The potential for biofuels alongside the EU-ETS

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Summary

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On its March 2007 summit the European Council agreed to embark on an ambitious policy for energy and climate change that establishes several targets for the year 2020. Amongst others this policy aims to reduce greenhouse gas emissions by at least 20% compared to 1990 and to ensure that 20% of total energy use comes from renewable sources, partly by increasing the share of biofuels up to at least 10% of total fuel use in transportation. In meeting the 20% reduction ceiling for greenhouse gas emissions the EU Emissions Trading Scheme (EU-ETS) will play a central role as the 'pricing engine' for CO_2-emissions. The higher the emissions price will be, the sooner technological emission reduction options will tend to be commercially adopted. The 20% target for renewable energy may undermine this role of the EU-ETS. The fostering – by subsidization or prescription – of renewables has the danger to depress the emissions price and to prevent (or postpone) the commercial advent of cleaner technologies. However, the promotion of the use of biofuels in road transport will not directly affect the functioning of the EU-ETS as long as the scheme will not cover fuel use for transportation. In this study we assess the impacts of raising the share of conventional biofuels to at least 10% within this specific policy environment, making use of simulation outcomes from the global general equilibrium model WorldScan.

As the EU-ETS covers only part of the economy, other policy measures must ensure that the part that is not covered, reduces emissions as well to meet the overall reduction targets. that member states have taken on by the EU Burden Sharing Arrangement. Hence, permit allocation to the sectors covered by the EU-ETS implicitly puts a complementary, national cap on the emissions left outside the scheme. A wide variety of policy measures aims to constrain member state emissions that are not capped by the ETS-ceiling. We summarize the impact that these various policy efforts should have with separate national carbon taxes in the sectors that do not belong to the EU-ETS.

Within this policy environment our analysis shows that the emissions price of the EU-ETS is indeed hardly affected when various targets for the share of biofuels in transport fuels are met. Hence, promoting biofuel use in road transport is a form of enhancing the use of renewables that will not – by lowering the emissions price – hinder the commercial advent of cleaner technologies in EU-ETS sectors. Increasing biofuel shares in transport fuel use does have a mitigating effect on the policy efforts needed to curb emissions in the other sectors. This is reflected by a drop in the carbon taxes at the member state level. Hence, the negative impacts of these distortionary taxes on economic welfare will decline.

The introduction of biofuels may, depending on the biofuel excise regime and the impact on the carbon tax, raise the user price of transport fuels. This affects economic welfare negatively. On balance the net effect on economic welfare turns out to be very small, either

slightly positive or negative. When carbon taxes are very small the benefits of reducing them fall short of the extra burden of raising biofuel usage. Hence, overall economic welfare is declining in the new member states. When biofuel targets are increased above 10% the negative impacts on welfare tend to dominate: the additional benefits of reducing distortionary carbon taxes tend to outweigh the additional costs of raising biofuel usage.

The impacts on food prices of conventional biofuel promotion up to the 10% target turn out to be negligible. Meeting this target would require an increase of the biofuel feedstock share in current global arable acreage from 1% to approximately 3.5%. Hence, large impacts on food prices are hardly to be expected.

Full liberalisation of biofuel trade will make biofuels cheaper (enhancing welfare) but leave carbon taxes in non-ETS sectors at a higher level (reducing welfare). On balance economic welfare is hardly increasing when biofuels are imported rather than produced domestically.

Summary Table Biofuel scenarios, selected indicators, in % deviation from the policy baseline, 2020

	Emissions price	Carbon tax (EU average)	Arable land rents (EU average)	Economic welfare
No trade liberalization				
No excise, target 10%	0.2	-10.9	2.2	0.03
Competitive excise, target 10%	0.2	-14.7	2.3	0.02
Full excise, target 10%	0.1	-21.6	2.2	-0.00
Full excise, target 15%	0.2	-31.8	3.4	-0.01
Full excise, target 20%	0.2	-41.2	4.6	-0.03
Raising fossil fuel excises	-0.3	10.1	0.3	-0.06
Biofuel trade liberalized				
No excise, target 10%	0.2	-10.6	1.5	0.03
Competitive excise, target 10%	0.2	-14.8	1.6	0.02
Full excise, target 10%	0.2	-20.8	1.6	-0.00
Full excise, target 15%	0.2	-30.8	2.4	-0.01
Full excise, target 20%	0.3	-40.0	3.3	-0.02
Raising fossil fuel excises	-0.3	9.7	0.3	-0.06

Source: WorldScan

These results are quantified with various counterfactual WorldScan simulations and are summarized here with some selected indicators in percentage deviations from the policy baseline: the EU-ETS emissions price, the carbon taxes and arable land rents averaged at EU-level, and economic welfare. In the summary table three different ways of taxing biofuels are distinguished: no excise, a competitive biofuel excise equating the user costs of biofuels and fossil fuels in transportation, and a full excise equal to existing transport fuel taxes. Moreover three targets for the share of biofuel use in transport fuel use are represented: 10%, 15% and 20%. For each of the scenario’s either existing biofuel import tariffs are maintained (no trade liberalization) or put to zero (full trade liberalization). Finally, we report scenarios with no increase in the biofuel targets, and a fuel tax instead that achieves the same emission reduction within the transport sector as would accomplished with a 10% biofuel target..

The table illustrates - at the level of EU-27 - our main findings: biofuel promotion does hardly affect the emissions price, has large impacts on carbon taxes, raises arable land rents to some extent and has limited impacts on economic welfare. The latter are raised almost negligibly by the liberalization of biofuel trade. Achieving transport specific emission targets by a fuel tax instead of biofuel quotas drives average carbon related taxes up and is detrimental to economic welfare.

1 The potential for biofuels alongside the EU-ETS

1.1 Introduction

On its March 2007 summit the European Council agreed to embark on an ambitious policy for energy and climate change. The aims of this policy which may be called the three times 20 targets for 2020, are the following: the EU will reduce greenhouse gas emissions by at least 20% compared to 1990, will ensure that 20% of total energy use comes from renewable sources and will accomplish a 20% decrease in energy intensity over and above business as usual developments. Part of the target for renewable energy will be covered by increasing the share of biofuels up to 10% of total transport fuel use in 2020.

With the target to reduce greenhouse gas emissions by at least 20% in 2020, if need be unilaterally, the EU demonstrates that it takes its ambition seriously to limit global warming to 2° Celsius above pre-industrial levels. According to current knowledge this temperature target can only be met if emissions are reduced by this order of magnitude in all industrialized countries and if large and fast-growing emitters as China, India and Brazil are starting soon to curb emissions as well (Boeters *et al.*, 2007). The EU initiative may not only bring afloat the international negotiations about post-2012 climate policies, but also conveys a significant signal to EU energy users and producers that greenhouse gas emissions will become increasingly costly in the medium term. This signal is instrumental to the long-term decision making process on transitions to cleaner technologies, in particular in power generation.

The EU Emissions Trading Scheme (EU-ETS) can be considered as the ‘pricing engine’ for CO_2-emissions. Though its current coverage is confined to large combustion installations that together emit almost halve of EU fossil CO_2 emissions, other greenhouse gases and emitters are scheduled to be brought into the scheme as well. The higher the emissions price will be, the sooner technological emission reduction options will tend to be adopted commercially.

The 20% target for renewable energy may undermine this role of the EU-ETS. Subsidization of renewable electricity generation will reduce the demand for permits, and lower the permit price, unless the cap is tightened simultaneously. Hence, the fostering – by costly subsidization or prescription – of renewables has the danger to depress the emissions price and to prevent (or postpone) the commercial advent of cleaner technologies. The promotion of the use of biofuels for transport will, however, not directly affect the functioning of the EU-ETS as long as the EU-ETS will not cover fuel use for transportation. Yet, without further investigation, it is not clear whether a policy that fosters the use of biofuels is more or less costly than alternatives, such as a further rise in fuel excises.

In this section the impacts of alternative policy measures are assessed that aim to exploit the biofuel potential, using (an adaptation of) the climate change version of the global general equilibrium model WorldScan (see Appendix A for characteristics of the model version used). The outcomes of WorldScan are of a long-term nature as the model does not reflect the temporary costs of structural adjustments. Moreover, we do not carry out a complete welfare analysis. In the model consumer utility depends on consumption, but not on leisure, environmental quality or inequality. By consequence, the simulation outcomes do not represent the trade-offs between consumption and leisure or environmental quality, nor between efficiency and equity. These limitations of our quantitative analysis have to be borne in mind when interpreting the simulation outcomes.

The policy options are assessed for the year 2020, in general with respect to their differential impacts on economic welfare in the member states and in particular with respect to their cost effectiveness. The assessments are made against a policy baseline with modest economic growth in which all Annex I countries impose ceilings on fossil CO_2 emissions. It is assumed that within the EU an ETS is operational that does not cover CO_2 emissions from road transport. This policy baseline is described in Section 1.2 and compared to a business as usual scenario. The impacts of alternative biofuel promotion policy measures are assessed in Section 1.3. Here, the assessments are made with respect to the policy baseline. An alternative policy that raises transport fuel excises to curb emissions from road traffic is also analysed (Section 1.4). Conclusions are drawn in Section 1.5.

