avoided. In reality, energy cropping on dedicated land is in competition with food production as of day one.

This can be illustrated by looking at the land requirements of the best case (alternative policy) scenario from the World Energy Outlook, in which biofuels' share of the transport market is growing to 7%. In this case, 3.8% of all arable land in the world would be used for biofuels production. On a global scale this might appear modest, but consequences at the regional level may be much more dramatic. In Europe, for instance, the area dedicated to growing oilseeds for energy use already uses 22% of the land planted in oilseed crops. To meet the EU's target volumes for 2012 would require dedicating 84% of the area currently planted in oilseed, clearly an unrealistic outcome. Therefore, extensive imports will be needed to fill the gap (Jank *et al*, 2007).

The IEA (2005) states that at some point, probably above the 5% displacement level of gasoline and diesel fuel, biofuels production using current technologies and crop types may begin to draw substantial amounts of land away from production of crops for food, animal feed and fiber. Given the high ambitions of the EU, the US, China, Brazil and others, it is certain that without a serious change in policy the "food-versus-fuel" debate will become more acute in coming years.

Overall environmental impacts

The supposed environmental benefits of biofuels have come under increased scrutiny in recent years. A comparison with fossil fuels should not be limited to GHG emissions. Biofuels have a more positive record in respect of their end-of-pipe emissions, but those made from grains and oilseeds are generally more damaging to the environment up-stream. Production of biomass for biofuels can therefore have widely differing impacts on biodiversity, water quality (through the use of fertilizers and pesticides), water use and soil erosion.

The Swiss Institute, EMPA (Zah *et al.*, 2007) performed a full life cycle assessment of a large number of biofuels and compared the environmental footprint with those of transport fuels derived from petroleum and natural gas (Fig. 7). The whole environmental impact was calculated using indicators measuring the damage to human health, ecosystems and the deple-

