Chapter 2.

Quantitative Analysis of Biofuel Policies and Developments

Model-based analysis of policy effects on agricultural markets, land use and related environmental implications

The tool to analyse market and land use changes

To analyse the implications of support policies for biofuel supply and demand, as well as for agricultural commodity markets and land use, the OECD medium-term simulation model for world agricultural markets Aglink has been employed, complemented by the FAO-developed Cosimo model to cover a large set of developing countries. Aglink-Cosimo is a partial equilibrium model of domestic and international markets for major temperate-zone agricultural commodities, with detailed mapping of policies affecting these markets. In preparation of this analysis, the combined model has been extended to include the markets for sugar and other sweeteners. Furthermore, a specific module representing biofuel markets in major producing and consuming regions has been developed. At the same time, the FAO has developed biofuel modules for 13 developing countries.[1]

Generally speaking the biofuel modules include a rather complete representation of the whole biofuel chains. This includes the investment decisions of increased biofuel production capacities as well as the (short-term) decision of using the existing capacities; related feedstock use is directly linked to the production of biofuels from individual feedstocks, with limited substitution across feedstock types; distillers grains as a valuable by-product from grain-based ethanol production is specifically represented, together with its feed use in the livestock industries (differentiated between ruminant and non-ruminant production according to differences in using distillers grains across animal types). Similarly, the model reflects the increased availability of oilseed meals as oilseed crush for biodiesel expands.

The model also represents the production of second-generation biofuels – both the ethanol chain (cellulosic ethanol) and the biodiesel chain (BTL). Given the even more limited data availability representation of these chains is more reduced than that of first-generation fuels, but distinguishes between fuels from agricultural residues (straw, stover) and dedicated biomass (such as switchgrass or fast-growing trees). Additional incentives for cereal production from the use of residues and area requirements for dedicated biomass are derived from biofuel production quantities via coefficients that change over times, reflecting yield improvements and technical progress in the biomass conversion.

The ethanol demand system is set up to reflect both the high-value replacement of other additives by low-level ethanol blends, technical constraints in blending ethanol to gasoline at higher rates for unmodified vehicles, as well as the options of high-level blends for flex-fuel vehicles. The number of flex-fuel vehicles in the different countries covered is treated as exogenous, growing over time in line with observed trends. Details on the way biofuel production, use and trade as well as their links to agricultural markets have been modelled can be found in the Annex.

The analysis shown below is based on a preliminary baseline for the OECD/FAO Agricultural Outlook 2008-2017). In particular, this baseline projects a substantial further growth in the production and use of both ethanol and biodiesel, assuming a continuation of existing policies supporting biofuel production and use at different stages of the marketing chain. The US Energy Independence and Security Act (EISA) enacted in December 2007, the new EU Directive on Renewable Energy (DRE) currently in the legislative process, and the blending mandates for biodiesel in Brazil valid since early 2008 are not accounted for in the baseline. This baseline assumes crude oil prices to remain within the range of USD 90-104 per barrel for the decade to come. International prices for agricultural commodities are projected to remain at levels substantially higher than those observed in the past decade, reflecting a tightened balance for most products.

The baseline, as well as the model used for its generation, does not assume second-generation biofuels to become commercially relevant within the decade to come. For the analysis of potential implications of a faster development of these fuels, including cellulose based ethanol and biomass-to-liquid (BTL) fuels based on either crop residues (straw, stover) or dedicated biomass production (such as switch-grass and willow- or poplar trees), however, an add-on module for these fuels has been developed for four model regions, including the US, Canada, the EU and Brazil.[2]

The Aglink-Cosimo based analysis includes a sequence of scenarios aiming to shed light on a number of major questions related to biofuel markets and support policies. First, the effects of existing biofuel support policies on biofuel developments and agricultural markets are analysed by simulating an elimination of biofuel support policies. Second, two new programs affecting the supply and demand of biofuels are analysed, including the US EISA, and the new EU DRE. While both of these programs explicitly include the developments of second-generation biofuels, a third section looks at these developments more specifically and analyses their potential impacts by assuming future biofuel growth to come from these rather than first-generation fuels. Finally, in analysing alternative assumptions on crude oil prices, the relevance of biofuels in the link between agricultural and energy markets is discussed.

The tool to analyse environmental impacts

The Stylised Agri-environmental Policy Impact Model (SAPIM) has been developed to analyse the linkages between agricultural policies and their environmental effects. The SAPIM framework adopts an integrated approach: an economic model of decision making on representative farms is combined with a stylised site-specific biophysical model predicting the impacts of different policy instruments on production practices and then on the multiple environmental effects. Due to the site-specific nature of many agri-environmental issues analysis at a disaggregated level is necessary in order to capture the underlying heterogeneity of agricultural productivity and environmental sensitivity across different parcels of land. To this end the SAPIM is specifically developed to capture the environmental effects of different agricultural policies through their impacts at the intensive margin (input use intensity), the extensive margin (land use allocation) and the entry-exit margin under those heterogeneous conditions.

In the SAPIM framework the environmental process functions (*e.g.* nutrient and herbicide runoff or greenhouse gas emissions) are integrated into economic optimization models, which maximize an objective function (*e.g.* to maximize social benefits or private profits) subject to resource and technical endowments, and policy incentives. Incorporation of social valuation estimates for environmental effects – when reliable valuation estimates are available - provides a benchmark for policy analysis. SAPIM allows the analysis of many different types of policy instruments including area payments, input use taxes and regulations, payments for environmentally friendly production practices and technologies, green auctions and tradable permits. The results of the SAPIM modelling exercises thus have the potential to show the various environmental outcomes, farm income impacts and government budgetary expenditures as a result of different policy measures being applied in heterogeneous farm conditions, which can then be summarised in terms of outcomes of private and social benefits.

The impact of biofuel support policies

Potential implications of a removal of biofuel support policies

Several forms of public support for producing and using biofuels are represented in the model. In particular, these include budgetary support policies (tax concessions, tax credits and direct support for the production of biofuels), biofuel mandates (minimum rates of biofuel use in the overall consumption of gasoline and diesel type fuels), and import tariffs. To analyse the relevance of these different policies, the scenario was split in three steps, eliminating subsequently the three groups of biofuel support policies (budgetary support policies first, then biofuel mandates, and finally import tariffs).[3] In the results shown here, these policy changes are assumed to be implemented in all countries covered simultaneously. While it is of course possible, and certainly interesting, to also look at the impacts of isolated policy changes in only individual countries, such results are not presented here in the interest of brevity. It should be noted that the representation of ethanol markets in China (supply and demand) and Japan (net trade only) is not policy specific, while ethanol and biodiesel production and use in Australia *de facto* is exogenous to the model. Moreover, lacking data availability resulted in some policy measures not to be taken into account in the baseline (and hence in this analysis), most notably tax incentives for ethanol use in Brazil and state-level blending mandates for biofuels in the US.

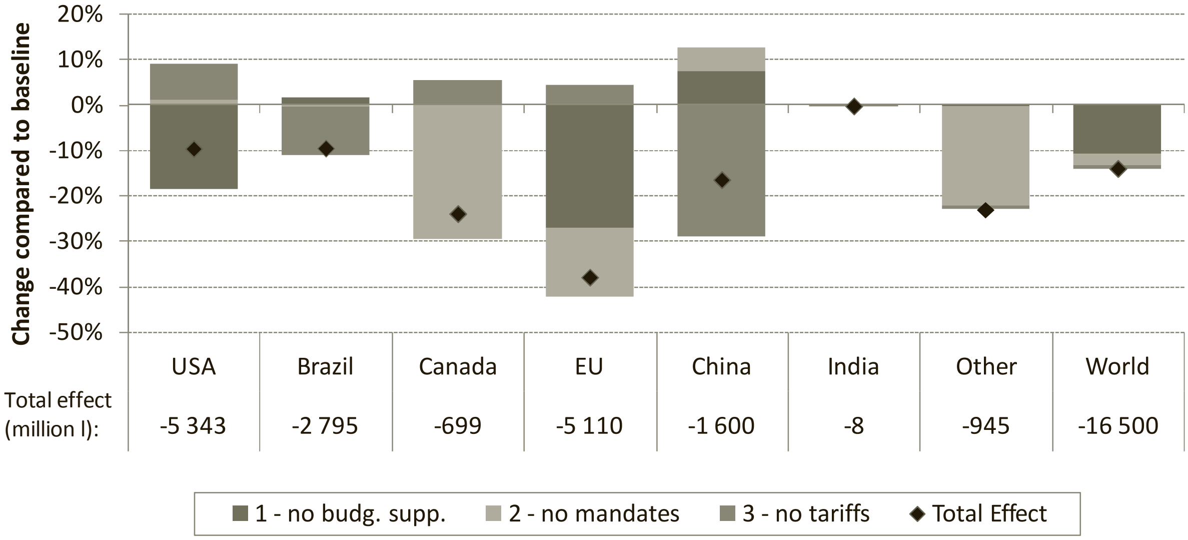
A removal of the existing biofuel support policies taken into account in this analysis would significantly reduce medium-term biofuel use in major biofuel consuming regions. Given the structure of biofuel support across countries, the relative impact of removing budget support (in particular tax concessions) and mandates for biofuel use differ widely, as visible in Figure 2.1 and Figure 2.2 below.[4,5] In this analysis, however, the order in which policies are removed has implications as well: if policies were eliminated in the inverse order, *i.e.* tariffs, mandates, budget policies, these latter become more relevant particularly in Canadian and EU ethanol use, as well as in EU biodiesel use. This suggests that in these markets tax concessions and mandates strongly interact and complement each other. Globally, the results show that the use of biodiesel is much more dependent on public support than the use of ethanol: World biodiesel use would be cut by half relative to baseline projections – compared to a 14% decline in ethanol use. Without support, biodiesel demand in the EU and the US would be reduced by 87% and 55%, respectively. Biodiesel use in Brazil and Canada benefits from lower biodiesel prices following liberalisation in other countries – indeed, a removal of Canadian support policies only would lead to a reduction in biodiesel use by more than 80%. The strong response of biodiesel use in major biodiesel using countries reflects the higher production costs of biodiesel relative to ethanol (Figure 1.7).

Production incentives are not only affected through the market effects of reduced biofuel use as a result of elimination of budgetary support and mandates, but also directly by the elimination of tariffs in countries importing biofuels. Given that many countries charge significantly higher tariffs on ethanol imports (which are considered an agricultural product under WTO nomenclature) compared to biodiesel (considered a chemical product), tariff elimination mostly affects ethanol production (Figure 2.3 and Figure 2.4). While domestic market prices decline with tariffs eliminated, world prices benefit significantly, with the net effect different across countries.[6]

The simultaneous removal of support policies in all countries[7] results in substantial reductions in biofuel supply. Several changes are worth a more detailed discussion. The simulations suggest that ethanol production is cut particularly in Canada and the EU, while biodiesel production would be lower particularly in the EU and the US. Much of the differences across countries and biofuels has to do with differences in the economic viability and hence the relative dependences on public support in the different sectors. As shown in Figure 1.7, the gap between net production costs of biofuels and their economic value in replacing gasoline and diesel is particularly wide for biodiesel. Among the different ethanol chains, wheat (the main feedstock used in the EU) represents a feedstock that is substantially less economic than maize (principal feedstock used in the US). In Canada, both of these feedstocks are used in important quantities. Differences are, however, caused also by other factors, including the structure of biofuel support and the maturity of the biofuel industries.