1.2 Climate policy baseline

All counterfactual scenarios are assessed against a policy baseline scenario that has both the EU-ETS in place and emission reduction targets in the other countries of Annex I. As the EU-ETS covers only part of the economy (hereinafter: the regulated sector), other policy measures must ensure that the part that is not covered (henceforth: the non-regulated sector) reduces emissions as well to meet the overall reduction targets. By the EU Burden Sharing Arrangement each member state has taken on a reduction target for total emissions. Hence, permit allocation to the regulated sectors implicitly puts a complementary, national cap on emissions from the non-regulated sectors. Reduction of emissions from the non-regulated sectors is to be addressed by a large variety of policies at EU and national levels: caps at the sectoral level, either absolute (*e.g.* for Dutch horticulture) or relative (*e.g.* under the Climate Change Levy system in the United Kingdom), voluntary agreements (*e.g.* with personal car manufacturers at EU-level to reduce CO_2 emissions), prescribed energy efficiency standards or additional taxation. We represent these various policy efforts with separate carbon taxes for the non-regulated sector at the member state level.

We necessarily have to implement the EU-ETS in a rather coarse way, as a sectoral classification of plants according to the size of their combustion installations is not available. Thus, we assume that the following sectors are covered by the EU-ETS: electricity, energy intensive and chemical products and capital goods and durables. Taken together, these sectors emit somewhat less than half of EU-27 fossil CO_2 emissions. Households and the remaining production sectors belong to the non-regulated sector.

In addition, cap-and-trade systems are also assumed to operate in the other Annex I countries, though here the caps are assumed to be more modest in terms of the emissions reduction with respect to the 1990 level. The policy baseline has the following characteristics.

- For the period 2008-2012
  - all Annex-I parties impose their Kyoto ceilings, except for the USA which backed off from the Kyoto Protocol,
  - the ceilings for individual member states of EU-27 are determined by the Burden Sharing Agreement,
  - within the EU an overall cap is imposed on the regulated sectors, while national caps are to be met for the non-regulated sectors; in the model the policy impacts on the non-regulated sectors are represented by an carbon tax; the caps in other Annex I countries cover their complete economy,
  - permits are freely tradeable within EU-27; all other Annex-I countries follow a stand-alone system without international permit trade; no use is made of the Clean Development Mechanism (CDM) or Joint Implementation (JI)
- For the period 2013-2020
  - all Annex-I parties, except EU-27 and USA, reduce their cap by 1% of the 2012 emissions targets annually,
  - the USA takes actual 2012 emissions as the basis of an annual 1% reduction,
  - EU-27 engages to reduce emissions with 20% below 1990 emissions in 2020, using the dual system of the preceding period; the Burden Sharing Agreement of this period is taken as a point of departure; hence, the overall EU reduction is allocated to member states in proportion to their 2010 shares in the EU Kyoto ceiling,
  - permits are freely tradeable within EU-27 only and no use is made of CDM or JI.

One may question the likelihood of the mere reliance on domestic reductions in the Annex I parties in this policy baseline. This assumption was deliberately made in order to enable a focus in the counterfactual analyses on internal EU impacts, without having the need to account for the influences of international permit trade.

The policy baseline has been constructed against a business as usual scenario that describes how the economies would develop in the absence of such policies. We adopt a scenario that has recently been developed by the Netherlands Environmental Assessment Agency (MNP) (van Vuuren *et al.*, 2007). This scenario is characterized by medium economic growth. It does not include climate change policies or carbon taxation. It is very similar to the reference scenario of the International Energy Agency (IEA) and can be seen as an update of the IPCC B2 scenario. We inserted actual biodiesel and ethanol production in the background scenario over the period 2001-2004, freezing the share of biofuel use from 2004 onwards until 2020. Further characteristics of the background scenario are given in Appendix A.2.

The impacts of the policy baseline in 2020 vis-à-vis the policy-free business as usual scenario are as follows (see Table 1.1). First, within Annex I, the distribution of emission abatement efforts is rather skew. In particular, the USA profits from its withdrawal from the Kyoto Protocol. The USA target in terms of 1990 emissions is 17% up, while the targets of EU-27 and the rest of the OECD are 20% and 22% down respectively. Emission prices are especially high in the

Table 1.1 Policy baseline impacts, 2020

	Percentage CO_2 reduction			Emission price or carbon tax a)	Economic welfare
	Target compared to 1990 emissions	Target compared to background emissions	Emissions compared to background emissions		Change compared to background scenario
	(%)	(%)	(%)	€ / tCO_2	(%)
Annex I	-7	-24	-24	41	-0.63
EU-27	-20	-33	-33	54	-0.62
Germany	-31	-35	-33	66	-0.63
France	-13	-36	-33	68	-0.47
United Kingdom	-23	-30	-30	83	-0.56
Italy	-18	-42	-34	116	-1.06
Spain	0	-41	-36	80	-0.72
Other EU-15	-14	-40	-33	90	-0.77
Poland	-18	-1	-34	6	1.00
Bulgaria and Romania	-20	0	-25	4	1.19
Other EU-12	-19	-32	-39	46	-0.64
USA	17	-9	-9	6	-0.07
Rest of OECD	-22	-48	-48	125	-1.56
Former Soviet Union	-8	14	2	0	-1.07
Non-Annex I			2		-0.14
Brazil			4		-0.04
China			2		-0.09
India			3		0.03
World			-12		-0.51

a) The emissions price for EU-27 is the price of the EU-ETS; at member state level the carbon tax is shown of the non-regulated sectors rest of the OECD which has to reduce emissions by almost 50% compared to the background scenario and meets abatement costs of 125 € per ton CO_2. The EU-reduction with respect to the background scenario is more than 30% and the EU-ETS emission price is above 50 euro per ton CO_2. In the USA emissions prices are, at 6 euro per ton, about ten times smaller than in the EU. The target of the former Soviet Union is not binding. In Annex I countries, welfare (as measured by equivalent variation) is on average 0.6% less than in the background scenario. Welfare losses are higher than average in other OECD (-1.6%) while some of the new EU member countries benefit from their sales of emission permits within the EU-ETS. Hence, Poland, Bulgaria and Romania experience welfare gains of 1 to 1.2% because of permit exports. The welfare level in the USA remains almost unchanged.

Because permits are tradeable within the EU-ETS, member states need not reduce their emissions in the regulated sectors by the full amount indicated by their emission targets. The member states of EU-15, including – to a minor extent – the United Kingdom, tend to reduce their emissions less than targeted, importing the permits from the new member states. Hence, in some countries, notably Poland and Bulgaria and Romania, that have targets slightly above business as usual emissions, nevertheless sizable reductions are induced by the height of the EU-ETS emissions price. In the non-regulated sectors trade in reduction obligations is not possible. Hence, the carbon taxes for these sectors vary by member state and are in general higher in EU-15 than in the new member states. In EU-15 the carbon tax generally reaches levels that are above the emissions price of the EU-ETS, whereas in Poland, Bulgaria and Romania the tax is relatively small.

In non-Annex I countries emissions increase, mainly because of the relative decrease in prices of energy carriers in comparison to the background scenario. With the exception of India, these countries experience minor welfare losses due to the increased prices of non-energy imports.

Globally, emissions are 12% below emissions in the background scenario. Boeters *et al.* (2007) – using the same baseline – conclude that such a reduction tends to fall short of meeting the 2°C temperature target.

1.3 Promoting the use of biofuels

Our assessments focus on conventional biofuels that are produced from food or feed crops. Biodiesel is produced from vegetable oils and ethanol from cereals or sugarcrops (see textbox). Thus, raising biofuel production puts extra claims on arable land. As in all scenarios the availability of arable land is kept constant, land rents will increase when the use of biofuel feedstocks is expanding. We do not assess the prospects of the so-called ‘second-generation’ biofuels that are produced from cellulosic and ligno-cellulosic material and from biowaste.

Though these fuels would reduce the biofuel claim on arable land, they are still too costly to be competitive with conventional biofuels. An analysis of these fuels is not within the reach of WorldScan and beyond the scope of our analysis.

Though the direct use of convential biofuels does not add to greenhouse gas emissions, using conventional biofuels is not climate-neutral as fossil CO_2 is emitted in biofuel crop production and in the extraction of biofuels from these crops. Moreover, the strain on arable land use may induce farmers to raise the use of nitrogen fertilizers, which would increase the emissions of the greenhouse gas nitrous oxide (N_2O). The latter emissions are not reflected in the WorldScan version used here.

Biofuel production technologies

Biodiesel is generally produced from vegetable oils or animal fats. The process involves filtering the feedstock to remove the water and contaminants, and then mixing it with methanol and a catalyst. This causes the oil molecules to break apart and reform into esters (biodiesel) and glycerol, which are then separated from each other and purified. The process yields glycerine as a by-product which is used in may types of cosmetics, medicines and foods. Biodiesel can be made from almost any naturally occurring oil or fat. Currently, the predominant oils used in biodiesel production are rape- and sunflower oil in the EU, and soya oil in North- and South-America. Other oleaginous crops used as biodiesel feedstock include castor seed, coconut, jojoba, oil palm and Jatropha. Biodiesel can also be produced from waste cooking oils, fish oil and tallow. The cost of the feedstock represents the major component of total production costs of biodiesel, such that cheaper oils such as palm oil, Jatropha oil or used frying oil could bring significant cost advantages.

Ethanol is produced by fermenting sugar to alcohol which then is distilled to remove the water. Starchy feedstocks first have to undergo a high-temperature enzymatic process that breaks the starch down into sugars. The sugar thus produced or obtained directly from sugar crops is then fermented into alcohol using yeasts and other microbes. The cereals-to-ethanol process yields protein-rich animal feed as a by-product. By-products reduce the overall costs of ethanol. They may also reduce the CO_2-emissions involved in its production, when crop residues such as straw or bagasse are used to provide heat and power for the ethanol plant. In OECD countries, most ethanol is produced from starchy crops like corn, wheat and barley, but ethanol can also be made from potatoes or cassava, or directly from sugar cane and sugar beet. Again, the feedstock value represents an important share in total production costs. Currently the ethanol produced in Brazil from low-cost sugar cane represents the only biofuel that can compete almost without subsidieswith oil-based gasoline.