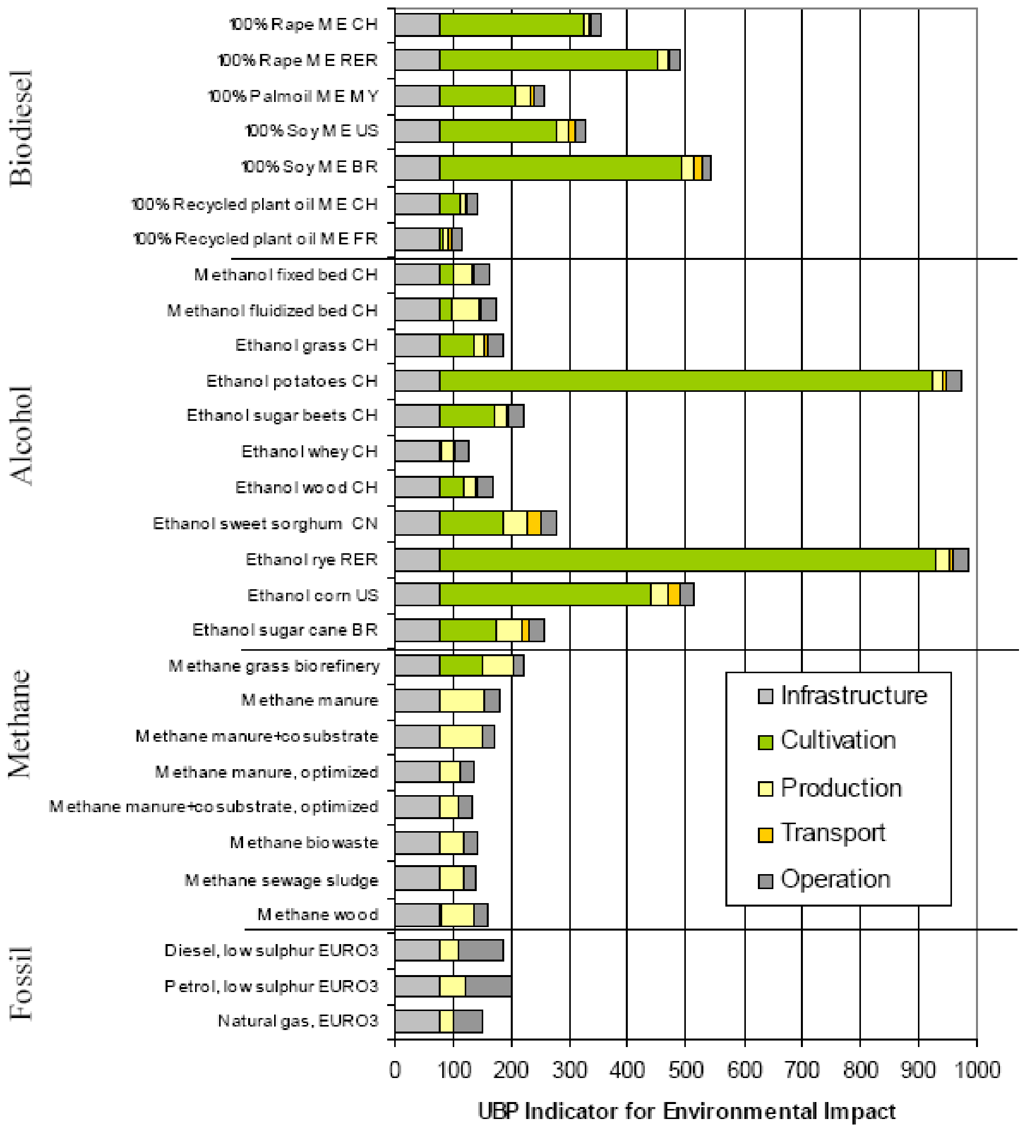

Figure 7. Comparison of aggregated environmental impact of biofuels in comparison with fossil fuels
Source: Zah et al (2007a).
Note: UBP stands for UmweltBelastungsPunkte : a Swiss indicator for the environmental impact .

tion of natural resources aggregated in a single indictor (UBP). Environmental impacts of vehicle operation are indeed much higher when fossil fuels are used. However, this is more than offset in many cases by the very high environmental impacts from agricultural production in terms of soil acidification and excessive fertilizer use, biodiversity loss, air pollution caused by slash-and-burn and the toxicity of pesticides.

To qualify for preferential tax treatment under a new law enacted by Switzerland this year, a biofuels should not only have a positive GHG balance but also a favourable overall environmental score as opposed to its fossil-fuel-alternative. EMPA has visualised this comparison by placing the environmental impact and the greenhouse gas reduction performance of biofuels related to their fossil alternative in one figure with two axes (Fig. 8). The values shown are relative to gasoline (which is 100%). The green (shaded) area means a particular fuel has both lower GHG emissions and a lower overall environmental impact than petrol.

Most biofuels have an overall environmental performance that is worse then gasoline, though their relative performance differs considerably (Fig. 8). EMPA gave maize-based ethanol in the USA a poor environmental score, whereas it determined that ethanol from sugar beets and sugarcane are only moderately better than gasoline in terms of their overall environmental impacts. Biodiesel scores negatively as well, in general. Only when waste products such as recycled cooking oils are used do their overall