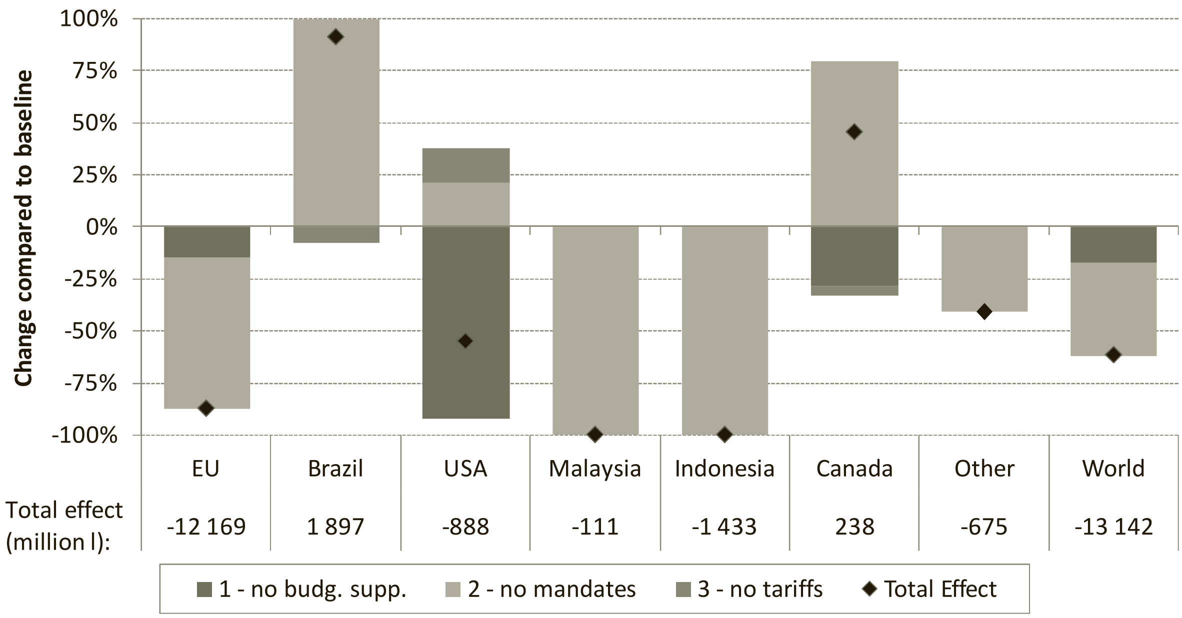
In the US, the budgetary support is given through tax credits for blenders - so producers are affected by an elimination only indirectly through its effects on ethanol prices. In Canada, in contrast, where producer prices would fall in line with the US prices, ethanol producers would additionally face the elimination of their direct production subsidy – on top of the cost disadvantage due to the wheat share in their feedstock mix – causing them to respond more strongly than the US producers. Finally the policy change would affect the existing capacities (which are already relatively large in the US) much less strongly than those to be built over the projection period with policies in place. While the baseline projections relative to which policy impacts are presented here expect ethanol production to increase by some 75% over the ten year period in the US, this growth is projected at some 170% in Canada and more than 300% in the EU.[8] This additionally explains the more significant effect the elimination of support has on ethanol production in these two countries when compared to the US. It is worth noting, however, that in absolute terms the medium-term reduction in ethanol production in the US following a removal of support to biofuels larger than in the EU and particularly in Canada.

Figure 2.1. Impact of biofuel support removal on ethanol consumption, 2013-2017 average



Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

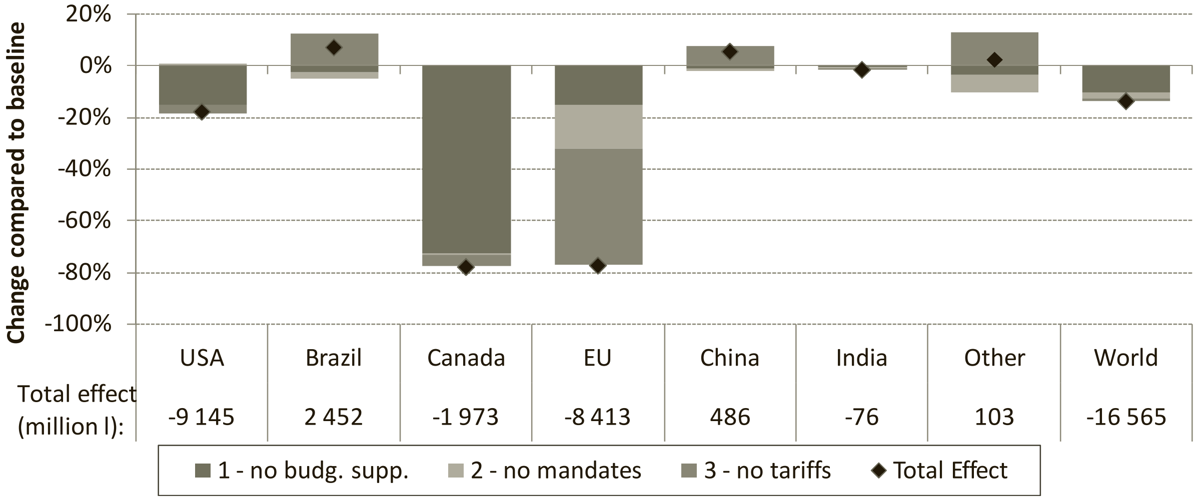
Figure 2.2. Impact of biofuel support removal on biodiesel consumption, 2013-2017 average



Note: The relative impact of removing different policies depends on the order of this removal as indicated in the text. Results for Malaysia and Indonesia are due to model-related simplifications and hence likely to overestimate the actual impact of the mandates.

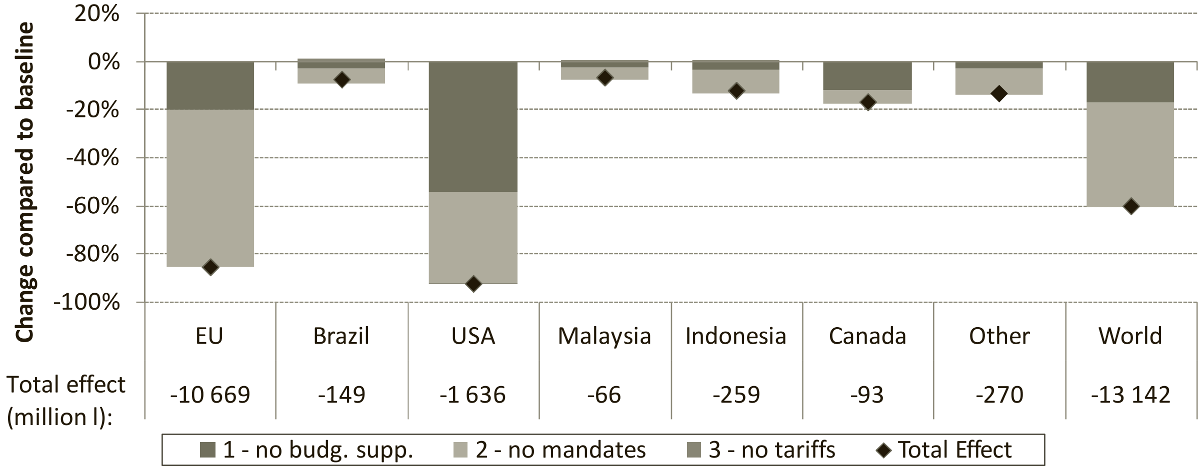
Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Figure 2.3. Impact of biofuel support removal on ethanol production, 2013-2017 average



Note: The relative impact of removing different policies depends on the order of this removal as indicated in the text.
Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Figure 2.4. Impact of biofuel support removal on biodiesel production, 2013-2017 average



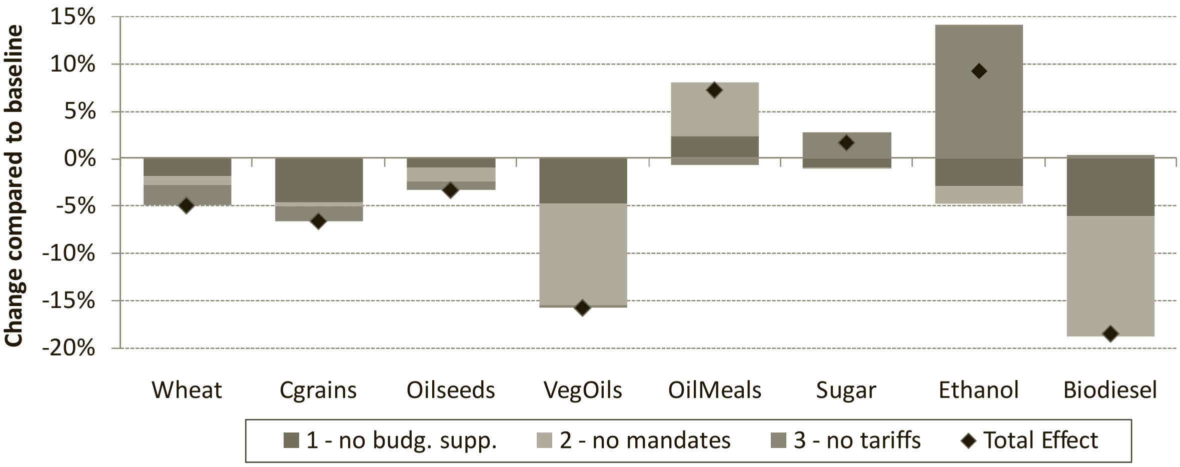
Note: The relative *impact of removing different policies depends on the order of this removal as indicated in the text.*
Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

International trade in ethanol would be reduced by the elimination of budget support and incorporation mandates. EU net imports in particular would be reduced by about two thirds as the removal of both mandate and tax concessions result in lower ethanol use, while US net imports would be cut by more than half. The elimination of import tariffs would, in contrast, result in an important increase in international trade, mainly as the EU tariff reduction would overcompensate the trade effects of budget and mandate policies by far. Both larger use and particularly the shrunken domestic ethanol supplies would result in a net increase in EU imports by some 130% on average for the 2013-2017 period. Both US and Canadian ethanol imports would strongly increase as well –

largely supplied by expanding Brazilian exports. In consequence, a complete removal of biofuel support policies would result in a 90% expansion in total international ethanol trade during the 2013-2017 period.

If all biofuels policies were removed, prices for biodiesel would drop by more than 20% in the initial years and recover only slightly as production and consumption adjust. On average over the 2013-17 period, biodiesel prices would decline by about 19%. In contrast, ethanol prices would drop only little initially, and would gain substantially from reduced tariffs, averaging around 9% higher than in the baseline for the 2013-17 period. With global production of ethanol and biodiesel reduced by 14% and 60% on average, respectively, the use of feedstock commodities would be substantially lower. While in absolute terms, the use of grains would be reduced most significantly (US maize use for ethanol would be lower by more than 23 million tonnes per year, wheat use for EU ethanol production by almost 16 million tonnes), the effect relative to global production is most pronounced in vegetable oil markets. The EU alone would use almost 10 million tonnes of vegetable oils less in the biodiesel sector per year on average during the 2013-2017 period, equivalent to 8% of global production. In consequence, international prices for vegetable oils would, on average, be about 16% lower than under baseline assumptions, those for wheat and coarse grains by some 5% and 7%, respectively (Figure 2.5). Due to the offsetting effect of higher prices for oilseed meals, world oilseed prices would drop by only 3%. Sugar prices, in contrast, would gain slightly, as Brazil ethanol producers take advantage of eventually higher ethanol prices, and as the slightly lower molasses-based ethanol production in a number of African and Asian countries reduces sugar supply.

Figure 2.5. Impact of biofuel support removal on world commodity prices, 2013-2017 average

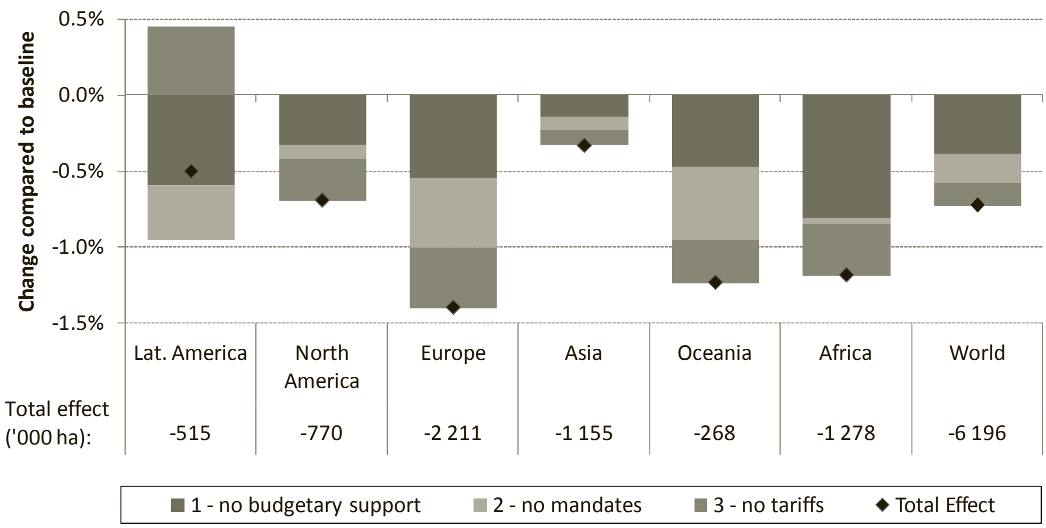


Note: The relative impact of removing different policies depends on the order of this removal as indicated in the text.

Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Land used for crop production would be affected mainly through lower crop prices and hence lower incentives for farmers, including the (partly offsetting) effects the lower production of feedable by-products (such as DDG) would have on animal feed markets. While this can be seen on a global scale, the effect is particularly pronounced in Europe, where production currently responds strongly to increased commodity use for biofuel production by slowing down longer-term trends in reduced overall crop area use[9,10] and where the reduced domestic use of feedstock commodities would result in particularly strong price adjustments especially on wheat and rapeseed markets. Globally, some 6.2 million hectares (0.7%) less would be used for main crops (Figure 2.6). This represents about 23% of the increase of global crop area projected over the coming decade. While some of this land would be used for other commodities instead[11], other parts may not go into production without biofuel support.[12]

Figure 2.6. Impact of biofuel support removal on total crop area (wheat, coarse grains, rice, oilseeds), 2013-2017 average



Note: The relative impact of removing different policies depends on the order of this removal as indicated in the text.
Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

In summary this analysis shows that biofuel support policies remain crucially important in many countries. A removal of these policies would substantially affect the (private) profitability of biofuel production and use in those countries where production costs are particularly high. Ethanol production in the US would be affected to a lesser extent following somewhat better economics in this industry. This, and the large ethanol industry based on sugar cane in Brazil help to keep global ethanol production growing, although at substantially reduced rates, even without public support. In contrast, world biodiesel production (dominated by the EU industry) would decline by more than a fourth after removal of all support policies and grow much more slowly thereafter, ending up around 60% below the baseline in 2013-17.

Despite the importance of support policies for biofuel markets, the analysis also shows that the medium-term impact on crop markets should not be overestimated. With cereal and oilseed prices impacted by 5% to 7% and 3%, respectively, the medium-term effect of biofuel support policies is substantially smaller than recent price hikes on international markets. The effect of growing biofuel industries on crop markets is larger than that as shown further below, but some important parts of those industries would still keep growing even after removing the public support. This price-related conclusion also holds for land use which would grow some 20% more slowly without the existing biofuel support. But growth in land use is for a larger part independent from biofuel support policies.

Even without a removal of domestic support policies, a liberalisation of trade in biofuels could have significant effects. Even though global production and use of biofuels would change only little, an elimination of import tariffs would cause higher ethanol prices in international trade and some relocation particularly of ethanol production and use across countries, with increased exports particularly from Brazil (+11 billion l) balanced by higher imports to the US, Canada and particularly to the EU (again, +11 billion l on average for the 2013-2017 period). In consequence, production of grain-based ethanol would decline, while cane-based ethanol would expand, causing lower cereal (-2% to -3% on average) but higher sugar prices (+3%). As one might expect, this would also cause changes in the land use allocation across regions, with increased crop area in Latin America more than offset by lower crop land use in other regions, particularly in Europe and in Africa.

Finally, it should also be noted that the response of biofuel use and, in particular, production on changes in economic incentives is heavily dependent on parameters that, in this analysis, are based on a limited amount of data. These parameters therefore exhibit a substantial degree of uncertainty. The use of ethanol as a fuel in spark-ignition engines can substitute for gasoline fairly easily in certain ranges of low-level blends as well as for users of flex-fuel vehicles, but less well as ethanol blends reach certain, technically defined levels. These factors can be modelled relatively accurately (though a certain degree of uncertainty remains). Biodiesel use does not have these technical thresholds, but required (modest) vehicle modifications should result in somewhat lower substitutability with fossil diesel at least in the short run. In contrast, the responsiveness of biofuel capacity building as well as that of capacity use is more uncertain. Higher parameters and hence stronger responsiveness of investment in biofuel plants to changes in production incentives would further increase the impact of biofuel support on production capacities and hence biofuel supply, thus resulting in more pronounced implications for commodity prices. Conversely, a weaker responsiveness of biofuel industries would imply less important price effects.

Potential implications of recently announced or enacted changes in biofuel policies

In December 2007, the US Energy Independence and Security Act (EISA) was signed into law. This new energy legislation defines, among other elements, a new Renewable Fuel Standard calling for US biofuel use to grow to a minimum of 36 billion gallons per year (bngy) or 136 billion litres per year (bnly) by 2022. Corn-based ethanol is to grow to 15 bngy or 57 bnly until 2015 and to remain constant thereafter. Given that the US is the only major producer of corn ethanol, this consumption requirement can be seen as a production mandate as well. Requirements for first-generation biodiesel are given only for the period 2009-2012. Beyond 2012, further growth in biodiesel use is included in a total for biofuels other than corn-based and cellulosic biofuels. Production of biofuels from cellulosic materials is scheduled to start in 2010 at low levels, but with 16 bngy (60.6 bnly) to represent the bulk of biofuel use in 2022. The EISA institutes several safeguards that allow waiving some or all of these requirements in the case of adverse impacts on agricultural markets or for fuel cost reasons.

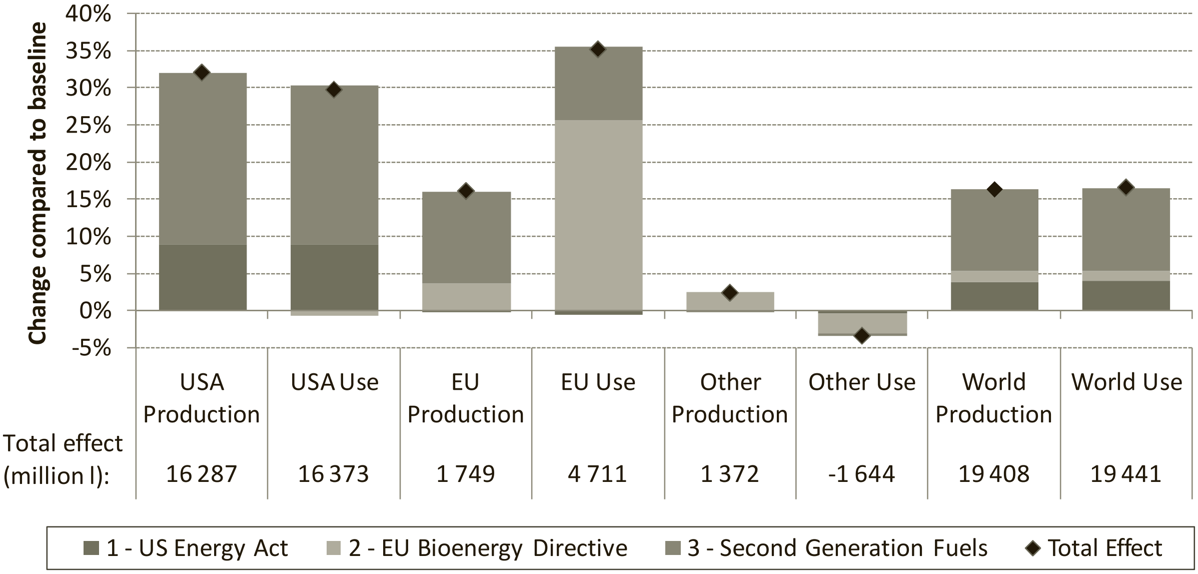
A new EU Directive on Renewable Energy (DRE) is still in the legislation phase. In its part on transport fuels the current draft calls for biofuels to replace at least 10% of all transport fuel consumption in energy terms by 2020. In contrast to the existing Directive of 2003, this rate would be mandatory. While no specific rates are given to distinguish ethanol from biodiesel use (nor from any other biofuel such as biogas), nor does the Directive provide details about alternative feedstocks. It does, however, assume second-generation biofuels to become commercially available and to represent a substantial share of biofuel supplies in the target year.

As in the case of support removal, the scenario analysing these new regulations was performed in three steps. First, the realization of the EISA was analyzed. Second, the new EU DRE was simulated. Both these runs were performed assuming that second generation biofuels were not to become available at any significant scale within the decade analyzed. In consequence, and as foreseen in the respective regulations, shares of biofuel use in the US and the EU were assumed to reach lower levels than what the regulations would ask for otherwise.[13] A final step considered the increasing availability of second generation biofuels in both countries to fill the requirements set out in the legislations.[14,15] This third scenario assumes that second generation fuels can be offered to consumers at the prices projected for first generation biofuels - be it due to improvements in the economic viability of second generation biofuels, public support, or a combination of the two. Particularly in the US, second-generation biofuels would account for the majority of the growth of biofuel markets.

Figure 2.7 and Figure 2.8 show that the two programs in the US and the EU imply ambitious plans for growth in biofuel use, over and above the growth already implied in the baseline. By construction, the additional ethanol used in the US would be domestically produced – partly from maize, but to a larger degree from cellulosic material (from crop residues and, increasingly, dedicated biomass). In contrast, the increased first-generation ethanol use in the EU would be partly provided for by foreign supplies, in particular from Brazil, while cellulosic ethanol is assumed to be domestically produced.[16] Globally, and looking again at the 2013-2017 average, these two programmes call for medium-term use of ethanol higher by some 17%.

Biodiesel use in the US is set to increase most in relative terms[17], but biodiesel use in the EU would increase substantially in absolute terms as well. Taken together, these two regions would consume some 16 bn litres per year more than without the new regulations on average over the 2013-2017 period – 9 bn litres of these would be first-generation biodiesel.[18]

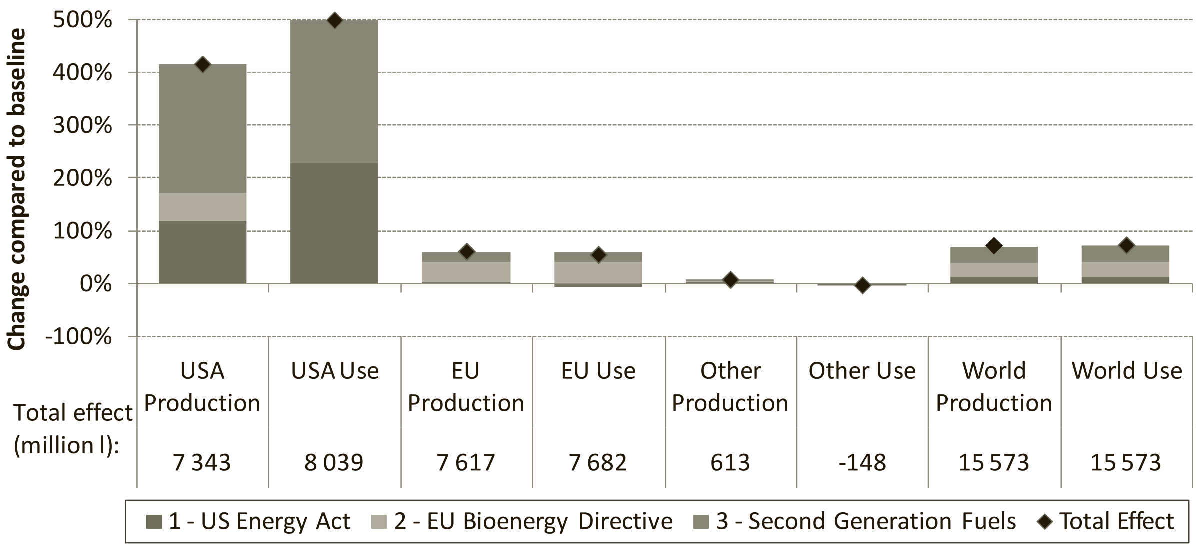
Figure 2.7. Impact of US EISA and EU DRE on ethanol production and use, 2013-2017 average



Total effects on world production and use differ slightly as world totals exclude Japan (net trade represented only).

Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Figure 2.8. Impact of US EISA and EU DRE on biodiesel production and use, 2013-2017 average

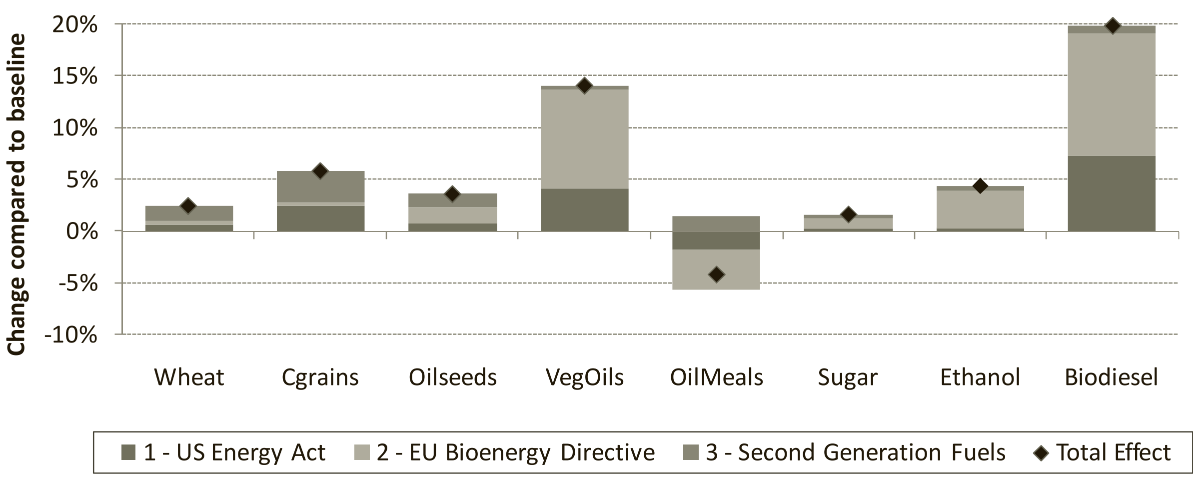


Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

The additional production of first-generation biofuels following EISA and DRE as modeled for this analysis requires substantial quantities of feedstock commodities. This additional demand pushes up prices particularly for maize (due to larger maize-based ethanol production in the US), vegetable oils (biodiesel production in both the US and the EU) and sugar (due to larger Brazilian ethanol supplies destined to the EU), while wheat prices would gain through both ethanol production in the EU and through reduced wheat plantings following higher coarse grain prices. With +3% on average for coarse grains and +14% for vegetable oils the magnitude of these price changes is, however, smaller than the price effect of existing biofuel policies analysed in the previous section.