Biofuels can also be produced from so-called second generation feedstocks: biowaste and the ‘woody’ parts of grasses, bushes, trees and plants. Cellulosic and ligno-cellulosic materials are difficult to break down into their component sugars and require extensive and expensive processing before being converted into biofuels. New technologies, like enzymatic hydrolysis, have raised high expectations, and older approaches, such as biomass gasification followed by a chemical process to convert the gas into synthetic fuels, are being revived and further developed. Yet, the costs of these technologies are still prohibitive.

The use of biofuels need not require large investments in distribution infrastructure or in car engine adjustments (see textbox). Promoting the use of biofuels will increase energy security as it reduces oil demand. Biofuels have air quality benefits as well. Benefits from ethanol and biodiesel blending into petroleum fuels include lower emissions of carbon monoxide, sulphur dioxide and particulate matter (IEA, 2004). However, the use of biofuels will also increase some emissions, such as those of nitrogen oxides (Steenblik, 2006). Biofuels have vehicle performance benefits: ethanol has a very high octane number, while biodiesel can improve diesel lubricity and raise the cetane number. Hence, both biofuels aid fuel performance. Finally, the production of biofuels may bring economic benefits to rural communities. Yet, large scale production may raise food prices and have negative impacts on the long-term sustainability of biofuel crop production and on biodiversity.

Using biofuels in road transport

Low-rate biofuel blends (such as B5, up to 5% of biodiesel in conventional diesel, or E10, up to 10% of ethanol in gasoline) do not require any modifications to existing vehicle engines. Both biofuels can be supplied in the same way as conventional diesel or gasoline through existing petrol stations. Higher shares of biodiesel or ethanol require only modest modifications in tanks, fuel pipes, valves and/or engine components. Biodiesel blends of 20% (B20) are available in some countries and B100 is available at more than 700 service stations in Germany. A flex-fuel car engine which is compatible with any ethanol blend share between 0% and 100% is sold by some car-makers. E85 is widely available in Sweden to be used in such engines.

A scan of the recent literature on assessments of the biofuel potential yields as the main insight that biofuels are generally more expensive than fossil fuels. According to OECD (2004) current techniques would require very high emission prices to make them competitive with fossil transport fuels, with the exception of ethanol produced from sugar cane. Ethanol from cereals would require an emission price in the range of 250-600 dollar per ton CO_2 (maize, USA) or 400-800 dollar (wheat, EU), while ethanol from sugar cane would be much more cost-effective, at around 20-60 dollar per ton CO_2. Biodiesel would require emission prices in the range of 280-380 dollar per ton to break even with fossil diesel. It should be noted that these estimates are based on 2004 assessments of cost characteristics and emission reduction indicators. Moreover, the use of biofuels has also co-benefits that generally are not accounted for in the analysis.

In the World Energy Outlook 2006 (IEA, 2006), a chapter is devoted to an outlook for biofuels that presents three scenario’s. In the Reference Scenario biofuels meet 4% of world road-transport demand in 2030, or 92 Mtoe, up from 1% today. In the Alternative Policy Scenario the biofuel share rises to 7% of road fuel use, 147 Mtoe in 2030. In the Second-Generation Biofuels Case the share of biofuels in transport demand is pushed up to 10% in 2030 globally. The arable land requirements are assessed to amount to 34.5 mln ha in the Reference Scenario, 52.8 mln ha in the Alternative Policy Scenario and 58.5 mln ha in the Second-generation biofuels case, against an actual use of 13.8 mln ha for biofuel crop production in 2004.

Two recent model studies (OECD, 2006; Economic Commission, 2006) focus on the agricultural dimension of biofuel production making assessments with partial equilibrium models with a focus on agriculture (Aglink at OECD and Esim at the EC).

The OECD-study concludes that a biofuel share in 2014 of 10% in domestic transport fuel use would require between 30% and 70% of crop areas to be devoted to biofuel crops in the OECD countries USA, Canada and EU-15. However, only 3% would be required in Brazil, due to the high yield of sugar cane and Brazil's relatively low fuel consumption per head. The strongest impact of a 10% biofuel share on food prices would be for the world price of sugar which might rise by 60%, while vegetable oil prices might go up by 20% en cereal prices by 4%.

The EC-study assesses the implications of three scenarios aiming to increase the biofuel share of the EU in 2020 to 7%, 14% with a domestic orientation and 14% with an import orientation. At the 7% target 23 Mtoe of fossil oil would be replaced against 43 Mtoe at the 14% targets. The extra costs involved would range from 4-8 bln euro (7%), 10-17 bln euro (14% domestic) to 5-15 bln euro (14% import). Greenhouse gas emissions would go down by 48 $MtCO_{2eq}$ (7%) and 101-103 $MtCO_{2eq}$ (14%).

In our assessment we distinguish five technologies for producing biodiesel and ethanol: biodiesel from vegetable oils and ethanol from sugar cane, sugar beet, maize or wheat. In establishing a breakdown of production costs we assumed that those technologies are applied that operate at lowest cost, neglecting greenhouse gas emissions (see Table A.6 in Appendix A.3 for the breakdown of costs used for our 2001 base-year).

In this section we describe a number of different scenarios where biofuels are promoted to various degrees and with various supporting policy measures. In all scenarios, the biofuel shares in transport fuel use are imposed directly, introducing them linearly from 2006 onwards to achieve the targeted value in 2020. We use the 2001 split between gasoline and diesel use to calculate separate targets for biodiesel and bioethanol. In addition to the EU, we also account for biofuel targets in some other countries, such as Brazil, India and the USA, where explicit biofuel promotion policies exist (cf. Unctad, 2006).

In general our scenarios follow one of three ways of fostering the increase of biofuel use:

- full exemption of transport fuel excises; this assumption is also made in the policy baseline
- competitive excise on biofuels to establish equality of the biofuel user price with the user price of fossil transport fuels; this tax is determined endogenously in the model,
- full taxation of biofuels with existing fossil transport fuel excises (see van Leeuwen, 2007, for the rates adopted).

Imposing a biofuel share of 10% in 2020, leaving biofuels fully exempted from transport fuel excises, has rather limited impacts on economic welfare (see Table 1.2). The table shows the percentage deviations with respect to the policy baseline for fossil CO_2 emissions, the emissions price, the price of arable land, the agricultural producer price, the food consumer price and economic welfare[1].

Table 1.2 Emissions, prices and economic welfare, in % difference with respect to the policy baseline, for a biofuel target of 10% with biofuels fully exempted from fuel excises, 2020

	Emissions	Emission price a)	Arable land price	Agricultural producer price	Food consumer price	Economic welfare
Annex I	-0.0		0.9	0.2	0.1	0.01
EU-27	-0.0	0.2	2.2	0.5	0.1	0.03
Germany	0.0	-8.1	2.4	0.6	0.1	0.03
France	0.0	-9.3	2.4	0.5	0.0	0.03
United Kingdom	0.0	-17.7	6.1	1.0	0.1	0.07
Italy	0.0	-9.1	2.5	0.5	0.1	0.04
Spain	0.0	-14.3	2.6	0.4	0.0	0.01
Other EU-15	0.0	-8.8	2.1	0.2	0.1	0.02
Poland	0.0	-36.1	1.8	0.7	0.2	-0.05
Bulgaria and Romania	-0.6	-100.0	0.7	0.3	0.2	-0.15
Other EU-12	0.0	-11.0	2.1	0.6	0.1	-0.02
USA	0.0	-0.1	0.5	0.2	0.0	0.00
Rest of OECD	0.0	0.0	0.5	0.1	0.1	0.00
Former Soviet Union	-0.1		0.2	0.1	0.1	-0.01
Non-Annex I	0.0		0.3	0.1	0.1	0.00
Brazil	0.0		0.6	0.2	0.1	0.01
China	0.0		0.2	0.1	0.1	-0.01
India	0.0		0.1	0.1	0.1	0.00
World	0.0		0.5	0.2	0.1	0.01

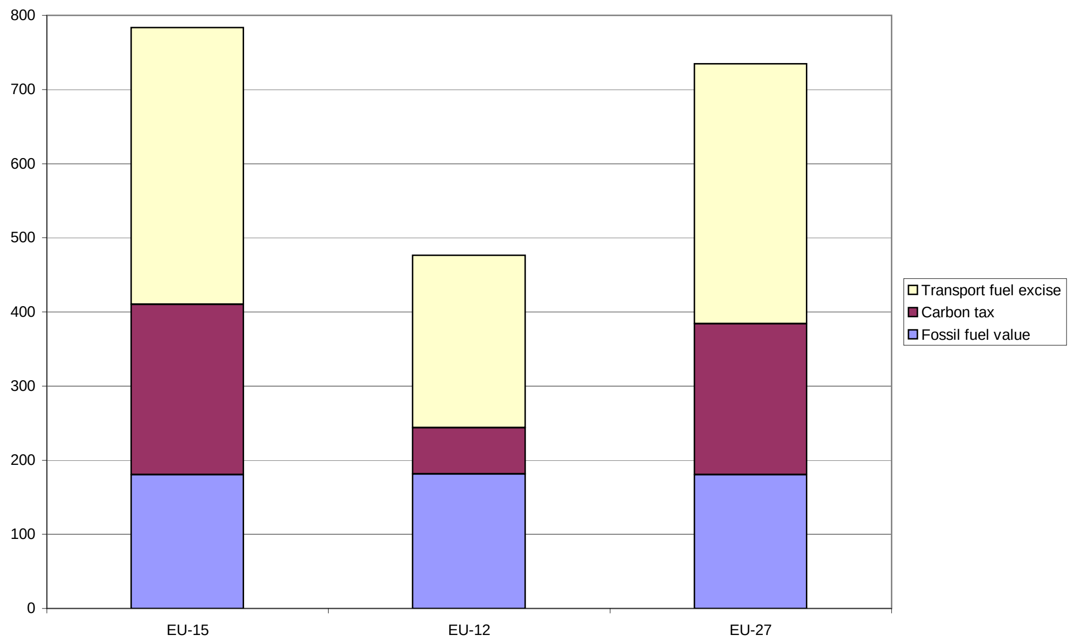
a) The deviation of the emissions price for EU-27 is with respect to the price of the EU-ETS; at member state level the deviation with respect to the carbon tax is shown for the non-regulated sectors