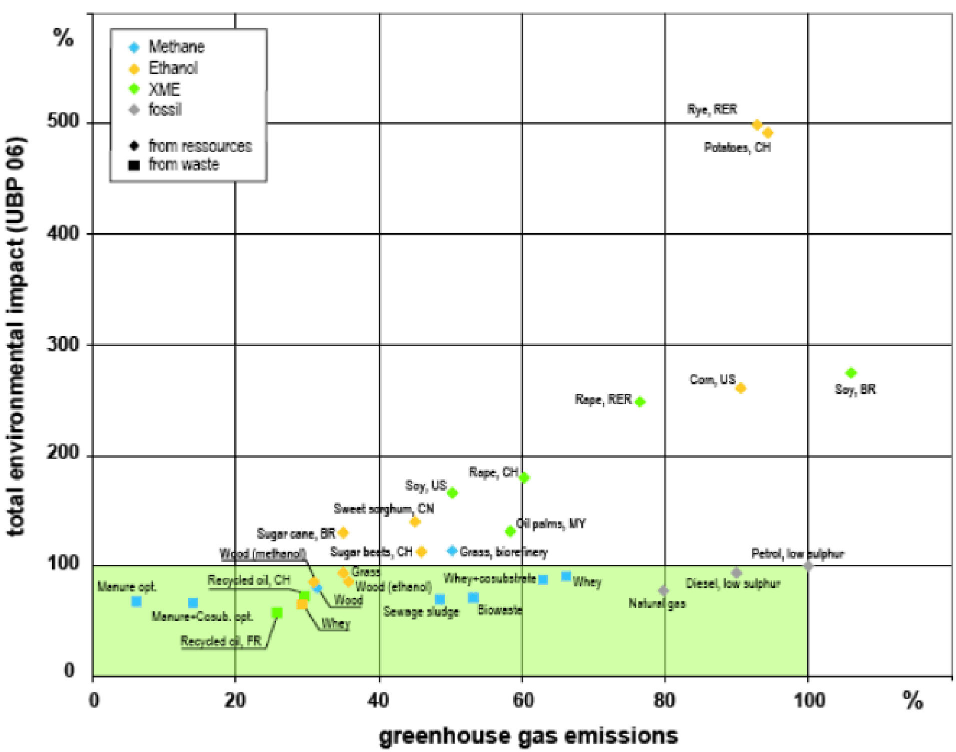

Figure 8. GHG emissions of biofuels related to their gasoline or diesel alternatives and overall environmental impact assessment
Source: Zah et al (2007a).
Note: UBP stands for UmweltBelastungsPunkte : a Swiss indicator for the environmental impact .

environmental performances fare better than that of gasoline. Biofuels made from woody biomass rated better than gasoline in all cases.

The emission balance and total environmental impact varies widely. However, support policies for biofuels until now have made little or no distinction according to how they have been produced. The notable exception is the biodiesel excise tax credit in the United States, which actually subsidizes producers of biodiesel from used cooking oil at half of the rate it subsidizes the production of biodiesel from virgin agricultural feedstock (vegetable oils and tallow), and in Brazil, which has created a system that discriminates in favor of local producers of biodiesel located in economically disadvantaged regions that procure their feedstocks from certified suppliers. In short, governments can end up supporting a fuel that is more expensive and has a higher negative environmental impact than its corresponding petroleum product.

The impact on energy security

The idea that producing biofuels at home will reduce a country's dependence on foreign sources of energy, particularly oil from the Middle East, has helped to increase the political popularity of biofuels. This rationale, present at the time that Brazil's and the United States' first biofuel-support programs were crafted, waned during the 1980s and 1990s but has recently returned to centre stage. Overall it is fair to say that the roughly 65 billion liters of biofuels consumed in 2006 displaced around 32 billion liters of fossil fuels (or approximately 1% of energy demand in the transport sector).

Security of supply is perhaps the pre-eminent goal of "energy policy", often expressed in terms of minimizing risk of interruptions in supplies (such as imports of petroleum or natural gas, or electric-power outages), but it is more accurately stated in economic terms. In essence, governments want to keep prices of energy carriers low, minimize volatility and reduce the environmental impacts.

Public subsidies to biofuels are often defended as a way of weaning a country from dependence on fossil fuels in general, and petroleum in particular. How efficiently biofuels subsidies help to reduce reliance on petroleum or on fossil fuels in general depends on the amount of petroleum (or fossil energy in general) invested in creating and delivering that liter.

The degree to which the use of biofuels displaces fossil energy varies fairly widely across estimates by different researchers and across production technologies and regions. In general, displacement factors for fossil fuels overall are considerably worse for starch-based ethanol than for cellulosic ethanol. This is due to a fossil-intensive fuel cycle of the first, including feedstock production and high consumption of natural gas within the plants themselves (except in Brazil, where bagasse is used). Unfortunately, natural gas markets are developing many of the same supply insecurities as exist with imported oil. Coal can also be used to fuel ethanol refineries, as is becoming commonplace in the United States; but that then worsens the environmental profile of ethanol substantially. Furthermore, the energy content of a liter of ethanol is typically only two-thirds of the energy content of a liter of gasoline.