The impact of growing feedstock demand for second-generation biofuels, however, could be much larger, and would be concentrated on the commodities particularly important in the two regions considered: Assuming 50% of the biomass for second-generation biofuels to be produced on land otherwise used for food and feed production[19], prices for coarse grains would increase by another 3% on average over the 2013-2017 period; those for wheat and oilseeds would each be higher by another 1% (Figure 2.9). While the increased demand for ethanol in the US – and for second-generation biofuels in both US and EU – are assumed to be met by domestic production irrespective of biofuel prices (which in effect means that, to the degree technological improvements do not reduce production costs sufficiently far the supplies will be ensured by additional public support), biofuel prices are affected directly by the increased use of first-generation fuels in the EU and by biodiesel in the US. Given the relative magnitudes, this price effect is particularly pronounced for biodiesel, while increased ethanol use in the EU would drive up ethanol prices by some 4% on average over the final five years of the period analysed. Higher cereal and oilseed prices due to land reallocation for second-generation biofuels would, however, result in only slightly higher biofuel prices, causing biofuel production in a number of smaller markets (such as in Canada) to be reduced.

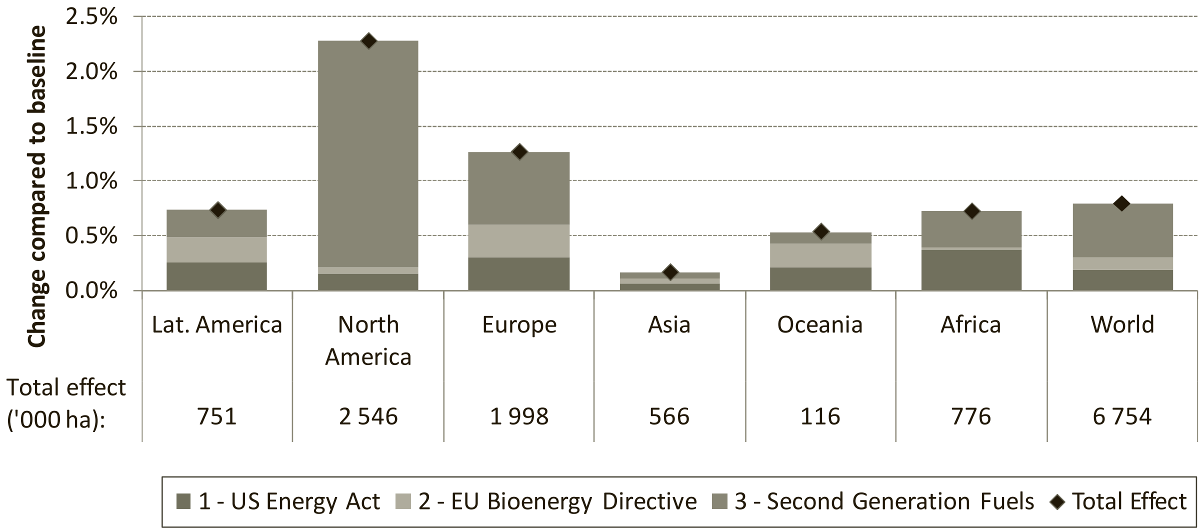
Figure 2.9. Impact of US EISA and EU DRE on world crop prices, 2013-2017 average



Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Increased use of biofuel feedstocks and hence higher commodity prices also result in more land to be used for the production of cereals, oilseeds and fuel-biomass (Figure 2.10). Consistent with the results found for the existing biofuel policies (see above), the extended use of first-generation biofuels affects land use in most parts of the world. The amount of land additionally used as second-generation biofuels are added to the picture can be substantial and would, by assumption, be mostly located in the two regions considered, *i.e.* the US and the EU. Other regions, however, would face area expansions as well following higher crop prices.

Figure 2.10. Impact of US EISA and EU DRE on total crop area (wheat, coarse grains, rice, oilseeds and biomass for second generation biofuels), 2013-2017 average



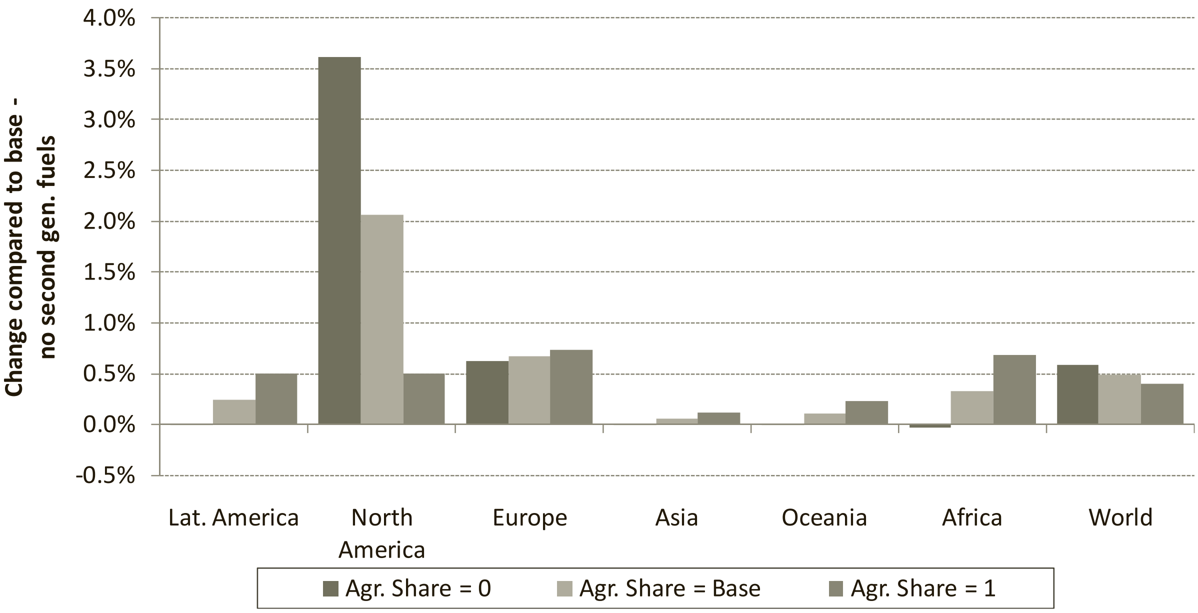
Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

The results above assume that, in North America and the EU, 50% of the land required for dedicated biomass production would come from land that otherwise would be used for the production of cereals, oilseeds or sugar crops - for Brazil, this share is assumed to be 20%. The impact of increased second-generation biofuel production crucially depends on this parameter, as it directly determines the degree of competition between land for food production and land for energy production. The figures below (Figure 2.11 and Figure 2.12) show the impacts on area use and crop prices, corresponding to the third part of the above scenario (“3 – Second Generation Fuels”). Given the large quantities of biomass needed to replace the projected growth in US ethanol production, the bulk of the impact is caused by differences in North America: if all additional biomass were to be produced on land other than that used for crop production, the impact on land use would obviously be the strongest, whereas the impact on crop production would be least – the share of second generation biofuels produced from crop residues would increase cereal production and hence marginally reduce grain prices.

The magnitude of this negative price effect will depend on two factors: first, and most obviously, it will depend on the share of second-generation biofuels to be produced from crop residues such as straw and stover. In this analysis, this share is assumed to be high in the first years but to strongly decline as total quantities of cellulosic ethanol and BTL increase. Higher shares would increase the additional value of the cereal production and hence incentives to produce grains, causing lower crop prices. The second factor is the price biofuel plants will be able to pay for the straw and stover. While this price will need to cover farmers' opportunity costs (*i.e.* fertiliser value plus harvesting and transport costs), any revenues from the residuals beyond those will again increase the incentives to produce.[20]

In contrast, if the additional biomass were to be produced on land that otherwise was crop land, total land use would increase only because of higher crop prices, which result from the strong competition between energy and food/feed crops. As the quantities of second-generation biofuels are assumed to be much larger in the US compared to the EU, the additional land use in the US declines substantially as the share of agricultural land for biomass production increases, whereas higher crop prices offset lower biomass area in the total land use change in the EU.

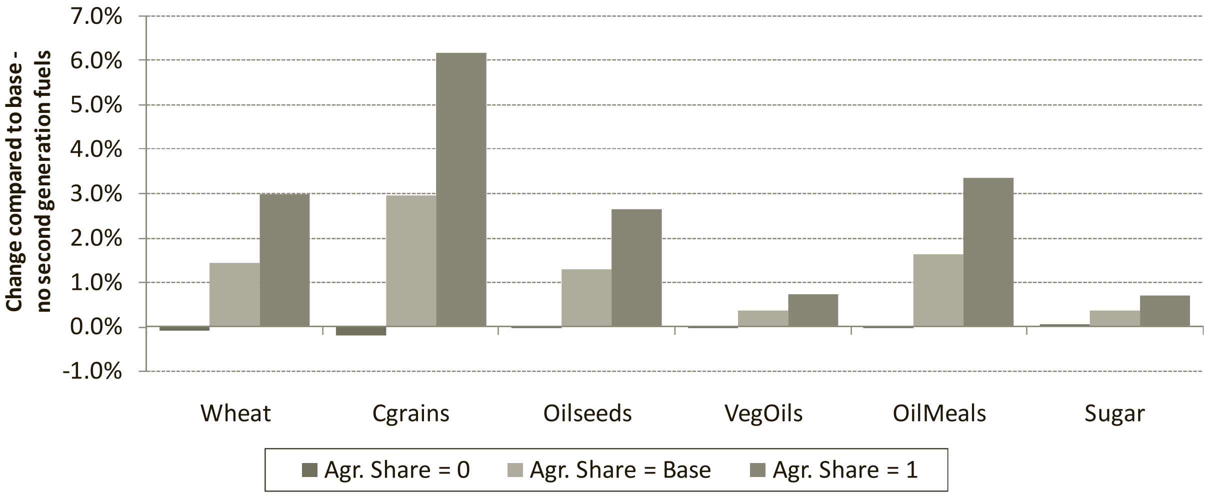
Figure 2.11. Alternative assumptions on the crop land share in the land used of biomass for biofuels – Impact on total crop area (wheat, coarse grains, rice, oilseeds and biomass for second generation biofuels), 2013-2017 average



While in the base scenario ("Agr. Share = Base") the share of agricultural crop land in the land used for fuel-biomass production is assumed to be 50% in Europe and North America, and 20% in Brazil, this share is changed to zero ("Agr. Share = 0") and one ("Agr. Share = 1") in the sensitivity scenarios shown as the first and third bar in each block in this and the figure below.

Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Figure 2.12. Alternative assumptions on the crop land share in the land used of biomass for biofuels – Impact on world crop prices, 2013-2017 average



Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

In summary, this analysis suggests that the two new biofuel regulations in the US and EU have the potential to substantially affect agricultural commodity markets and land use. Both programmes set ambitious biofuel targets which clearly depend on the rapid commercialisation of second-generation biofuels, including cellulosic ethanol and BTL. While on a per unit basis these advanced fuels have the potential to affect agricultural commodity markets much less than ethanol and biodiesel from cereals and oilseeds, the large quantities scheduled in the two regulations can still have strong impacts. Much will depend on how the feedstock biomass for these new biofuels will be produced. If large quantities are to be produced on crop land these compete with food and feed commodities and may have similar market effects as current production chains. On the other hand, biomass production on land other than current crop land will significantly expand total production area. Policies will then need to ensure the protection of sensitive areas and high-carbon soils to avoid negative environmental effects, including increased greenhouse gas emissions.