In spite of the caps, emissions in the EU-27 are slightly reduced. This is caused by a decrease of emissions from the non-regulated sectors in Bulgaria and Romania (where the carbon tax drops to zero). In the Former Soviet Union the cap remains unbinding. In non-Annex I emissions remain virtually constant. The impact of imposing targeted biofuel shares in transport fuel use on EU carbon taxes is relatively large. These taxes decrease in all member states (in Bulgaria and Romania they vanish altogether) because road transport belongs to the non-regulated sector. The biofuel target reduces emissions in road transport. Therefore a lower carbon tax suffices to meet the cap of the non-regulated sectors. The EU-ETS emissions price rises slightly due to increased demands for fossil fuels in the regulated sectors. In all countries the price of arable land increases because the biofuel feedstocks compete for arable land with other agricultural activities. The land price increase is particularly high in the United Kingdom. Presumably this is

[1] The welfare impact shown is in terms of relative equivalent variation. This indicator represents the change in income against policy baseline prices that would make consumers just as well of in the policy baseline as they are in the counterfactual simulation case, expressed as a percentage of policy baseline consumer expenditure.

due to the high base-year share of permanent pastures and meadows in total agricultural area of the United-Kingdom, leaving a relatively small acreage for crop production. In the wake of rising land prices agricultural producer prices and food consumer prices also rise, but to a much smaller extent. In the end economic welfare is affected positively to a minor extent in the member states of EU-15 and negatively in the new member states. In fact this outcome means that the freezing of biofuel shares at 2004 levels in the policy baseline is constraining welfare in the member states of EU-15. By increasing the biofuel share to 10% transport fuel users can evade both the carbon tax and the fossil fuel tax and this improves welfare. In the new member states these taxes are relatively small (see Figure 1.1). In these countries the benefits of tax evasion fall short of the extra costs of biofuel consumption. Hence, on balance welfare declines in the member states of EU-12.

Figure 1.1 User costs of fossil transport fuels in euro per Mtoe, policy baseline, 2020



How do the impacts of imposing a 10% EU biofuel share differ under the three alternative ways of fostering the increase of biofuel use (no excise, competitive excise and full excise)? Unsurprisingly, as fuel blends become more expensive, less fuel will be consumed. Hence, emission taxes will fall if excises are imposed that make biofuels just competitive with fossil fuels and they fall even more when biofuels are taxed on just the same basis as fossil fuels (see Table 1.3). As the transport fuel bill in the member states is heavily distorted by fossil fuel excise taxes, welfare losses are to be expected when the excise burden is raised. The latter impacts tend to outweigh the gains from reduced carbon taxes as economic welfare decreases in all member states when taxes on biofuels rise. Yet, when biofuels are not taxed, Poland, Romania and Bulgaria loose from the imposition of a biofuel target, while all other member states experience modest gains in this case.

Table 1.3 Emission prices in euro per ton CO_2 and economic welfare with respect to the policy baseline, for a biofuel target of 10% in three excise variants, 2020

	No excise		*Competitive excise*		*Full excise*	
	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare
EU-27 a)	54	0.03	54	0.02	54	-0.00
Germany	60	0.03	58	0.02	54	-0.01
France	62	0.03	60	0.02	55	-0.00
United Kingdom	68	0.07	61	0.05	49	0.02
Italy	105	0.04	100	0.04	95	0.03
Spain	69	0.01	66	0.01	61	-0.01
Other EU-15	83	0.02	80	0.01	76	-0.00
Poland	4	-0.05	3	-0.06	2	-0.13
Bulgaria and Romania	0	-0.15	0	-0.15	0	-0.26
Other EU-12	42	-0.02	41	-0.04	38	-0.09

a) The emissions price for EU-27 is the price of the EU-ETS; at member state level the carbon tax is shown of the non-regulated sectors

Table 1.4 shows how the prices of fuel blends change and the use of transport fuels alters with biofuel taxation procedures. The table confirms that blended fuel prices (the average price of transport fuels with a 10% biofuel share) are highest and transport fuel use is lowest when biofuels are taxed to the same extent as fossil fuels. Note that this is not self-evident because the carbon tax on fossil fuels is decreasing simultaneously. Even in the case of a full excise tax on biofuels, the average fuel price may decrease in some countries (United Kingdom, Italy, Spain). This is because the higher cost of biofuels are more than compensated by a decrease of the fossil fuel price and of the carbon tax in the non-regulated sector.

Table 1.4 Blended fuel prices and blended fuel volumes, in % deviations from the policy baseline, for a biofuel target of 10% in three excise variants, 2020

	No excise		*Competitive excise*		*Full excise*	
	Fuel price	Fuel volume	Fuel price	Fuel volume	Fuel price	Fuel volume
EU-27	-6.9	4.7	-4.5	3.2	1.1	-0.6
Germany	-5.9	3.9	-2.7	1.8	4.0	-2.4
France	-6.1	4.2	-3.5	2.5	2.9	-1.8
United Kingdom	-9.5	7.0	-6.9	5.1	-1.6	1.3
Italy	-8.1	6.0	-5.3	3.8	-2.0	1.5
Spain	-8.0	6.0	-6.7	5.0	-3.1	2.5
Other EU-15	-7.2	5.0	-4.3	3.0	-0.3	0.3
Poland	-2.7	1.6	-1.8	1.1	9.2	-5.6
Bulgaria and Romania	-1.4	0.7	-3.8	2.2	9.6	-5.5
Other EU-12	-4.1	2.4	-3.2	2.1	4.3	-2.5

The economic impacts of biofuel targets become the larger, the more ambitious biofuel targets are. In the next two tables we show the consequences of raising the targets to 15% and 20% compared to the 10% target in the scenarios discussed thus far. In all these counterfactual scenarios full taxation of biofuels is assumed.

Table 1.5 Emission prices in euro per ton CO_2 and economic welfare with respect to the policy baseline, for biofuel targets of 10%, 15% and 20%, with full excises on biofuels, 2020

	10%		*15%*		*20%*	
	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare
EU-27	54	-0.00	54	-0.01	54	-0.03
Germany	54	-0.01	48	-0.02	43	-0.03
France	55	-0.00	49	-0.01	43	-0.01
United Kingdom	49	0.02	34	0.01	20	-0.01
Italy	95	0.03	85	0.05	74	0.06
Spain	61	-0.01	51	-0.02	41	-0.03
Other EU-15	76	-0.00	68	-0.01	61	-0.02
Poland	2	-0.13	0	-0.20	0	-0.27
Bulgaria and Romania	0	-0.26	0	-0.40	0	-0.54
Other EU-12	38	-0.09	34	-0.14	30	-0.20

a) The emissions price for EU-27 is the price of the EU-ETS; at member state level the carbon tax is shown of the non-regulated sectors

Higher biofuel targets lead to substantially lower carbon taxes in the non-regulated sector, the most striking example being the United Kingdom where the tax is more than halved when the target is doubled. The consequences for economic welfare are rather small however. In general, increasing the targets leads to a deterioration of welfare (Italy is the only exception with a small further welfare increase.) The welfare losses are again highest in the new member states, especially in the countries where the carbon tax is very small – as in Poland – or even absent – as in Bulgaria and Romania.

Table 1.6 **Blended fuel price and blended fuel use, in % deviation from the policy baseline, for biofuel targets of 10%, 15% and 20%, with full excises on biofuels, 2020**

	10%		*15%*		*20%*	
	Fuel price	Fuel volume	Fuel price	Fuel volume	Fuel price	Fuel volume
EU-27	1.1	-0.6	2.3	-1.3	3.9	-2.3
Germany	4.0	-2.4	6.3	-3.7	8.9	-5.2
France	2.9	-1.8	4.8	-2.9	7.0	-4.2
United Kingdom	-1.6	1.3	-1.2	1.1	0.2	0.1
Italy	-2.0	1.5	-2.5	2.0	-2.6	2.1
Spain	-3.1	2.5	-4.0	3.3	-4.3	3.7
Other EU-15	-0.3	0.3	0.1	0.1	0.9	-0.3
Poland	9.2	-5.6	14.3	-8.5	20.5	-11.6
Bulgaria and Romania	9.6	-5.5	16.2	-8.9	22.9	-12.1
Other EU-12	4.3	-2.5	6.9	-3.9	9.9	-5.6

Table 1.6 confirms that biofuels may have different impacts on the member states. On average and in most countries of EU-15 higher biofuel targets lead to an increase in the average fuel price compared to the policy baseline. However, in Italy and Spain the average fuel price falls below the level of the policy baseline. Fuel use responds directly to average fuel prices. The reductions in fuel use are particularly pronounced in Poland, Bulgaria and Romania.