The paradox noted above is also that greater biofuel production may lead to less protection against high petroleum prices. Higher oil prices increase production cost and the demand for biofuels, pushing feedstock prices up. Kojima *et al*. (2007) suggest a threshold level of diversion of a given crop to the biofuels market of about 10%. A higher share of biofuels will link the price movement of that crop to the world petroleum market. For this reason, they conclude that biofuels are unlikely to become the solution to rising crude-oil prices.

Cost-effectiveness of government support policies

One way to evaluate the cost effectiveness of public support for biofuels is to calculate support per liter of fossil fuel replaced and per tonne of CO_2-equivalent avoided. Such calculations are only as good as the underlying data, of course. The quantification of support is itself hampered by the obscurity of data on spending relating to biofuels; the net energy ratios and life-cycle emissions of biofuel plants, drawn from engineering studies or representative cases, can only be considered approximate at best.

Nonetheless, numerous independent analyses (CSIRO *et al*., 2003; IEA, 2004; Farrell *et al*., 2006; Zah *et al*. 2007a and 2007b) have been produced from which value ranges can be drawn. The results, drawn from studies undertaken for the Global Subsidies Initiative, are shown in Table 7.

The overall cost-effectiveness of biofuels seems to be low in almost all cases. Costs are relatively high per unit of fossil energy displaced or per unit of CO_2 emissions reduced. To displace one liter equivalent of fossil fuel, for example, would cost between $0.66 and $1.40 in the United States. In the European Union these costs are even higher. And that is in addition to what customers pay for the fuel at the pump. In several cases the use of biofuels is roughly doubling the cost of transportation energy for consumers and taxpayers together. Such high rates of subsidization might perhaps be considered reasonable if the industry was new, and ethanol and biodiesel were being made on a small-scale, experimental basis us-

	units	ethanol		biodiesel	
		low	high	low	high
Support per liter equivalent of fossil fuels displaced					
United States	$/litre equiv.	1.03	1.40	0.66	0.90
European Union	$/litre equiv.	1.64	4.98	0.77	1.53
Switzerland	$/litre equiv.	0.66	1.33	0.71	1.54
Australia	$/litre equiv.	0.69	1.77	0.38	0.76
Support per tonne of CO_2-equivalent avoided					
United States	$/tonne of CO_2 equiv.	NA	545	NQ	NQ
European Union	$/tonne of CO_2 equiv.	590	4520	340	1300
Switzerland	$/tonne of CO_2 equiv.	340	394	253	768
Australia	$/tonne of CO_2 equiv.	244	1679	165	639

NA = not applicable. NQ = not quantified.

Note: The ranges of values reflect corresponding ranges in the estimates of total subsidies, variation in the types of feedstocks, and in the estimates of life-cycle emissions of biofuels in the different countries.

Australia: ethanol from sugarcane molasses: waste starch and grains; biodiesel from used cooking oil and canola; exchange rate used: AUD 1 = USD 0.87. European Union: ethanol from sugarbeets and maize and biodiesel from used cooking oil and canola oil; exchange rate used: EUR 1 = USD 0.76. Switzerland: cellulosic ethanol for ethanol and biodiesel from recycled waste oils and Swissgrown rapeseed; exchange rate used: CHF 1 = USD 0.83. United States: ethanol from grain and biodiesel from soya bean. Conversion values used to calculate from GJ to litres oil: average conversion factor for oil 1 Mtoe = 0.0209 mb/d and therefore 28.97 litres oil = 1 GJ (source: IEA 2006b and IEA unit converter)

Table 7. Subsidies to ethanol and biodiesel per litre net fossil fuel displaced and per metric ton of CO_2-equivalent avoided
Source: Global Subsidies Initiative. Koplow (2006), Steenblik and Simón (2007), Kutas and Lindberg (2007, forthcoming), Centre for International Economics (2007, forthcoming).

ing advanced technologies, but most of the support is directed at production from mature, first-generation manufacturing plants.