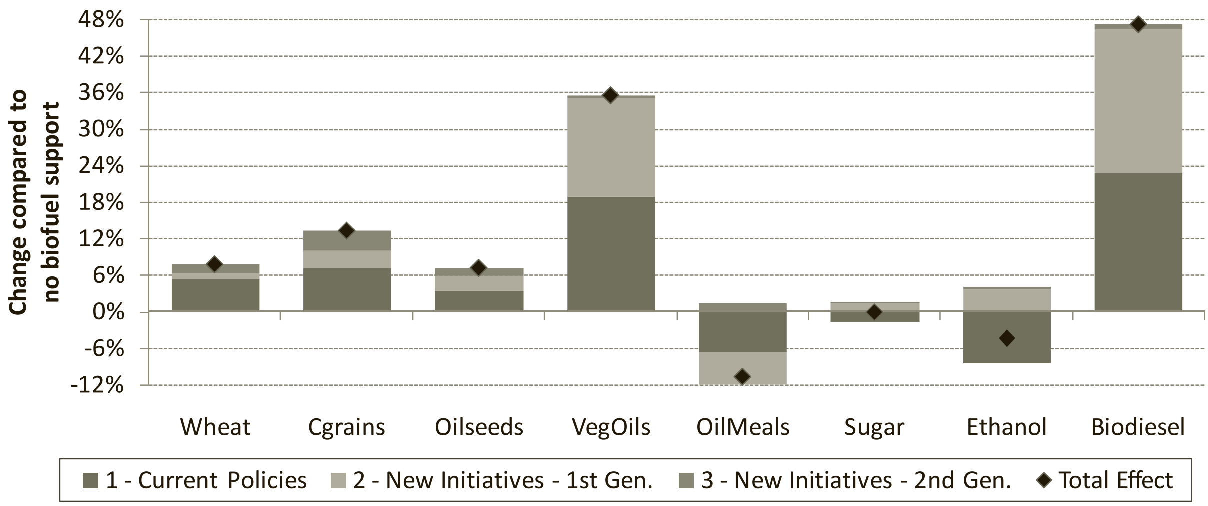
Overall effect of biofuel policies

The impacts of existing support policies and those of the US EISA and the EU DRE on agricultural markets and land use are largely additive. The overall effects of all the policies involved are of particular interest and will be briefly outlined here.

The combined impact of current and new policies on projected commodity markets is relatively pronounced (Figure 2.13). Compared to a situation without biofuel support, international prices for wheat, coarse grains and oilseeds would by about 8%, 13% and 7% higher on average for the 2013-2017 period. While prices for vegetable oils are increased by 35% following the strong increase in biodiesel production, those for oilmeals are reduced by 11% due to the higher crush and DDG supplies. Sugar prices would be little affected in the medium term.

As discussed above, these results strongly depend on the amount of crop land used for second-generation fuel biomass – as opposed to land not otherwise used for crops. Depending on that share, the total price effect for coarse grains may range from +10% to +17%, while that for wheat and oilseeds would both range from +6% to +9%. These ranges show that on the one hand the use of alternative land resources for second-generation biofuels matters, but that on the other hand biofuel policies have a significant impact on agricultural markets even if no food-crop land is used for second-generation biomass production.

Figure 2.13. Impact of existing and new biofuel policy programmes on world crop prices, 2013-2017 average

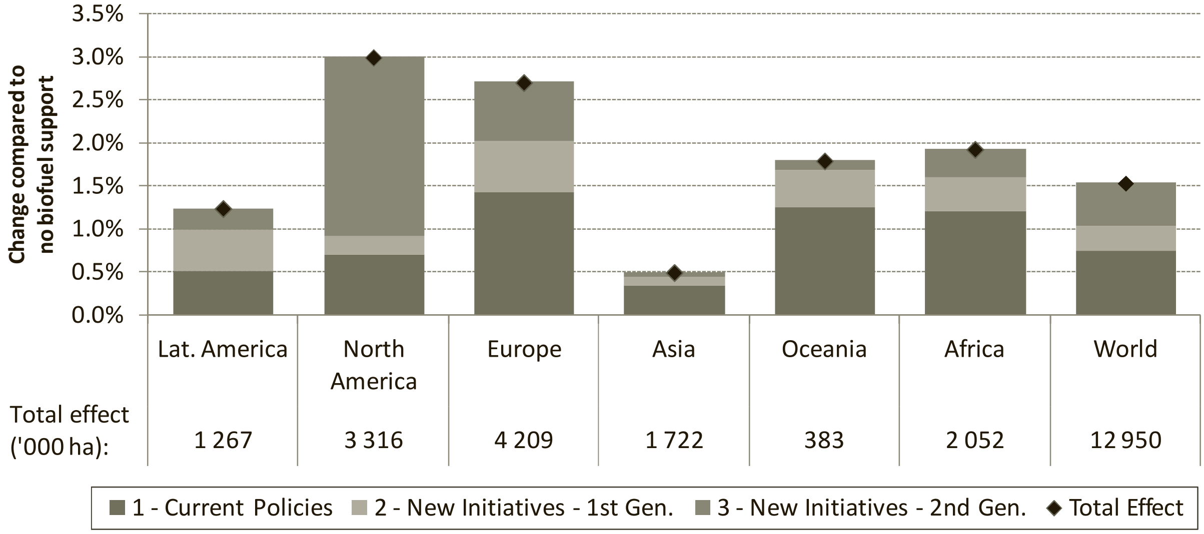


Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Both the feedstock production for second-generation biofuels and the higher prices for many crops would result in a significant larger area used for the crops and feedstocks considered. When compared to the scenario without biofuel support, global land used for cereals, oilseeds, sugar crops and fuel biomass would be some 13 million ha or 1.5% larger on average over the five year period. While again some of that increase would be in fact a reduction of declining trends in land use for crops, area expansion would be accelerated significantly in large parts of Africa, Latin America and Asia. Here, the biofuel support programmes would result in 6.5 million ha additionally used.

In contrast to the impact on agricultural market prices, the effect on global land use depends very little on the share of fuel biomass to be produced on crop land. However, the differences in the impacts for different regions are important, as discussed in the previous section: The changed effect for the United States is largely offset by the opposite effects for other regions responding to the price changes shown above (Figure 2.14).

Figure 2.14. Impact of existing and new biofuel policy programmes on total crop area (wheat, coarse grains, rice, oilseeds and biomass for second generation biofuels), 2013-2017 average



Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

The use of feedstock commodities is directly linked to the production incentives and therefore for some biofuel chains strongly depends on the policy environment. This is particularly true in the case of vegetable oil use for biodiesel which, without support, would represent some 5% of global supplies for the 2013-2017 average (Table 2.1). Under current (pre-EISA) policies, this share would increase to 14% of world production, whereas the new initiatives in the US and the EU could boost this share to almost 20% on average over the 2013-2017 period. Higher shares are found in the case for sugar cane, largely dominated by Brazil's ethanol industry, but these are much less sensitive to the policy scenarios discussed here[21] and range between 27% and 28% of global production. Coarse grain use for ethanol, dominated by the United States, would represent some 10% of world production without support, but could exceed 13% of global supplies under the Energy Independence and Security Act.

Table 2.1. Use of feedstock commodities in global biofuel production under alternative policies, 1 000 tonnes, 2007 and 2013-2017 average

Feedstock commodity		Actual 2007	Policy scenario, 2013-2017 average		
			No Support	2007 policies	New initiatives
Coarse grains	Total	89 394	117 813	147 242	159 540
	of which US	81 286	106 081	129 317	140 872
Share in global production		8.4%	10.1%	12.4%	13.4%
Wheat	Total	3 551	2 113	19 403	19 979
	of which EU	2 851	1 659	17 614	18 122
Share in global production		0.6%	0.3%	2.9%	2.9%
Sugar cane	Total	255 968	532 209	500 688	513 429
	of which Brazil	243 602	489 530	458 396	470 216
Share in global production		17.3%	28.4%	27.1%	27.7%
Sugar beet	Total	9 281	5 204	12 789	13 475
	of which EU	9281	5 204	12 789	13 475
Share in global production		3.8%	2.0%	4.9%	5.1%
Vegetable oils	Total	9 267	6 842	19 040	27 215
	Of which EU	5 698	1 698	11 648	16 505
Share in global production		8.7%	5.2%	14.0%	19.6%

Vegetable oils include rapeseed oil, sunflower oil, soya oil and palm oil.

Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

The potential impact of "next-generation biofuels" replacing commodity-based biofuels

This scenario analyses the hypothetical implications of second-generation biofuels replacing the growth in first generation biofuels projected in the baseline. It is clearly a purely synthetic scenario as neither are second-generation biofuels commercially available today nor are first-generation biofuels expected to stop their significant growth. Instead, this part of the analysis aims to illustrate two questions: first, the impact the growing biofuel industries (as opposed to biofuel support, see above) on agricultural commodity markets, and second, the relative impact equivalent quantities of second-generation biofuels would have.

In consequence, this scenario again is cut in three steps: First, all biofuel quantities are assumed to be fixed to their respective 2007 levels, thus assuming the absence of any growth in biofuel supply and demand. Second, biofuel production and use is assumed to grow as under baseline conditions in most countries, but to remain at their 2007 levels in the four countries with specific representation of second generation biofuels (US, Canada, EU and Brazil). Third, second generation biofuels are assumed to grow along the path projected for first generation biofuels in these four countries, *i.e.* first generation biofuels remain at their 2007 level, and the growth that they would otherwise have exhibited is now assumed to be realised through second generation biofuels.[22]

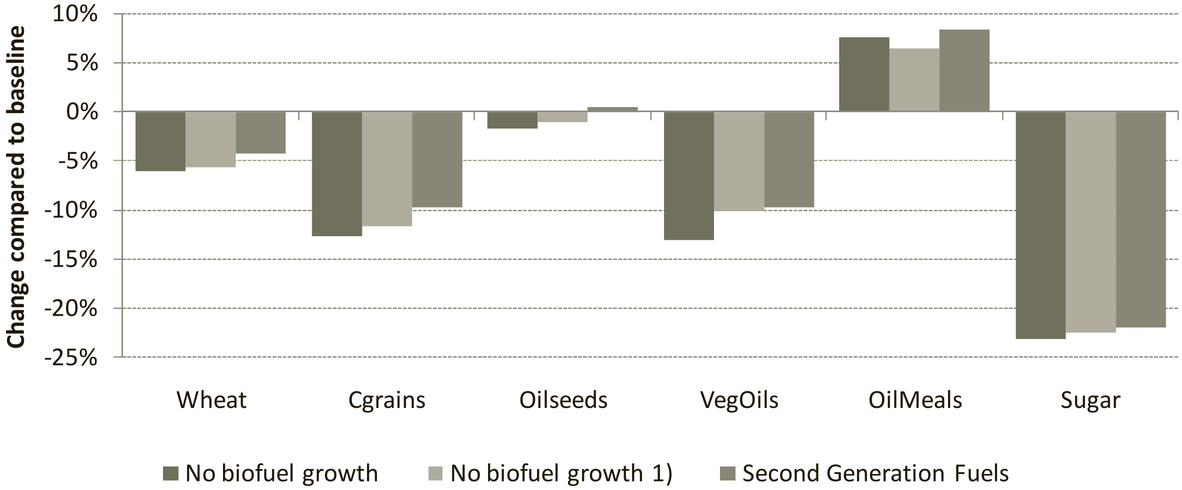
Figure 2.15 and Figure 2.16 show the implications of these hypothetical developments for international crop prices as well as land use. Without further growth in biofuel production (as opposed to a removal of support as discussed above), medium term world prices for coarse grains and sugar would be about 13% and 23% lower on average than projected in the baseline, *i.e.* than under the continuation of current policies. Relative to future market developments to be expected with implementation of the recent US and EC initiatives, keeping biofuel production constant at 2007 levels would have even more pronounced effects in terms of reducing agricultural commodity prices. These price changes compare to -7% and +2% found for a removal of biofuel support policies, respectively. The differences stem from the fact that, even in the absence of support, ethanol production in the US (and hence the use of maize in this industry) would, according to the model analysis used here, still grow even though at lower rates, whereas higher ethanol prices would increase ethanol production in Brazil (and hence the use of sugar cane) beyond baseline levels.

The impact on prices in the oilseed sector are similar to those found for a removal of biofuel support policies – given that without support biodiesel production would effectively stop growing (and in fact decline in some countries) the two scenarios are largely equivalent for the oilseed sector.

Most of this price change stems from biofuel production in the four regions Brazil, US, Canada and the EU – growth in biofuel production in other countries affects international commodity prices only little. This is a direct consequence of most other countries producing only small quantities of biofuels, and given the use of other feedstocks (including jatropha and cassava) in some of them, the impact on cereal and oilseed use as biofuel feedstocks is even smaller.

Growth in second generation biofuel production comparable to the projected growth in first generation fuels would increase commodity prices through competition in land markets, but depending on the share of biomass produced on current crop land, the effect is substantially smaller than the price effect of the projected feedstock use in first generation biofuel production. The increased use of biomass for second-generation biofuels would increase cereal prices by about one fifth of the price the projected growth in impact first-generation ethanol has in the medium term. The effect of second-generation fuels on sugar prices is even smaller – a consequence of a larger share of fuel-biomass in Brazil to be produced on land other than projected crop area.