Table 1.7 **Prices of arable land, agricultural production and food consumption, in % deviation from the policy baseline, for biofuel targets of 10% and 20%, biofuels being fully excised, 2020**

	10%			*20%*		
	Land	Agriculture	Food	Land	Agriculture	Food
EU-27	2.2	0.5	0.1	4.6	0.9	0.2
Germany	2.4	0.6	0.1	4.9	1.2	0.2
France	2.4	0.5	0.0	4.9	1.1	0.1
United Kingdom	6.1	1.0	0.1	12.4	1.9	0.2
Italy	2.5	0.5	0.1	5.3	1.1	0.2
Spain	2.6	0.4	0.0	5.5	0.8	0.1
Other EU-15	2.1	0.2	0.1	4.4	0.5	0.2
Poland	1.8	0.7	0.2	3.6	1.3	0.4
Bulgaria and Romania	0.7	0.3	0.2	1.3	0.6	0.4
Other EU-12	2.1	0.6	0.1	4.3	1.3	0.2

Table 1.7 shows the consequences of biofuel targets on agricultural prices. We compare the scenarios with 10% and 20% targets (both with full biofuel excises in place) and show the responses of the prices of arable land, agricultural production and food consumption in percentage deviations from the policy baseline. Due to the additional demand for biofuel crops, land rents increase considerably, the rise being most pronounced in the United Kingdom. Yet,

in WorldScan arable land allocation is not founded on a detailed representation of agricultural production possibilities. Hence, the increase of land rents may be understated. A sensitivity analysis with respect to the elasticity of transformation for arable land (see Appendix A.4) does, however, show no sizable impacts on land rents when land allocation is made less flexible. The impacts of increasing land rents on, first, agricultural producer prices and, next, food consumer prices are much smaller, if not negligible. At the various production stages involved, many substitution possibilities are met. Though these substitution possibilities may be overstated in a general equilibrium model as WorldScan, one would hardly expect the consequences for food prices to be significantly higher at this relatively high aggregation level.

Thus far we kept the import tariffs on biofuels at their baseline levels of 2006. Biofuel trade is hindered by tarification. This is particularly relevant for ethanol, where the EU import tariff appears to be prohibitive. For biodiesel, the import tariffs seem less restrictive. A biofuel promotion policy aiming to obtain biofuels at minimal costs would leave the decision whether to produce the fuels domestically or to import them from elsewhere to the market. We simulate the situation of improved opportunities for sourcing from abroad in additional scenarios in which the EU tariffs on biofuels are put to zero.

Table 1.8 Emission prices in euro per ton CO_2 and economic welfare with respect to the policy baseline, for a biofuel target of 10% in three excise variants, at zero biofuel import tariffs, 2020

	No excise		*Competitive excise*		*Full excise*	
	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare
EU-27	54	0.03		0.02	54	-0.00
Germany	60	0.03	58	0.02	54	-0.01
France	62	0.03	60	0.02	55	-0.00
United Kingdom	69	0.07	61	0.05	51	0.02
Italy	106	0.05	100	0.04	96	0.04
Spain	69	0.01	66	0.01	61	-0.00
Other EU-15	81	0.02	78	0.01	75	-0.00
Poland	4	-0.05	3	-0.06	2	-0.12
Bulgaria and Romania	0	-0.14	0	-0.14	0	-0.24
Other EU-12	41	-0.01	41	-0.03	38	-0.08

a) The emissions price for EU-27 is the price of the EU-ETS; at member state level the carbon tax is shown of the non-regulated sectors

Biofuel trade liberalization tends to raise the carbon taxes of the non-regulated sectors because lower transport fuel costs will induce more fuel consumption. The impacts are very small however (see Table 1.8, compared with Table 1.3). Economic welfare is in general improving, but – again – the impacts are very small.

Table 1.9	Blended fuel prices and blended fuel volumes, in % deviation from the policy baseline, for a biofuel target of 10% in three excise variants, at zero biofuel import tariffs, 2020					
	No excise		*Competitive excise*		*Full excise*	
	Fuel price	Fuel volume	Fuel price	Fuel volume	Fuel price	Fuel volume
EU-27 a)	-7.1	4.9	-4.6	3.2	0.4	-0.2
Germany	-6.1	4.1	-2.7	1.9	3.4	-2.0
France	-6.4	4.4	-3.6	2.5	2.1	-1.2
United Kingdom	-9.7	7.1	-6.9	5.1	-2.4	1.8
Italy	-8.3	6.1	-5.3	3.9	-2.5	1.9
Spain	-8.3	6.2	-6.7	5.0	-3.7	2.9
Other EU-15	-7.5	5.2	-4.4	3.0	-1.0	0.8
Poland	-3.0	1.8	-1.8	1.1	8.3	-5.1
Bulgaria and Romania	-2.0	1.0	-3.8	2.2	8.5	-5.0
Other EU-12	-4.6	2.7	-3.2	2.1	3.3	-1.8

Table 1.9 shows that the blended fuel price is generally lower in the scenarios where import tariffs are slashed, and total fuel demand is correspondingly higher. The differences with the scenarios of Table 1.4 are very small, however. The reason may be that in WorldScan trade in biofuels is specified as trade in heterogeneous goods (according to the so-called Armington assumption). This implies that relatively high price changes are necessary to attract substantial imports from outside the EU. The relative prices of biofuel trade amongst member states remain – of course – unaffected by the zero tariff policy.

Table 1.10	Percentage share of ethanol according to origin of production, for a biofuel target of 10%, with and without baseline ethanol import tariffs, 2020					
	Ethanol tariffs			*No ethanol tariffs*		
	Domestic	From EU-27	From abroad	Domestic	From EU-27	From abroad
EU-27	96	4	0	51	2	47
Germany	97	3	0	57	2	42
France	95	5	0	43	2	55
United Kingdom	96	4	0	51	2	47
Italy	97	3	0	59	2	40
Spain	96	4	0	50	2	47
Other EU-15	96	4	0	52	2	46
Poland	96	4	0	54	2	44
Bulgaria and Romania	94	5	0	43	2	54
Other EU-12	92	7	1	36	3	62

Nevertheless, the shift from domestic production to imports from abroad is substantial in the case of ethanol (see Table 1.10). The share of domestic production decreases from almost 100% to about 50%. Yet, our results show a strong tendency to continue domestic production. The share of domestic production under undistorted trade varies considerably between countries, ranging from almost 60% in Italy to not much more than a third in Other EU-12.

Table 1.11 Percentage share of biodiesel according to origin of production, for a biofuel target of 10%, with and without baseline biodiesel import tariffs, 2020

	Biodiesel tariffs			*No biodiesel tariffs*		
	Domestic	From EU-27	From abroad	Domestic	From EU-27	From abroad
EU-27	28	4	68	23	3	75
Germany	72	1	27	63	1	36
France	17	8	76	12	5	83
United Kingdom	26	5	69	18	4	78
Italy	13	3	84	9	2	89
Spain	8	0	92	5	0	95
Other EU-15	9	4	87	6	3	91
Poland	72	4	24	64	4	32
Bulgaria and Romania	91	0	9	86	0	13
Other EU-12	55	5	40	45	4	50

For biodiesel the shift to imports is less pronounced (see Table 1.11). Whether the tariffs are slashed or not, domestic production shares are rather different across member states. As the tariffs on biodiesel imports are considerably lower than those on ethanol, the difference between the two scenarios is less pronounced than in the case of ethanol.

The promotion of biofuels is not without consequences for regional production patterns (see Table 1.12). The share of agriculture in value added increases in all regions, most significantly so in the EU itself. In the scenario with no biofuel tariffs the increase in agricultural value added is somewhat lower in Europe, and higher in the non-European countries. The change is most pronounced for Brazil, that benefits most from the abolition of the high tariff on bioethanol.

Table 1.12 Percentage share of agriculture in total value added, changes in agriculture value-added share for a biofuel target of 10%, with and without baseline biofuel import tariffs, 2020

	Baseline shares	*Biofuel tariffs*	*No biofuel tariffs*
EU-27	2.6	0.7	0.5
Germany	1.5	0.8	0.6
France	2.6	0.8	0.6
United Kingdom	0.9	1.0	0.7
Italy	2.7	0.7	0.5
Spain	3.5	0.7	0.6
Other EU-15	3.3	0.5	0.4
Poland	5.0	1.0	0.7
Bulgaria and Romania	25.7	0.5	0.3
Other EU-12	3.6	1.0	0.7
USA	1.2	0.3	0.3
Brazil	6.1	0.3	0.8
China	10.8	0.1	0.1
India	19.4	0.1	0.1
Rest of East Asia	7.6	0.1	0.1

The changes in the production structure due to trade liberalization also induce some welfare effects in non-European countries. For most regions, these are negligible, but, again, Brazil forms an exception. Here the welfare gain triples from 0.01% (Table 1.2) to 0.03%.