In a similar vein, the cost of obtaining a unit of CO_2-equivalent reduction through subsidies to biofuels is well over $500 per tonne of CO_2-equivalent avoided for corn-based ethanol in the United States, for example, even when assuming an efficient plant uses low-carbon fuels for processing. In Switzerland and Australia the results are hardly any better, although the ranges are large depending on the feedstock. The implication of these calculations is that one could have achieved far more reductions for the same amount of money by simply purchasing CO_2-equivalent offsets at the market price.

VII. Can certification ensure that biofuels are produced sustainably?

Biofuels are thus not an easy solution for weaning the world from its dependency on petroleum. Because most liquid biofuels will be consumed as blends with gasoline or petroleum diesel, biofuels will, for some time to come, be complements to petroleum-based transport fuels, not major competitors with them. Their potential is limited and their environmental benefits rely on critical assumptions that must be met in order for biofuels to be sustainable. The conclusion of the European Council to establish a 10% biofuels target in 2020 for the EU was made "subject to production being sustainable, second-generation biofuels becoming commercially available and the Fuel Quality Directive being amended accordingly to allow for adequate levels of blending". This therefore seems appropriate.

A key question is how to ensure that production will indeed be sustainable. One answer currently being explored intensively is to certify the conformity of biofuels with minimum environmental and social standards on a life-cycle basis.

Certification schemes

Private-sector standards

Private-sector standards and certification schemes may be led by producers, consumers, even by parties without a direct financial interest in the business, or any combination thereof. Numerous indicative standards are being developed at the national level, and at the international level stakeholders with interests in the oilseed and sugarcane industries have formed, respectively, the Roundtable on Sustainable Palm Oil (www.rspo.org) and the Roundtable on Sustainable Soy, as well as the Better Sugarcane Initiative (www.bettersugarcane.org). These initiatives tend to be aimed at improving environmental and social standards of producers within the industry, often through creating voluntary codes of good practice.

At a more global, all-encompassing level, is the Roundtable on Sustainable Biofuels, formally launched in April 2007. The Roundtable, which is hosted by the Energy Center at the Ecole Polytechnique Fédérale de Lausanne, Switzerland, has assembled non-governmental organizations, companies, governments, inter-governmental organizations, experts and other concerned parties "to draft principles and criteria to ensure that biofuels deliver on their promise of sustainability." Four sets of criteria are being developed: greenhouse gas lifecycle efficiency; environmental impacts, such as impacts on biodiversity, soil and water resources; social impacts, ranging from labor rights to impacts on food security; and implementation (i.e. that the standards are easy to implement and measure). The Roundtable has set a target of early 2008 for its first draft standards. It hopes that these standards will then "create a tool that consumers, policy-makers, companies, banks and other actors can use to ensure that biofuels deliver on their promise of sustainability" (EPFL Energy Center, 2007).

The G8 helped establish in Gleanegles the Global Bioenergy Partnership (GBEP) launched in May 2006 that will update the inventory of existing networks, initiatives and institutions dealing with bioenergy and identify any gaps in knowledge. GBEP will assist in identifying and implementing bilateral and multilateral projects for sustainable bioenergy development and support the formulation of guidelines for measuring reductions in greenhouse gas emissions due to the use of biofuels.

Standards linked to tax exemptions or subsidies

There is at least one operating and two proposed examples of this type of standards in the world today. Brazil's Social Fuel Seal, which was created at the end of 2004 (Decrees 5297 and 5298) as part of a package of measures under the country's National Biodiesel Programme, strives to take into account regional social inequalities and the agro-ecological potential for biodiesel feedstock production of different regions. Certification enables biodiesel producers to benefit from reduced rates of taxation on biodiesel, compared with the rates normally applied to petroleum diesel. The rate of exemption is 100% for biodiesel certified with the Social Fuel Seal produced from castor oil or palm oil in the North and Northeast regions, versus 67% for biodiesel produced from any source in other regions that do not qualify for the Social Fuel Seal. In the way that it operates, only Brazilian firms can qualify for the higher tax breaks.