Figure 2.15. Impact of second-generation biofuels replacing growth in first-generation biofuels on world crop prices, 2013-2017 average



No biofuels growth refers to constant biofuel quantities in all regions;

No biofuel growth 1) refers to constant biofuel quantities in Brazil, the US, Canada and the EU, the four regions with explicit representation of second-generation biofuel production. Biofuel markets in other regions were kept unchanged relative to the baseline;

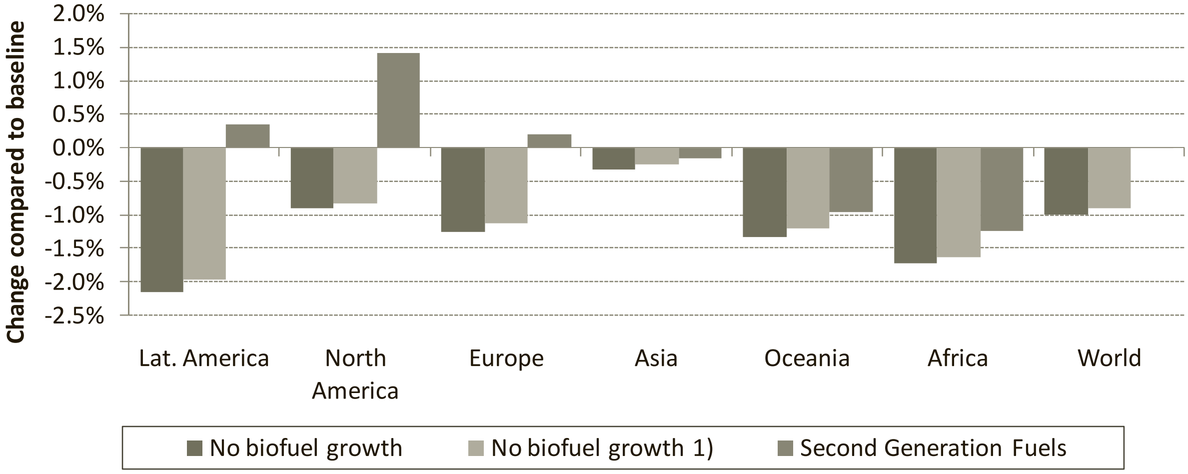
Second Generation Fuels refers to growth in second-generation biofuel production replacing that of first-generation fuels in the four regions mentioned. Biofuel production in other regions, as well as biofuel demand in all regions, were kept unchanged relative to the baseline.

Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Land use would be affected significantly, both by eliminating the projected growth in first-generation biofuel production and by assuming it to be replaced by second-generation fuels. The results suggest that the projected growth in first-generation biofuels is responsible for about a third of the crop area expansion globally, equivalent to some 9 million hectares. The effect shows both in countries with a high importance of the biofuel sector such as Brazil, and in countries where biofuels are not expected to play a major role in land use such as large parts of Africa and developing Asia. In other countries, the growth in first-generation biofuels is found to slow down the decline in crop area, such as in the US. For the EU, the baseline projections imply largely unchanged harvested land after some initial increase, while without the biofuel production crop area would decline – in line with historical patterns.

With second-generation fuels growing in line with projected biofuel markets, total land use would in fact be equally affected as with first-generation fuels, at least on a global scale. Regionally, however, the impact on land use is quite different, with the decline in land use stopped in the US and accelerated area expansion in Brazil on the one end, and substantially lower land use compared to the first-generation biofuel baseline in large parts of Africa on the other end.

Figure 2.16. Impact of second-generation biofuels replacing growth in first-generation biofuels on total crop area (wheat, coarse grains, rice, oilseeds and biomass for second generation biofuels), 2013-2017 average



No biofuels growth refers to constant biofuel quantities in all regions;

No biofuel growth 1) refers to constant biofuel quantities in Brazil, the US, Canada and the EU, the four regions with explicit representation of second-generation biofuel production. Biofuel markets in other regions were kept unchanged relative to the baseline;

Second Generation Fuels refers to growth in second-generation biofuel production replacing that of first-generation fuels in the four regions mentioned. Biofuel production in other regions, as well as biofuel demand in all regions, were kept unchanged relative to the baseline.

Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

As shown above in the case of the US EISA and the EU DRE, the impact of second-generation biofuels strongly depends on the share of feedstock-biomass produced on cropland. Indeed, most of the area increase shown above for North America disappears if the biomass is produced on land otherwise used for food and feed commodities. Similarly, the increase in Latin America would be substantially smaller. Much of these differences would be offset by inverse differences in other regions. Globally, the difference between none and all of the fuel-biomass coming from crop land is less than 0.3%-points on total land use for cereals, oilseeds, sugar crops and fuel-biomass.

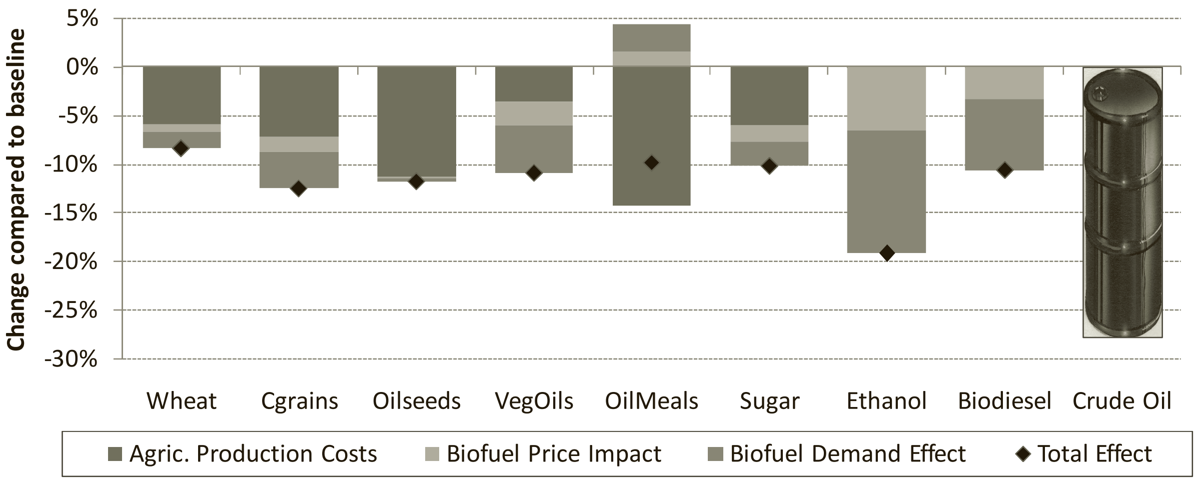
This assumption has, however, major effects on world commodity prices, with fuel biomass competing for crop land causing higher commodity prices. Even with all fuel biomass for second generation biofuels coming from land otherwise used for food and feed commodities, however, cereal and sugar prices would be substantially lower than those projected with growing first-generation biofuels.

The impact of alternative crude oil prices

This section looks at the relevance of one of the main external factors outside the biofuel markets. As discussed above, crude oil prices have increased significantly over the past few years and have exceeded the mark of USD 100 per barrel in early 2008. While the base assumptions for this analysis include crude oil prices remaining at levels between USD 90 and just over USD 100 per barrel, different levels of crude oil prices are likely to affect agricultural and biofuel markets from two angles: first, fossil fuel prices are directly linked to crude oil. Consequently, the higher crude oil prices are, the stronger will be, all other factors unchanged, the demand for biofuels.[23] Second, as energy represents an important share in agricultural production costs and is also required in the conversion of feedstocks to biofuels,[24] higher energy prices will reduce agricultural production, increase agricultural commodity prices and hence will reduce biofuel supply.

A return of crude oil prices to the level of USD 30 per barrel is not expected. However, the annual average oil price in 2007 was just over USD 72 per barrel,[25] and a return to such prices from the current level of around USD 100 per barrel might be seen as a possible, though perhaps not likely scenario, while on the other hand prices could rise further to persistent levels of USD 130 per barrel or above. These two benchmarks are therefore used to analyse the implications that substantially different oil prices could have on biofuel markets and agriculture. In order to better understand the relevance of different levels in the biofuel economy, the scenarios are broken down into several subjects: first, the impact through changed costs in agricultural production is shown by keeping both fossil and biofuel prices at their original levels. Second, by letting biofuel prices adjust to the impact of crude oil prices on production costs, the impact of changes in feedstock markets on biofuel supply and prices are shown. Finally, changed prices for fossil fuels are allowed to affect the demand for biofuels, thus showing the implications of alternative crude oil prices from the biofuel use side.[26]

Figure 2.17. Impact of lower oil prices on world crop and biofuel prices, 2013-2017 average effect relative to baseline



Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Figure 2.17 shows the global price impacts of alternative assumptions on crude oil prices for the average of the final quintennium of the simulation period, 2013-2017. Lower energy prices have an important impact on production costs in agricultural production and hence commodity prices. With oil prices being some 28% lower than in the baseline on average, and energy costs in agricultural production moving with oil price changes to some degree,[27] world crop prices would decline by between 6% and 12% on average even without considering response in biofuel prices. Their downward response further reduces the crops use in biofuel production and hence commodity prices. Finally, biofuel use would decline with lower crude oil prices, putting further pressure on both biofuel and agricultural commodity prices.

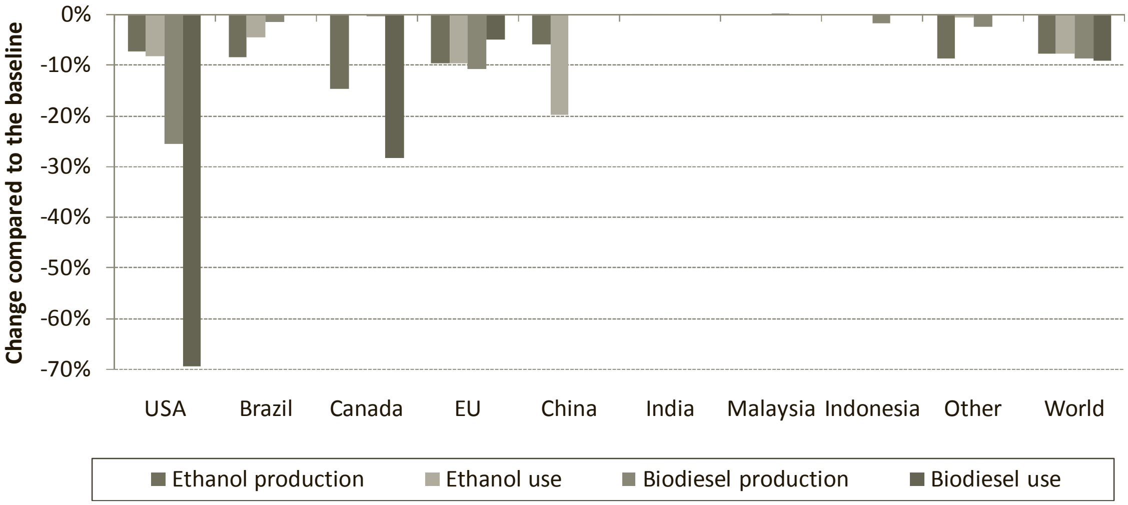
In total, world ethanol and biodiesel prices would be some 19% and 11% lower than in the baseline on that five-year average, respectively. These reductions are smaller than the change in oil prices mainly for three reasons: First, while substitution between biofuels and fossil fuels is assumed to be fairly high, it is less than perfect due to technical differences in the fuels and hence engine modifications needed to run higher biofuel blends. Second, domestic fuel prices generally are subject to relatively high taxes, causing gasoline and diesel prices to decline by less than crude oil in relative terms. Third, blending requirements effectively limit the response in biofuel demand in a number of countries as blenders have no flexibility to react to price changes. For instance, as visible in Figure 2.18, biodiesel use in the EU, the largest biodiesel producing and consuming region, hardly changes with lower crude oil prices, as in fact biodiesel use in the EU is bound by mandates to a large extent. The same holds for a number of Non-Member Economies including India, Malaysia and Indonesia, for which the use of ethanol and biodiesel is assumed to be fixed to blending mandates in the projection period. Blending mandates also keep the biodiesel use in Brazil unchanged, while in Canada, biodiesel use would fall with lower crude oil prices, but given existing mandates the effect is limited. In contrast, biodiesel use in the US, where no blending requirements are considered in the baseline,[28] would be substantially lower as fossil fuels become cheaper.

The decline in ethanol use generally is much smaller in comparison, even though a lesser part is supported by mandates: as the ethanol price declines more significantly in response to falling crude oil prices, a larger share of this biofuel remains in use despite lower crude oil prices.