1.4 Increasing transport fuel excises as a policy alternative from the CO_2-emission reduction point of view

One of the purposes of the biofuel target is to reduce CO_2 emissions from road transport. It is therefore interesting to compare biofuel promotion with the impacts of alternative policies that would obtain emission reductions in the same range. In this section, we explore the consequences of raising transport fuel excises to the extent that the CO_2 emission reductions originating from road traffic become similar to the case of a 10% biofuel target. Specifically, we assume that biofuel use is kept at policy baseline levels. We calculate the reduction in CO_2 emissions in the transport sector due to a 10% biofuel target (with fully excised biofuels and current import tariffs), correct it for the indirect emissions in biofuel production and impose this modified target on the transport sector. Thus, we end up with a scenario that imposes three emissions caps: one for the EU-ETS at the EU-level, a second one for the transport sector (separately in each member state) and a third one for the remainder of the non-regulated sectors (again separately in each EU country).

Table 1.13 Emissions price in euro per ton CO_2 and economic welfare with respect to the policy baseline, 10% target with full excise versus increased transport fuel taxation, 2020

	Biofuel target 10%		*Emission reduction equivalent transport fuel tax*		
	Emissions price a)	Economic welfare.	Emissions price a)	Carbon tax in transport	Economic welfare
EU-27 a)	54	0.00	54		-0.06
Germany	54	-0.01	53	114	-0.08
France	55	0.00	54	110	-0.05
United Kingdom	49	0.02	48	139	-0.09
Italy	95	0.03	94	154	-0.01
Spain	61	-0.01	59	105	-0.03
Other EU-15	76	0.00	76	134	-0.04
Poland	2	-0.13	2	52	-0.15
Bulgaria and Romania	0	-0.26	0	46	-0.25
Other EU-12	38	-0.09	37	85	-0.11

a) The emissions price for EU-27 is the price of the EU-ETS; at member state level the carbon tax is shown of the non-regulated sectors

Raising fuel excises instead of imposing a 10% biofuel target to reduce transport CO_2 emissions implies a rise of carbon taxes for the non-regulated sectors, substantially larger increases in the taxation of road fuel use and a small decrease of the EU-ETS emissions price (see Table 1.13). The impacts of a further rise of transport fuel excises on economic welfare are negative in all member states (except for Bulgaria and Romania). Apparently, the increase of distortionary taxation of the transport sector is decreasing economic welfare.

1.5 Conclusions

Our assessment of fostering biofuel use is against the background of a policy baseline which has the EU-ETS in place with a 2020 reduction target that is 20% below 1990 emissions. In all other countries of Annex I emission caps are present too, though generally the targets are less ambitious. Our analysis shows that the emissions price of the EU-ETS is hardly affected when various targets for the share of biofuels in transport fuels are imposed. Though the emissions price will slightly increase with rising biofuel targets due to rising fossil fuel demand in the regulated sectors the increase of the emissions price remains almost negligible. Hence, promoting biofuel use in road transport is a form of enhancing the use of renewables that will not affect the EU-ETS price and will not prevent (or postpone) the commercial advent of cleaner technologies in the regulated sectors.

Increasing biofuel shares in transport fuels will have a mitigating effect on the policy efforts needed to curb emissions in the non-regulated sectors. In our assessments this is reflected by a drop in the carbon taxes in the non-regulated sectors in all member states where this tax is positive. Hence, the negative impacts of these distortionary taxes on economic welfare will decline. The introduction of biofuels will, in general and depending on the biofuel excise regime and the lowering of the carbon tax, raise the price of transport fuels. This affects economic welfare negatively. On balance the net effect on economic welfare is very small compared to the policy baseline, and either slightly positive or slightly negative. When carbon taxes are small or even zero the benefits of reducing them fall short of the burden of raising biofuel usage. Hence, overall economic welfare is declining in the new member states. When the targets for biofuel use are raised above 10% the beneficial impacts on welfare disappear: the additional benefits of reducing distortionary carbon taxes tend to outweigh the additional costs of raising biofuel usage.

In our study the impacts of biofuel promotion on food prices turn out to be negligible. Land rents may rise considerably, but agricultural producer prices are affected very modestly and food consumer prices almost negligibly. In our 10% biofuel target scenario's biofuel use is raised from 17 Mtoe in 2004 to 76 Mtoe in 2020 globally, whereas the increase in EU-27 is from 1 Mtoe in 2004 to 44 Mtoe in 2020. According to IEA(2006) 13.8 mln ha was devoted to biofuel crop production in 2004. This is about 1% of the global arable area. Without any yield improvements 71.6 mln ha would be needed in 2020 around the world in our 10% scenario's. With an annual yield increase of 1.5% of biofuel crops still 48.6 mln ha would be needed. Though this area is enormous, it would amount to only 3.5% of current global arable acreage.

Hence, indeed, large impacts on food prices are hardly to be expected when increased biofuel use would be the only reason for extra claims on agricultural land in the future.

When existing biofuel tariffs are slashed, biofuels become cheaper (enhancing welfare) but carbon taxes in the non-regulated sectors remain at a higher level (reducing welfare). On balance economic welfare is hardly improving when biofuels are imported rather than produced domestically. Due to the relatively high tariffs on ethanol the increase of ethanol imports is relatively large when biofuel trade is fully liberalised.

Biofuel targets aiming to reduce emissions are to be preferred to a further increase of excise taxes on transport fuels targeted at obtaining similar emissions reductions. The latter policy further raises the tax distortions of transport services that are already very distortionary due to high existing transport fuel excises.

Appendix A: Characteristics of the WorldScan model and of the baseline scenario

A.1 WorldScan

The quantitative, economic characteristics of the various scenarios are based on simulation outcomes from WorldScan (Lejour *et al.*, 2006), which is a general equilibrium model for the world economy. This model was developed in the 1990s for scenario construction and is often used both for scenario studies and policy analyses, also in the field of energy markets and global warming (see, for example, Bollen *et al.*, 2004, Bollen *et al.*, 2005, and Boeters *et al*., 2007). The model is based on neo-classical theory and shows the outcome of microeconomic behaviour of the agents, subject to equilibrium conditions and additional restrictions. In establishing an equilibrium for the global economy, the welfare of the various consumers is maximised and all balance equations and eventual policy restrictions (such as CO_2 emission ceilings) are met.
General equilibrium models generally take account of the interdependencies between individual markets for various goods and production factors. It is usually assumed that there are no frictions in these markets, so that each of the production factors is fully utilised. In addition, the use of production factors can be immediately reallocated across the various sectors. This means that the model outcomes for the policy scenarios can be seen as 'long-term' reactions to the policy used: the costs of restructuring and modifications in the medium term are not taken into account. Supply, demand and trade are modelled in WorldScan as follows.

Supply
Potential production is determined for each region by the availability of primary production factors. The version of WorldScan used in this chapter differentiates between labour, capital, land, natural resources and technology. The supply of labour is exogenous, and is based on projections of participation levels for various demographic cohorts. International capital mobility is incomplete. The capital goods available depend on both the investment opportunities and national savings. The availability of land, natural resources and the speed of technical progress are exogenous. The simulations take account of the fact that developing countries can learn from the rich nations. Across the globe there is some convergence of total productivity. However, at the sectoral level the rate of productivity expansion varies considerably – in accordance with historic patterns.

Demand
The demand for goods and services shifts over the course of time. The demand for services becomes relatively more important than that for manufactured or agricultural products. This

shift in demand is the result of varying income elasticities and varying developments of relative prices – which partially depend on sectoral growth differences. National savings rates depend on the demographic structure – according to empirical estimates.

International trade

Domestic market tensions between supply and demand can be partially relieved by international trade. However, trade opportunities are limited. Goods and services from different origins are not fully substitutable (the Armington assumption). International trade is made more difficult by transport costs, trade tariffs and non-tariff barriers.

Table A.14 Overview of regions, sectors and production inputs in WorldScan

Regions	*Sectors*	*Inputs*
Germany	Cereals	*Factors*
France	Oilseeds	Low-skilled labour
United Kingdom	Sugar crops	High-skilled labour
Italy	Other agriculture	Capital
Spain	Minerals	Land
Netherlands	Oil	Natural resources
Other EU-15	Coal	
Poland	Petroleum, coal products	*Energy carriers:*
Bulgaria and Romania	Natural gas	Coal
Other new member states	Electricity	Petroleum, coal products
United States	Energy intensive and chemical products	Natural gas
Other OECD	Vegetable oils	Biodiesel
Former Soviet Union	Other food products	Ethanol
Brazil	Non-food consumer goods	Other renewables
China	Capital goods and durables	
India	Road and rail transport	*Other intermediates*
Other South East Asia	Other transport	Cereals
Rest of World	Other services	Oilseeds
	Biodiesel	Sugar crops
	Ethanol	Other agriculture
		Minerals
		Oil
		Electricity
		Energy intensive and chemical products
		Vegetable oils
		Other food products
		Non-food consumer goods
		Capital goods and durables
		Road and rail transport
		Other transport
		Other services

WorldScan takes its data for the base year (2001) from the GTAP-6 database (Dimanaran and McDougall, 2006), which contains integrated data of bilateral trade flows and input-output data for 57 sectors and 87 countries (or groups of countries). The WorldScan version used in this chapter distinguishes twenty markets for goods and services and factor markets for labour, capital and agricultural land in each of the 20 countries and regions shown in Table A.1. Six different energy carriers are distinguished: coal, oil refinery products, natural gas, biodiesel, ethanol, and other renewable energy. Only the first three of these contribute to the CO_2 emissions generated by the model.