In March 2007, the Swiss Government amended its Mineral Fuel Tax in a way that will in the future (probably starting in 2008) also tie tax benefits for biofuels to a system based on various environmental and social criteria. Under the new rules, both domestic and imported biofuels that benefit from a reduced fuel excise tax require "proof of a positive total ecological assessment that ensures also that the conditions of production are socially acceptable". However, in addition, the government, "taking into account of the amount of domestically available renewable fuels, shall establish the quantity of renewable fuels that can be exempted from the tax at the time of the importation."

Even more recently, a group commissioned by the government of the Netherlands in 2006 submitted their proposals to the Dutch Minister of Housing, Spatial Planning and the Environment on how to create a market for sustainable bio-energy (Creative Energie, 2007). The report proposes that access to any subsidies for biofuels be contingent on satisfying nine major criteria and numerous sub-criteria. According to Rembrant (2007):

> *Many of these criteria still need to be worked out in further detail regarding how to monitor their compliance by bioenergy companies. A preliminary system with less stringent criteria will come into effect in the course of 2008 when the new subsidy scheme for sustainable energy of the Dutch Government will start to function. After that several years of development and testing will take place, [so] as to put the full system of criteria with the relevant indicators and monitoring systems in place in*

2011. By then, the European Commission probably will have proposed a similar system for the entire European Union.

Taken together, the proposed criteria are extremely stringent and would be a challenge to satisfy, even by many producers in OECD countries. Moreover, they are in several cases highly prescriptive. For example, Criterion 2.2 stipulates that the biomass production "will not take place in areas with a high risk of significant carbon losses from the soil, such as certain types of grasslands, peat lands, mangroves and wet areas." This criterion seems to exclude large areas without taking into account the specific characteristics and modalities of an operation.

Regulations linked to achievement of a domestic policy goal

The European Commission plans in future to allow only those biofuels whose cultivation complies with minimum sustainability standards to count towards the EU's renewable fuel targets. Details on how the scheme might work are still being discussed, but many are looking to the example of the UK's Renewable Transport Fuel Obligation (RTFO). Beginning 1 April 2008, the RTFO will oblige fuel suppliers to ensure that a certain percentage of their aggregate sales is made up of biofuels -5% by 2010. Obligated companies will be required to submit reports on both the net greenhouse gas saving and sustainability of the biofuels they supply. This information in turn will be used to develop sustainability standards, which may be imposed if the RTFO is extended.

Although the reporting requirement does not yet discriminate among sources, failure to report makes a fuel supplier ineligible for any certificates proving that they have met their biofuel obligations. It remains to be seen whether the reporting obligation will bias the fuel suppliers towards biofuel producers whose records are comprehensive, in English, and whose claims can be easily verified by inspection. Moreover, as described in the UK Department of Transport's web page on "Frequently Asked Questions"2, the Administrator of the RTFO expects that these reports, once published, will constitute a "league table" of suppliers and biofuel producers, thus encouraging better performance. Longer term, the scheme could evolve into one that specifically links RTFO certificates with GHG savings determined though a standardized GHG certification system. Already, a feasibility study, commissioned by the UK government (Bauen *et al*., 2005), has recommended such a scheme.

WTO considerations for certification schemes

Any restriction on trade, including labeling and certification requirements or any other form of discrimination between products, is potentially subject to the disciplines of the trade agreements administrated by the World Trade Organization (WTO). Mandatory policies that link standards to tax exemptions or subsidies should be designed in such a way so as not to discriminate between countries. And even if the certification requirements would apply to all countries and to domestic production in a similar way, the measure might still be found against by a WTO dispute panel on the grounds of having a disproportionate impact on trade.