The total impact on crop prices is smaller again, with a reduction by 8% to 13% for the different commodities. This reflects the fact that it takes a reduction in biofuel producers' margins to stimulate a decline in biofuel production, even though crop prices also and particularly decline due to lower production costs in agriculture. Overall, the existence of biofuel industries in various countries tends to increase the responsiveness of crop markets to changes in energy costs: about 20-30% of the price change in cereal and sugar markets results from the demand for these crops as a fuel energy source. This effect is more limited for oilseeds due to the opposite effect biodiesel production has on the markets for vegetable oils and for oilseed meals.

Global use of crop land would be slightly higher with lower crude oil prices mainly due to reduced agricultural production costs and hence increased output. This is particularly the case in developing countries, where the energy part of agricultural production costs, though lower in absolute terms, has a larger share in total production costs due to lower prices for land and labour. In large parts of the OECD, in contrast, lower crop prices outweigh or even overcompensate for lower production costs, resulting in a reduction of land used for crop production.

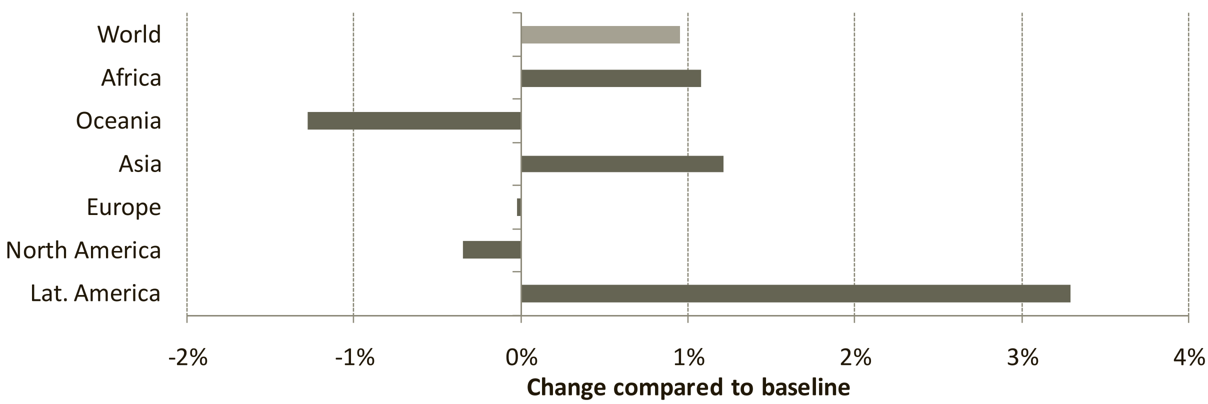
Figure 2.18. Impact of lower oil prices on biofuel production and use, 2013-2017 average effect relative to baseline



Results for biodiesel use in India, Malaysia and Indonesia are due to model-related simplifications and hence likely to underestimate the actual impact of oil price changes to biodiesel use.

Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

Figure 2.19. Impact of lower oil prices on crop land use, 2013-2017 average effect relative to baseline



Source: Aglink/Cosimo Simulation Results, OECD Secretariat.

In summary, this analysis shows that agricultural markets are sensitive to changes in energy prices, and that this sensitivity has increased with the emergence of biofuels. While the question whether biofuel industries create a more or less price responsive demand for feedstock crops very much depends on the individual country and the feedstock used – the established cane-based ethanol industry in Brazil can be expected to respond much more directly to changes in feedstock markets than *e.g.* the still relatively small grain-based ethanol industry in the EU where capacity tends to be a more limiting factor – the demand for crops as a source of fuel energy creates an additional link to crude oil markets. The relevance of this new demand for the link between energy and agricultural markets again depends on the feedstock crop. These results are confirmed by the second scenario assuming higher crude oil prices, though the results of that scenario are not shown here in detail: At USD 130 per barrel, medium-term crop prices would be higher by between 9% and 13%. Again the effect of higher fossil fuel prices on biofuel demand accounts for an important share of this overall crop price response.

Environmental effects of agricultural land allocation between bioenergy crops and food-feed crops using SAPIM[29]

There is a lot of public interest not only in the economic and market effects of biofuel production and consumption, but also the various environmental effects. A significant amount of research has explored the effects of biofuels on greenhouse gases, but very little on the multiple environmental effects. Moreover, integrating both the economic and environmental effects has been absent. The Stylized Agri-environmental Policy Impact Model (SAPIM), which adopts an integrated economic and natural science modelling approach, has the capacity to undertake such analysis. SAPIM combines an economic model of farmers' decision making with a biophysical model predicting the effects of farming practices on crop yields and multiple environmental effects. The environmental effects include GHG emissions, nitrogen and phosphorus runoff, herbicide runoff and the quality of wildlife habitats. As the focus of the application is on multiple environmental effects of alternative land use options, crop prices are exogenous and taken from the OECD AGLINK scenario results. The illustrative example below is an empirical application based on data from south-western Finland.

Environmental effects

This application of SAPIM focuses on three environmental issues: surface water quality, climate, and biodiversity. Moreover, the model addresses land allocation between different uses, each of which is associated with certain input use intensities and management practices. As regards CO_2-equivalent life cycle effects, the focus is on agricultural production activity, and thus the conversion of feedstock into end-products and final consumption are not considered in this application (Annex B Figure B.1).

In this application, both nitrogen and phosphorus runoff from cultivated fields to watercourses is estimated. As regards pesticide runoff, the focus is on herbicide runoff (MCPA as an active ingredient).[30]

Greenhouse gas emissions are modelled on the basis of life cycle assessment (LCA) estimates provided by Mäkinen *et al.* (2006). In this application the following elements are included: (i) CO_2-eq emissions related to the transportation of crops, (ii) CO_2-eq emissions related to the manufacturing, transportation and application of fertilizers, herbicide, and lime (iii) CO_2 emissions from soil and (iv) CO_2-eq emissions from tillage practices, such as ploughing, harrowing and planting as well as CO_2-eq emissions from harvesting and grain drying.

The effects of land allocation on biodiversity are quantified by a wildlife habitat indicator - a habitat quality index, developed in Lehtonen *et al.* (2008). This index measures the impacts of land use on the quality of wildlife habitats.

The monetary valuation of environmental effects is used to aggregate the environmental effects in alternative policy scenarios. These valuation estimates are based on published Finnish valuation studies quantifying the consumers' willingness to pay for reducing nutrient and herbicide runoff or to promote biodiversity. The price of emission allowances is used as a proxy for the climate damage (CO_2-eq emissions).

Results

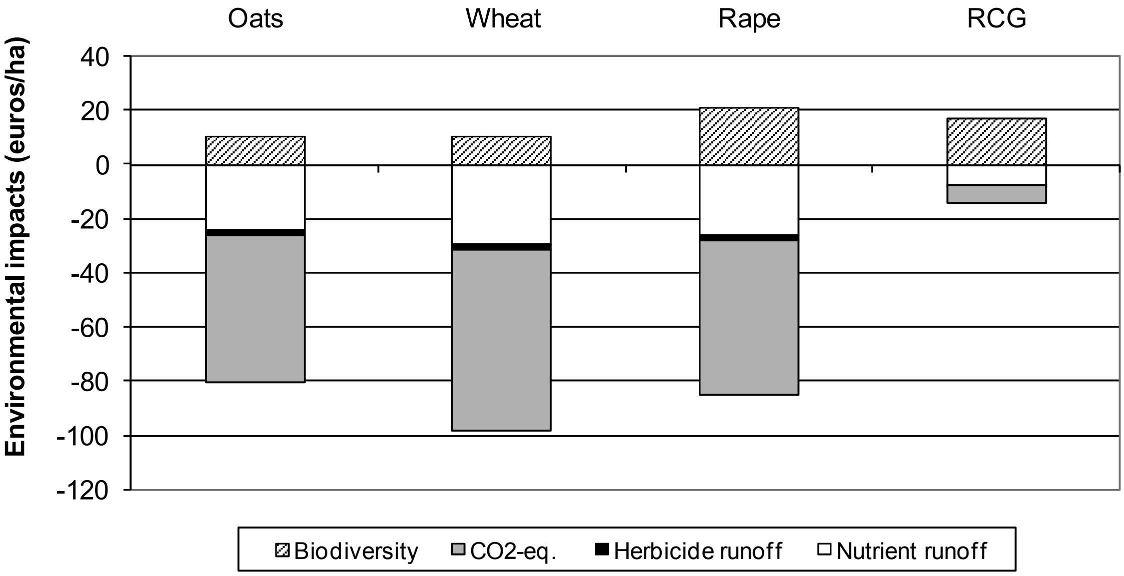
Results are presented for three scenarios: Baseline, Policy Scenario 1 (Removal of biofuel support) and Policy scenario 2 (New EU and US biofuel legislation). The Policy Scenario 1 incorporates the forecast average EU prices for wheat, barley, oats and rapeseed in 2013-2017. In this price scenario, all biofuel-related policy instruments are removed (budgetary support, mandates and tariffs). The Policy Scenario 2 also incorporates the forecast average EU prices for wheat, barley, oats and rapeseed in 2013-2017, but in this price scenario, the following policies and technology developments are taken into account: the US Energy Act, the EU Bioenergy Directive, and second generation biofuels.

Reed canary grass (RCG) - a perennial grass with 14 years rotation period - represents second generation biodiesel, while rape represents first generation biodiesel, barley is used for ethanol, oats is used for feed, and wheat is the food crop.

For all scenarios the basic results regarding land allocation, input use intensity, production and profits are presented in Annex C, Table C.1. Detailed empirical results concerning the environmental effects of alternative crops and policy scenarios are presented in Annex C, Table C.2.

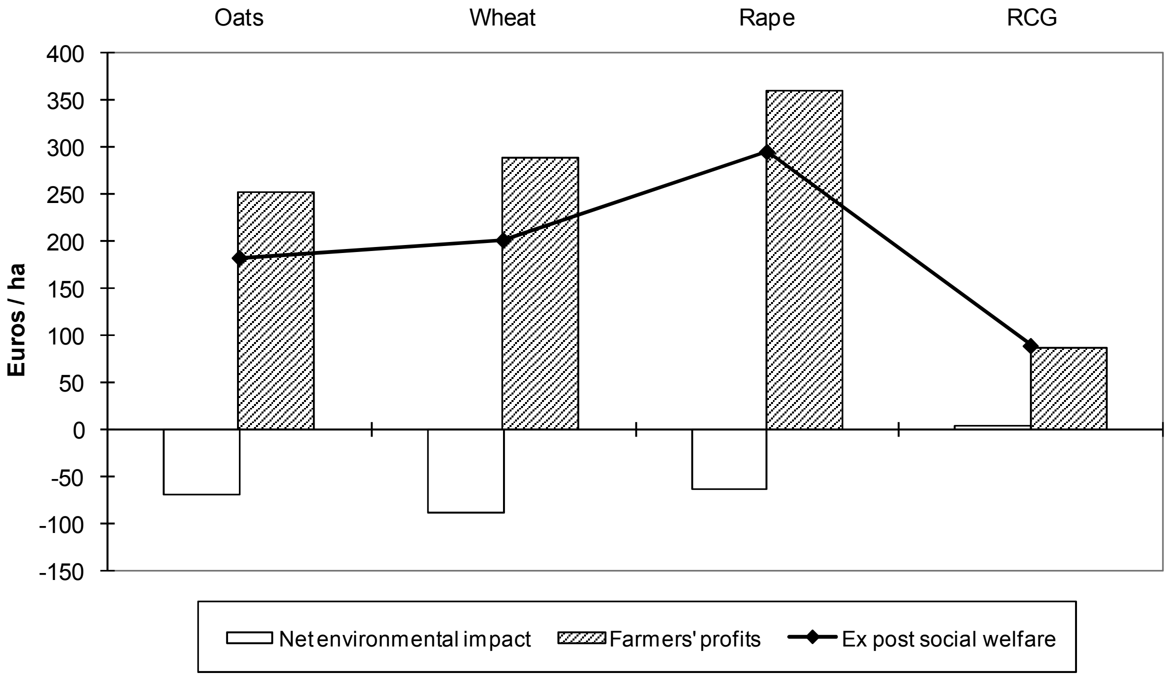
Concerning the **environmental effects**, Figure 2.20 illustrates that reed canary grass (RCG) performs well. Its good environmental performance is mainly driven by its low CO_2-eq emissions. This is largely explained by the fact that RCG is a perennial crop that sequesters carbon and thus soil CO_2 emissions are in fact negative, whereas for other crops, which are annual crops and cultivated with conventional tillage, soil CO_2 emissions are significant. Moreover, RCG is cultivated with low fertilizer intensity and thus low CO_2-eq emissions related to fertilizer use. Because of high fertilizer and herbicide use intensity wheat performs poorly with respect to both CO_2-eq emissions and nutrient runoff. With respect to the biodiversity benefits provided, rape is the highest ranked of the land use types in the Baseline scenario. This is because the wildlife habitat index uses butterflies as the key species and rape provides a higher quality habitat for butterflies than cereals. The overall environmental performance of alternative land use types is mainly driven by the value of CO_2-eq emissions and nutrient runoff damage. Herbicide use intensity and resulting herbicide runoff damage have only a marginal effect on the environmental performance of alternative land use types. Incorporation of biodiversity benefits favour rape and reed canary grass over cereals.