A.2 Background scenario

The policy baseline (see Section 1.2) is based on a so-called middle-course scenario without any climate policy, which has been developed by MNP (van Vuuren *et al.*, 2006). This scenario is based on estimates of trends, and is comparable to the reference scenario used by the International Energy Agency (IEA) and the so-called B2 scenario used by the IPCC. According to this background scenario, the global population will continue to expand to 9-10 bln in the middle of this century, and decrease slightly thereafter. Combined with a worldwide economic growth of around 2% per year, the global demand for energy will increase significantly: doubling current consumption in 2050, and trebling it in 2100. This expansion will primarily take place in the nations currently known as developing countries, which will thus partially reduce the gap in energy consumption per capita with the industrialized countries.

Table A.15 Data for base year, 2001

	Population	GDP	Energy consumption	Emissions	Energy intensity	CO2 intensity
	(million)	(billion $)	(Mtoe)	(GtCO2)	(USA=100)	(USA=100)
Annex I	1464	25807	4910	14.4	117	98
EU-27	483	8345	1385	4.1	102	99
USA	288	10082	1634	4.9	100	100
Rest of OECD	410	6966	1200	3.5	106	96
Former Soviet Union	282	414	691	1.9	1029	91
Non-Annex I	4828	5471	2551	8.0	288	104
Brazil	174	502	124	0.3	152	91
China	1292	1322	940	3.3	439	117
India	1033	477	309	1.0	399	110
World	6292	31279	7461	22.4	147	100

a) Total of coal, refinery products, natural gas, biodiesel, ethanol and renewable energy

Source: WorldScan

Without climate policy it would be primarily the fossil fuels that meet the energy demand and CO_2 emissions would increase accordingly. In the background scenario the total greenhouse gas emissions increase from around 30 bln tons (=Gt) CO_2-eq. in the year 2000 to some 50 bln tons in 2050, and 70 bln tons in 2100. The projections from other (alternative) baseline scenarios are sometimes higher and sometimes lower (between 40 and 90 bln tons). Fossil CO_2 emissions increase in the background scenario from 22 $GtCO_2$ in 2001, to around 32 $GtCO_2$ in 2020 (see Tables A.2 and A.3). Although historically the total greenhouse gas emissions were largely caused by the rich nations (around 80%), just as with energy consumption growth, the growth in emissions is now greatest in developing countries: their share in global emissions increases from around 50% (current levels) to 65% in 2100.

Table A.16 Characteristics of baseline scenario, average annual growth, 2001-2020

	Population	GDP	Energy consumption	Emissions	Energy intensity	CO2 intensity
	(%)	(%)	(%)	(%)	(%)	(%)
Annex I	0.4	2.7	1.3	0.9	-1.4	-0.4
EU-27	0.0	2.3	1.4	0.8	-0.9	-0.6
USA	0.9	3.0	0.8	0.7	-2.1	-0.1
Rest of OECD	0.8	2.7	1.6	1.3	-1.1	-0.3
Former Soviet Union	-0.2	5.5	1.8	1.2	-3.5	-0.6
Non-Annex I	1.3	5.4	3.5	3.2	-1.7	-0.3
Brazil	1.2	3.3	2.4	2.3	-0.9	-0.1
China	0.6	7.4	2.9	2.5	-4.2	-0.4
India	1.5	5.8	4.3	3.9	-1.4	-0.4
World	1.1	3.3	2.2	1.9	-1.1	-0.3

Source: WorldScan

This trend is also visible for fossil-based CO_2 emissions over the period 2001-2020. Although the contribution by non-Annex I countries to worldwide emissions amounted to around 36% in 2001 (see Table A.2), this appears to increase to over 46% in 2020 (according to Table A.3). Emissions per capita in the current OECD countries remain higher than those of developing countries.

A.3 Details of biofuel modelling

At the basis of the biofuel modelling in WorldScan are the cost information about biofuel production technologies from well-to-wheel analyses as compiled in Table A.6. We selected from the cost assessments of IES the ones that correspond to an oil price of 25 euro per barrel as this price was closest to the oil price in our base year data for 2001.

Table A.6 Biofuel production costs in euro per toe produced

Biodiesel from crude vegetable oils (EU-27)	672
Inputs	
Crude vegetable oil	596
Energy	52
Alcohol	27
Capital	46
Labour	11
Byproduct	
Glycerin	-61

	Ethanol from sugar cane (Brazil)	*Ethanol from sugar beet (EU-27)*
Ethanol	368	628
Inputs		
Sugar crops	217	515
Chemicals	20	22
Energy		38
Capital	17	113
Labour	114	27
Byproducts		
Animal feed		-88

	Ethanol from maize (USA)	*Ethanol from wheat (EU-27)*
Ethanol	478	544
Inputs		
Cereals	348	502
Chemicals	44	-31
Energy	75	22
Capital	63	147
Labour	60	37
Byproducts		
Animal feed	-112	-134

Sources: IES, 2006; OECD, 2006; Smeets *et al.,* 2005
Compilation: CPB

Table A.6 gives information only for specific regions (EU, USA, Brazil). We assume that, given the respective agricultural inputs are available, all regions can dispose of these technologies. The availability assumptions about agricultural inputs are summarised in Table A.7.

Table A.7 **Availability of agricultural inputs to biofuel production**

	Biodiesel from veg. oil	Bioethanol from sugar beet	Bioethanol from wheat	Bioethanol from corn	Bioethanol from sugar cane
Germany	home	(home)	home	yes	no
France	home	(home)	home	yes	no
United Kingdom	home	(home)	home	yes	no
Italy	home	(home)	home	yes	no
Spain	home	(home)	home	yes	no
Netherlands	home	(home)	home	yes	no
Other EU 15	home	(home)	home	yes	no
Poland	home	(home)	home	yes	no
Other EU 25	home	(home)	home	yes	no
Bulgaria and Romania	home	(home)	home	yes	no
United States	yes	no	yes	home	no
Other OECD	yes	no	yes (Australia)	yes (Australia)	no
Brazil	yes	no	no	no	home
China	yes	no	no	no	yes
India	yes	no	no	no	yes
Other South East Asia	yes	no	no	no	yes
Former Soviet Union	no	no	no	no	no
Rest of the World	no	no	no	no	no

"home": original data available for active technology

"(home)": original data available, but inactive because too expensive

"yes": technology available, price of main input relative to home region necessary for calibration

"no": technology not available

In those regions where a technology is assumed to be in use, but where no original data on cost structures are available, we adjusted the cost of the main agricultural input according to Table A.8. The cost of the other inputs is left unchanged.

Table A.8	**Prices of main agricultural inputs (2001, in US$ per kg)**				
	Biodiesel from veg. oil	Bioethanol from sugar beet	Bioethanol from wheat	Bioethanol from corn	Bioethanol from sugar cane
Germany	0.40	0.040	0.13	--	--
France	0.40	0.040	0.13	--	--
United Kingdom	0.40	0.040	0.13	--	--
Italy	0.40	0.040	0.13	--	--
Spain	0.40	0.040	0.13	--	--
Netherlands	0.40	0.040	0.13	--	--
Other EU 15	0.40	0.040	0.13	--	--
Poland	0.40	0.040	0.13	--	--
Other EU 25	0.40	0.040	0.13	--	--
Bulgaria and Romania	0.40	0.040	0.13	--	--
United States	0.38	--	0.12	0.10	--
Other OECD	0.42	--	0.16	0.11	--
Brazil	--	--	--	--	0.011
China	0.31	--	--	--	0.023
India	0.23	--	--	--	0.018
Other South East Asia	0.26	--	--	--	0.032
Former Soviet Union	--	--	--	--	--
Rest of the World	--	--	--	--	--

Sources: Trade Analysis System for vegetable oil, FAOSTAT for other products

Vegetable oil prices are export prices for rapeseed oil (EU), palm oil (China, India, Rest of South East Asia), soya bean oil (USA), several oils (Other OECD).

For bioethanol, we choose for each country/region the cheapest available technology. This technology is fixed for the whole span of the scenario. The possibility of an endogenous switch of technologies due to adjustments of the relative prices is not considered. With these specifications, we arrive at the production technologies and total production costs given in Table A.9.

Table A.9	**Biofuel production costs by region (before and after adjustment) in euro/toe**				
	Biodiesel		Bioethanol		
	before adjustment	after adjustment	before adjustment	after adjustment	production technology
Germany	672	470	544	343	wheat
France	672	449	544	321	wheat
United Kingdom	672	490	544	362	wheat
Italy	672	461	544	333	wheat
Spain	672	457	544	329	wheat
Netherlands	672	531	544	403	wheat
Other EU 15	672	459	544	331	wheat
Poland	672	457	544	330	wheat
Other EU 25	672	468	544	340	wheat
Bulgaria and Romania	672	480	544	352	wheat
United States	642	426	478	262	maize
Other OECD	701	529	513	341	maize
Brazil	538	336	369	167	sugar cane
China	419	239	544	365	sugar cane
India	463	251	507	295	sugar cane
Other South East Asia	448	257	783	591	sugar cane
Former Soviet Union	672	470	544	343	wheat
Rest of the World	672	449	544	321	wheat

The basic cost input data (columns “before adjustment” in Table A.9) had to be adjusted because the implicit GTAP average energy prices for petroleum products considerably deviate from the (before-tax) price of transport fuels in the IEA data (van Leeuwen, 2006). In this situation, there are in principle three options for introducing biofuel prices into the model: keeping the price relation constant, keeping the absolute deviation constant, keeping the absolute biofuel price constant. We chose the second option because we considered the absolute price difference as most important for welfare analysis. As a consequence, the relative price difference between biofuels and conventional fuels is too high, and the absolute biofuel prices are too low in the model.