However, WTO rules also give the right to discriminate in favor of other public policy objectives such as protection of the environment and conservation of natural resources. Recent dispute settlements have shown sensitivity to retaining the balance between trade and non-trade values. The design of a certification scheme is likely to influence its appropriateness: differentiating to reward better fuels is probably more acceptable than excluding fuels. This will be particularly so if the criteria for exclusion are not objectively measurable. The WTO is a forum where discussions on trade and environment may take place; for this reason a special committee on trade and environment has been created to channel these discussions that could be used to discuss proposed certification criteria.

Lessons learned from certification schemes for forest products

Since the early 1990s, the international community has worked hard to establish certification as a tool to guarantee that wood products are resourced in an environmentally, socially and economically sustainable way. Forest products certification is a procedure by which an independent third party inspects and provides written assurance that a product originates in a forest that complies with pre-defined social and environmental standards. The objective is to limit the market for products that are not produced sustainably.

Although the market is still under development, certain key lessons should be taken into account when considering certification as a tool in the biofuels market. First of all, it has proven to be extremely difficult to develop an effective chain-of-custody control that tracks wood products from the forest through to finished products. Wood is processed into many different products and sourced from many different wood species, origins and owners. Shipping documents are easy to falsify and the laundering of illegal products through trade between countries is also relatively easy without strong cooperation and communication between custom offices.

Second, the effectiveness of certification has been undermined by displacement of wood products. As certification is not a multilateral requirement but conducted on a voluntary basis, it has merely led to a segmentation of the market, not to a reduction of the problem. Wood products from sustainable sources are supplying the small higher priced market segment that demands certified products, whereas nonsustainably produced resources are serving the rest of the market. Certified and non-certified products lay next to each other in factories and trading companies. The result is that more than 90% of the certified products are coming from OECD countries, where it is easier to identify sustainably managed forest practices in the first place. Tropical regions supply the greater part of the market but less than 5% of the market for certified wood.

Third, the many different certification schemes have undermined the potential for increased transparency in the market and the costs facing sustainable producers. The result has been an increase in the negative cost differential between certified and non certified products.

Certification of biofuels could well suffer from similar problems if not properly planned. The numerous production technologies, feedstock and differing local circumstances will make establishing and agreeing on shared criteria for sustainable production challenging. Voluntary and unilateral initiatives and policies for using certification schemes will run the same risks of displacement as in the market for forest products. Strong financial incentives and targets for biofuel production without adequate supply from sustainable sources will put enormous pressure on vulnerable land and forested areas. Certification as a tool to stop illegal and unsustainably managed bio-crop plantations will become less likely when the premium to cheat on the criteria is very high.

A final but important limitation is that certification schemes only deal with the direct environmental and social impacts of particular biofuel projects, and cannot address spillover effects through the displacement of non-biofuel agriculture.

VIII. An alternative policy agenda

There is little doubt that current patterns of fossil fuel-based energy use are unsustainable and that a change in direction is needed. There is, however, no obvious technological fix available that will supply the world with a source of automotive fuel that is cheap, clean, flexible and easily scalable. Hydrogen has been discussed, but many problems are yet to be overcome. In such a situation, when technological change is unpredictable, a prudent policy would be to keep as many options open as possible while at the same time letting prices adequately reflect environmental and natural-resource scarcities.

The current push to expand the use of biofuels is creating unsustainable tensions that will disrupt markets without generating significant environmental benefits. The upward pressure first-generation biofuels create on food prices, and the increasing burden their subsidisation places on taxpayers, are likely to make policies that support them indiscriminately less and less acceptable to the public.

Current biofuel support policies are placing a significant bet on a single technology notwithstanding the existence of a wide variety of different fuels and power trains that have been posited as options for the future. Those policies -that support high blends of ethanol, in particular- necessitate major investments in vehicles and fuel-distribution infrastructure; investments that, once made, put pressure on policymakers to protect them.