Biofuels and conventional fuels are inputs to the production sector “road and rail transport” and the consumption good “consumer transportation” (the share of consumer transportation in the total use of petroleum products by private households is listed in Table A.10). All transport fuels are modelled as perfect substitutes. The split between biofuels and conventional fuels is exogenously determined by the biofuel targets, the split between biodiesel and bioethanol follows the actual split between diesel and gasoline in 2001 (see Table A.10). These shares do not respond endogenously to the relative price of the fuel varieties. The user price of the fuel aggregate is then determined as the weighted average of the prices of the individual fuel varieties.

Table A.10	Fuel related quotas in WorldScan	
	Share of gasoline in total fuel use for transport	Share of non-transport in total use of petroleum products by households
Germany	0.53	0.48
France	0.33	0.42
United Kingdom	0.57	0.17
Italy	0.48	0.33
Spain	0.33	0.27
Netherlands	0.44	0.02
Other EU 15	0.46	0.41
Poland	0.59	0.21
Other EU 25	0.47	0.06
Bulgaria and Romania	0.46	0.17
United States	0.78	0.12
Other OECD	0.66	0.16
Brazil	0.36	0.32
China	0.70	0.37
India	0.27	0.64
Other South East Asia	0.46	0.34
Former Soviet Union	0.75	0.22
Rest of the World	0.56	0.40

Source: IEA

For the calculations in the Scenario of Section 1.4, we need information about the indirect emissions from biofuel production. This information is implicit in the model, however, it is difficult to extract because the indirect effects extend over all sectors and countries, and because quantity and price induced effects are almost impossible to disentangle. Therefore we used exogenous information about the indirect emissions of biofuels (Table A.11).

Table A.11	CO_2 emissions of different fuel varieties	
	gCO_2/km	in % of fossil fuel average
bioethanol from wheat	100	64.52
bioethanol from sugar beet	75	48.39
bioethanol from sugar cane	25	16.13
bioethanol from corn	100	64.52
gasoline	160	103.23
biodiesel	65	41.94
diesel	150	96.77
fossil fuels	155	

Source IES, 2006, WTW 2b

Note: corn taken from wheat

The policy baseline contains actual biofuel shares of 2004 for all regions. In Europe, these Biofuel quotas are held constant after 2004, as the biofuel targets are the most important ingredient of the policy variants to be studied. In the non-European regions, we add declared biofuel targets to the baseline after 2004, where available. These baseline use of biofuels is summarised in Table A.17.

Table A.17 Biofuel shares (%) in total fuel use in the baseline scenario

	Biodiesel		Bioethanol	
	2004	2020	2004	2020
Germany	1.22	1.22	0	0
France	0.74	0.74	0.16	0.16
United Kingdom	0	0	0	0
Italy	0.62	0.62	0	0
Spain	0	0	0.42	0.42
Netherlands	0	0	0	0
Other EU 15	0.16	0.16	0.09	0.09
Poland	0	0	0.59	0.59
Other EU 25	0.59	0.59	0.05	0.05
Bulgaria and Romania	0	0	0	0
United States	0	0	1.16	3.48
Other OECD	0	0	0.07	0.07
Brazil	0	3.20	23.22	23.22
China	0	0	0.35	0.35
India	0	14.64	0.32	1.34
Other South East Asia	0	2.68	0	2.32
Former Soviet Union	0	0	0	0
Rest of the World	0	0	0	0

Source: EurObserv'ER, June 2005; Unctad, 2006

The import shares for biofuels are a highly speculative issue. This is because actual flows are low and erratic, so they cannot be used to extrapolate the structure of international trade in biofuels in a situation where these fuels make up a considerable share of total fuel use and are produced in many countries. We assume that in a reference situation where prices are the same for all import varieties, the biofuel import shares would mirror trade in vegetable oils (for biodiesel) and the production of the relevant inputs of bioethanol (plus a home-market bias of 80%). The resulting reference shares are listed in Table A.13.

Table A.13 Reference import shares for biofuels

	Biodiesel			Bioethanol		
	domestic	EU	outside EU	domestic	EU	outside EU
Germany	97.19	2.14	0.67	80.00	3.66	16.34
France	82.25	15.81	1.94	80.00	3.26	16.74
United Kingdom	71.97	24.22	3.81	80.00	3.85	16.15
Italy	82.03	14.03	3.94	80.00	4.05	15.95
Spain	94.86	1.91	3.23	80.00	4.07	15.93
Netherlands	36.45	19.99	43.56	80.00	4.21	15.79
Other EU 15	82.55	14.68	2.77	80.00	3.88	16.12
Poland	96.08	3.43	0.50	80.00	4.00	16.00
Other EU 25	90.06	8.54	1.40	80.00	3.92	16.08
Bulgaria and Romania	97.82	1.57	0.61	80.00	4.00	16.00

A.4 Sensitivity analysis with respect to land allocation

The modelling of agricultural land supply for biofuel production is a key element of the comprehensive assessment of biofuel promotion. In partial equilibrium studies (OECD, 2006; Economic Commission, 2006) it has repeatedly been stressed that even moderate increases in biofuel use will have significant effects on land and food prices.

A global general equilibrium model like WorldScan cannot be expected to give a picture of land allocation that is as accurate as in specialised partial-equilibrium agricultural studies. Similar to the representation of production processes with aggregate, smooth constant-elasticity-of-substitution (CES) production functions, we must take resort to a relative coarse way of land supply modelling. The usual way of representing the intricacies of different sorts of land with varying yield coefficients per crop within a CGE framework is through constant-elasticity-of-transformation (CET) functions (see OECD, 2003, Golub et al., 2007). The CET setup assumes that transformation between different uses is possible, but not frictionless. The more land is claimed by a specific use, the higher becomes the marginal rate of transformation, i.e. the more units of land in other uses have to be sacrificed to generate one unit of land for the use in question.

It is obvious that such a modelling approach produces difficulties in interpretation. After all, one hectare of land remains one hectare, irrespectively of how exactly it is used. The outcome of the CET modelling approach is thus usually interpreted in terms of “efficient land units”. Such efficient land units need not sum up to a constant, and inconsistency can be avoided. However, there remains an interpretation problem. There is no straightforward way to recover the land use in hectares from the efficient units without an explicit assumption about the distribution of the yield coefficients over the area available.

Even if we agree that CET is a reasonable representation of land supply in efficient units within a general equilibrium framework and restrain from being explicit about land use in hectares, we are left with the choice of the elasticity parameter. Unfortunately, empirical estimates that lend themselves to an interpretation of a CET elasticity are rare, and actual CGE models apply widely varying elasticities. Golub *et al.* (2007) start from an empirically based elasticity of transformation (EOT) between agricultural and forestry land of 1.5 and set the elasticity between crops and livestock at 3.0. The EOT between different sort of crops (not specified in the Golub *et al.* model) should then even be higher. In contrast, the OECD “PEM” model (OECD, 2003) uses significantly lower elasticities: 0.1 between COP (cereals, oil seeds and protein) crops and other farm uses, 0.4 between the three COP crops. (In a “high” variant for sensitivity analysis, the respective values are 0.3 and 0.8, still far below what seems reasonable according to Golub *et al.*)

We explore the consequences of this wide range of elasticities in a sensitivity analysis. The core version of WorldScan (used for the simulations in the main text) uses an EOT of 2.0, which can be considered middle ground between the high Golub *et al.* and the low OECD numbers. We contrast this with simulation runs where we put the EOT at 0.5 and 15 (close to perfect transformability) respectively (see Table A.18).

Table A.18 Arable land rents and economic welfare, in % deviation from the policy baseline, 2020, Sensitivity analysis with respect to the elasticity of transformation for arable land

	EOT = 0.5		EOT = 2.0		EOT = 15	
	Arable land rents	Economic welfare	Arable land rents	Economic welfare	Arable land rents	Economic welfare
No excise, target 10%						
No trade liberalization	2.2	0.03	2.2	0.03	2.1	0.03
Full trade liberalization	1.4	0.03	1.5	0.03	1.5	0.03
Competitive excise, target 10%						
No trade liberalization	2.2	0.02	2.3	0.02	2.1	0.02
Full trade liberalization	1.5	0.02	1.6	0.02	1.5	0.02
Full excise, target 10%						
No trade liberalization	2.2	-0.01	2.2	0.00	2.1	0.00
Full trade liberalization	1.5	0.00	1.6	0.00	1.6	0.00
Full excise, target 15%						
No trade liberalization	3.4	-0.02	3.4	-0.01	3.2	-0.01
Full trade liberalization	2.3	-0.01	2.4	-0.01	2.4	0.00
Full excise, target 20%						
No trade liberalization	4.6	-0.03	4.6	-0.03	4.3	-0.02
Full trade liberalization	3.1	-0.02	3.3	-0.02	3.2	-0.01
Raising fossil fuel excises						
No trade liberalization	0.3	-0.06	0.3	-0.06	0.3	-0.06
Full trade liberalization	0.3	-0.06	0.3	-0.06	0.2	-0.06

Source: WorldScan

Table A.18 shows that, as we would expect, land prices are in general lower and welfare is higher if land can be transformed more easily from one use to another (from left to right in the table). However, in quantitative terms, the differences between the variants of the model are hardly noticeable. They become somewhat larger if we move on to higher biofuel quotas (as we explored in some additional scenario runs), but even then the conclusions do not change fundamentally. We conclude that within the CET framework of land use modelling, our simulation results are fairly robust. We cannot be certain, though, that this would remain the case if we substituted the CET function by a representation of land-use patterns that would reflect more agricultural detail.

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