Governments should cease creating new mandates for biofuels and investigate ways to phase them out. Mandating blending ratios, market shares or volumes creates certainty for investors in biofuels production capacity, but in so doing simply transfers risk to other sectors and economic agents. Mandates do not save motorists money: biofuels still account for only a tiny fraction, perhaps 1%, of the total world market for petroleum-derived transport fuels -not enough to substantially affect prices. In any case, if prices of petroleum products were to rise above the cost of producing biofuels, the mandates would not be needed. If petroleum prices were to fall, mandating biofuels means that transport fuels containing them would cost more.

Mandates are blunt instruments for reducing net petroleum use and greenhouse gas emissions. Despite large differences in the contributions that particular feedstock/technology combinations can make in achieving these objectives, almost all of the mandates currently used by OECD countries make no distinction among biofuels except between ethanol and biodiesel. Some countries have started to investigate ways to differentiate biofuels according to their lifecycle GHG emissions, but it is still unclear how they can do this in a way that is compatible with WTO rules. Setting mandatory targets is risky when the potential supply of biofuel feedstocks that can be sustainably produced is unknown and the commercialization of second-generation technologies remains uncertain.

To the extent that subsidization of biofuels reduces the retail prices of transport fuels in some countries, biofuel-support policies are also insulating drivers from the true costs to society of their fuel consumption, be it reduced national security or increased emissions of CO_2. A far more neutral and efficient policy tool would be to tax fuels according to the externalities they generate.

Attempts to quantify support provided to biofuels also point to a more disturbing problem: that governments are providing billions of dollars or euros to support an industry about which they have only scant information. Yet without good statistics, it is difficult to imagine that policy makers are obtaining the feedback they need to respond to new developments in a timely fashion. In many countries, the only statistics available on production of biofuels are those collected by producers' associations. Statistics on consumption are even harder to obtain. And the fact that support is provided by multiple levels of government, in diverse forms, suggests that new policies are being introduced in the absence of comprehensive information on how they are affecting the marginal rate of assistance.

A number of other policies that governments could pursue would be less risky than those typically used by OECD countries. One would be to remove tariffs on imported biofuels. Tariffs are especially high on ethanol, and the longer they remain in place, encouraging inefficient investments in expensive productive capacity, the harder will be the adjustment needed once they are removed. Moreover, the countries most affected by import tariffs are generally developing countries with a comparative advantage in biofuel production.

The second would be to co-ordinate internationally on developing agreed standards for sustainable biofuels. Certification of biofuels to sustainability standards would not solve all the negative environmental consequences of expanded biofuel use, but it might help reduce some of the worst direct effects. At the least, international co-ordination would avoid an even worse situation where countries each require conformity to different standards.

If technology is the main barrier to the commercialization of second-generation biofuels, supporting R&D is likely to be more cost-effective than supporting production from first-generation facilities. Koplow (2006) points to the United States Energy Policy Act of 2005 as a good policy example. The Act calls for reverse auctions for cellulosic ethanol production, where the bidder requiring the lowest amount of public money per gallon produced will get the subsidy. Such an approach keeps development risks within the private sector and it reduces the chance of overcompensation.

The demand side of the transport fuel problem should receive proportionally more attention than the supply side. A litre of gasoline or diesel conserved because a person walks, rides a bicycle, carpools or tunes up his or her vehicle's engine more often is a full litre of gasoline or diesel saved at a much lower cost to the economy than subsidising inefficient new sources of supply. The IEA (2006a) points out that significant benefit can be achieved by improving vehicle efficiency. If all technical means of engine, transmission and vehicle technologies are implemented, a 40% improvement in the fuel economy of gasoline vehicles could be achieved at low costs by 2050.

Biofuels may well play a part in expanding the range of energy sources available in the future. The extent of their penetration will be limited by the opportunity cost of biofuel feedstocks being applied to competing end uses, and the extent to which second-generation technologies can significantly lower the costs of production. But in view of the fact that even the most optimistic studies posit no more than 13% of liquid fuel needs in 2050 being supplied by biofuels, it must be asked whether the diversion of such large amounts of public funds in support of this single technological option can be justified. Given that a much larger supply of clean transportation energy will be needed than biofuels can supply, governments need to apply their regulatory interventions and fiscal resources in ways that enable the widest array of technology options to compete.

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