Figure 2.20. Environmental profile of alternative land uses in the Baseline scenario, EUR/ha



Concerning **social welfare** (defined as the combination of the social valuation of environmental effects and farmers' private profits, without considering transfers from governments/taxpayers and consumers), Figure 2.21 illustrates the social profitability of alternative land uses in the Baseline. Profits are short-run estimates (revenue from production minus variable costs of production) augmented with the social value of retaining land in agriculture (which is represented here by LFA payments). The results show that the land use type that delivers the best environmental performance (reed canary grass) is the least profitable for farmers. Overall, first generation biodiesel crop rape provides the highest *ex post* social welfare, since it provides a combination of the highest farm profits with the second lowest negative net environmental impact. This social welfare ranking illustrates that in this example *ex post* social welfare of alternative land use types is mainly driven by profitability of land use rather than the social valuation of environmental effects.

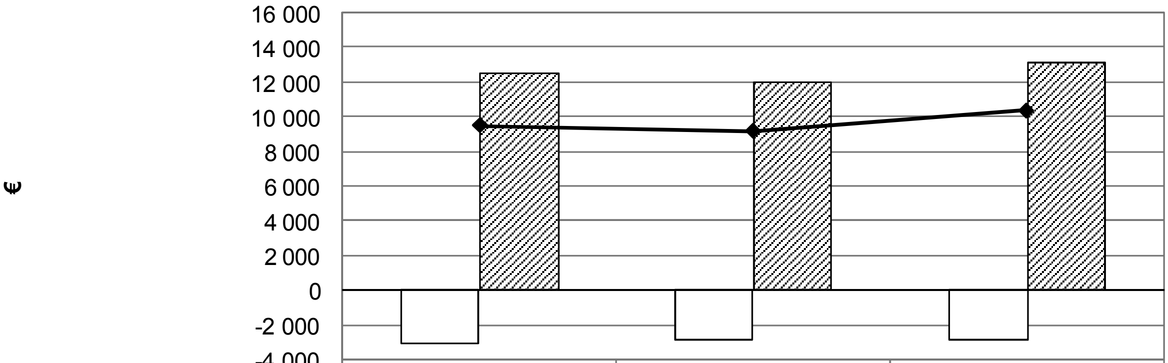
Figure 2.21. Social welfare under alternative land uses in the Baseline scenario, EUR/ha.



Extending the analysis to the *ex-post* social welfare estimates for alternative policy scenarios, the results presented in Figure 2.22 show that the removal of biofuel policies results in the lowest negative environmental impacts, although the difference is not very large when compared to the environmental impacts of new EU and US biofuel legislation. Improved environmental performance of these policy scenarios relative to the Baseline is mainly because of decreased CO_2-eq emissions under both policy scenarios, decreased nitrogen runoff in the scenario of the removal of biofuel policies, and increased value of wildlife habitats in the scenario of new EU and US biofuel legislation.

From overall social welfare perspective the policy scenario of new EU and US legislations clearly dominate other policy scenarios due to increased profits for farmers. The *ex post* social welfare of alternative land use types and policy scenarios is driven mainly by farmers' private profitability of alternative land uses rather than the social valuation of environmental effects. Naturally, socially optimal allocation of land between food, feed and bioenergy crops changes when relative prices change, including social valuation of environmental goods and services.

Figure 2.22. *Ex post* social welfare under alternative scenarios, €.



	Baseline	Removal of biofuel policies	New biofuel legislation EU and US
Net environmental impact	-3 083	-2 824	-2 830
Farmers' profits	12 584	11 991	13 200
Ex-post social welfare	9 501	9 167	10 371

This application of SAPIM is illustrative and depends on many assumptions, characteristics of farming systems and land productivities, and policy parameters. Clearly, the results will likely be different in a different set of circumstances. However, the value of this analysis is in using a model that can combine several economic, policy and environmental variables to provide both results on farmers' profits and social welfare. If policy makers wish to pay particular attention to, for example, the multiple environmental effects of biofuel production then this has implications for the adoption of policy measures that will provide the correct incentives to achieve balanced outcome.

Notes

1. In particular, the FAO co-ordinated the representation of biofuels in the following developing countries: Columbia, Ethiopia, India, Indonesia, Malaysia, Mozambique, Peru, Philippines, South Africa, Tanzania, Thailand, Turkey, and Vietnam.
2. Given the multitude of potential feedstocks for second-generation biofuels, these options are necessarily represented in a simplified manner. Results relating to second-generation biofuels therefore should be understood as largely indicative. In particular, the choice of feedstocks and the region considered imply differences in biomass yields and other variables from the assumptions used in this analysis. While some of these variables are subject to sensitivity analyses outlined below, these cannot reflect the whole range of possible outcomes. Details on related assumptions are provided in the context of the specific analysis below.
3. While the impact of removing each of these policy categories obviously is related to their relative importance in different countries, individual results also depend on the order in which policies are removed. This is discussed further below.
4. Lacking detailed data, existing biofuel mandates in several US states have not been included in the model analysis. The small positive effect of eliminating mandates on US biofuel use shown in Figures 2.1 and 2.2 may in fact be offset if such US mandates were removed.
5. Note that biodiesel use in many developing countries, including Malaysia, Indonesia and others, are assumed to be fixed by mandates – an elimination of these mandates therefore reduces biodiesel consumption to zero in those countries. While this obviously represents a simplification of actual developments, the quantities concerned are relatively small and global results are, therefore, largely unaffected.
6. Note that this analysis does not consider changes in support policies in China as these are not represented in the model. Changes in Chinese biofuel markets are therefore driven by price changes for biofuels and feedstock commodities.
7. As explained above, the lack of detailed data did not allow the full consideration of ethanol support in Brazil.
8. The relatively small impact of the policy change on Canadian biodiesel production is largely due to technical reasons in the model: a substantial share of Canadian biodiesel is produced from feedstocks other than vegetable (canola) oil and kept exogenous to the model. In consequence, the response to policy changes is likely to be underestimated here.
9. Existing legislation on EU and national levels aim at ensuring the sustainability of agricultural expansion in response to, among others, increasing demand for biofuel feedstock commodities. The expansion seen in recent years refers, i.a., to the use of set-aside land for energy crops permitted by the regulations.

10. Note that the energy crop payment of EUR 45 per hectare has not been taken into account. This payment scheme would further increase the impact of a support removal on EU crop area use.

11. The representation of agricultural commodities is incomplete and includes cereals, oilseeds, sugar crops (cane and beet), as well as, in developing countries, roots and tubers.

12. Note that the model does not explicitly take into account the various characteristics of land, such as different productivity irrigation or existing carbon stocks. This analysis therefore cannot provide detailed results of area use changes for alternative land types, but only aggregate changes in total land use for the main crops.

13. Note that, while requirements for individual years as well as for corn-based ethanol, biodiesel and cellulosic ethanol are provided in the US EISA (see, *e.g.* F.O.Licht's World Ethanol and Biofuel Report Vol. 6 No. 10 for details), the EU DRE largely focuses on a global biofuel share of 10% in the target year 2020. It is assumed that in the absence of second-generation biofuels, this share is reduced to 8%, of which 6.67% were to be reached by the last year of this analysis, 2017.

14. Second-generation biofuels, once available on a commercial scale, are likely to play an increasing role over time. In consequence, this medium-term analysis (until 2017) probably underestimates the effects these new technologies might have in the longer run (*e.g.* by the target years of the EISA – 2022 – and the DRE – 2020).

15. Assumptions were necessary on the respective shares between crop residues (cereal straw) and dedicated biomass (*e.g.* willow trees and switchgrass) in the feedstock requirements for second generation fuels. For this analysis, it is assumed that the year-to-year growth in second generation biofuel production would be based on crop residues with a share decreasing from 100% in 2009 to 0% from 2014, reflecting the more limited availability of crop residues when compared to dedicated biomass. Furthermore, assumptions were made on the biomass yield and conversion. Biomass yields are assumed to average 10.1 tons of dry mass per hectare in 2008, with conversion rates of 0.33 and 0.39 tons per hectoliter for the ethanol and biodiesel chain, respectively. These values improve over the projection period. It should be noted that specialized companies already today report substantially higher biomass yields. Given the small scale of current plants for second-generation biofuels and of related biomass production, an extrapolation of such higher yields is difficult. If realized, higher biomass yields will obviously reduce the market impacts of such biofuels.

16. Much of this obviously will depend on what shares of the total biofuel share will be attributed to ethanol and biodiesel, respectively. Historically, biodiesel played a predominant role in the EU biofuel markets, but the importance of ethanol has increased. As in the case of biofuel mandates in the underlying baseline, a further growth in the relevance of ethanol relative to biodiesel is assumed in this analysis as well. In consequence, the share of ethanol in total gasoline type fuel use, expressed in energy equivalent, would 7.5% by 2017 following the DRE, while that of biodiesel in total diesel type fuel use would reach 8.8% in that year (up from some 1.6% and 2.7% in 2007).

17. As noted above, the Renewable Fuels Standard (RFS) of the EISA explicitly gives data on biodiesel use only until 2012, after which growth for biofuels other than corn-based and cellulosic ethanol can be calculated (note that these may include first- and/or second-generation biodiesel, but also imported ethanol from feedstocks

other than corn starch). It is assumed that a decreasing share of the increments in this group would have to come from biodiesel made from vegetable oils, while the remainder would relate to biomass-based biodiesel ("Fischer-Tropsch diesel") produced in the US. The share relating to first-generation biodiesel, which according to the RFS shall be 50% in 2012, is assumed to decline from 50% in 2013 to 40%, 35%, 30% and 25% in the subsequent years until 2017, respectively. US use of biodiesel from vegetable oils would hence increase to 6.3 billion litres by 2017, more than four times the level in 2007.

18. It should be noted that biofuels from non-agricultural feedstocks, such as biodiesel from used cooking oils or ethanol from forest residues, are expected to play some role in total biofuel use both in the EU and the US. This is ignored in the present analysis but would obviously reduce the impacts found here to some extent.

19. This assumption is subject to a sensitivity analysis discussed further below.

20. In effect, this additional incentive to increase cereal production is likely to be limited to farmers situated close to the biofuel plants due to the rather high transportation costs of the biomass.

21. Note that these results would change with full representation of all support measures in Brazil, information on which are lacking in detail.

22. As above, assumptions need to be made on how feedstock for second generation fuels are split between crop residues and dedicated biomass. As the relevant quantities are much larger than those discussed in the previous scenario, the share coming from crop residues – based on the year-to-year growth – is assumed to decline from 50% in 2008 to 0% in and after 2013. Again assumptions are needed on the share of fuel-biomass to be produced on land otherwise used for crop production – in line with the former scenario this share is assumed to be 50% for the US, Canada and the EU and 20% for Brazil, reflecting in principle larger land reserves in Latin America compared to North America and Europe. Despite this reasoning, however, it should be noted that these shares are rather arbitrary assumptions which are subjected to sensitivity analyses, discussed briefly at the end of this section.

23. In the case of fixed blending mandates, the demand for biofuels obviously does not increase with higher crude oil prices. The model therefore differentiates between the price-responsive demand for biofuels and the minimum set by public mandates in several countries

24. Note that in both agricultural production and biofuel conversion processes energy is not only used in the form of crude oil derivatives, but also in other forms such as coal, natural gas or nuclear and water power. While not all the energy costs in biofuel production are therefore assumed to be linked to crude oil prices, petroleum is used as an energy cost indicator as in the medium term prices for other forms of energy are assumed to move with crude oil prices.

25. Brent crude averaged USD 72.35 per barrel in 2007 (OECD Aglink Database, 2008).

26. In principle, crude oil prices might in turn be affected by the production and use of biofuels as these tend to reduce demand for fossil fuels to some degree. This possible effect is not considered here – more in-depth analysis is needed to explore the effect of biofuel-induced reductions in crude oil use on international energy markets

27. Note that, while fuels used in tractors and transport are obviously directly linked to crude oil prices, other forms of energy (natural gas, coal, etc.) are often use in the production of energy intensive inputs such as fertilizers and pesticides. See Annex 3 of OECD (2006) for details on the modeling of production cost impacts of crude oil prices

28. Lacking detailed data, existing state-level mandates in the US are not accounted for in the baseline. The response particularly in biodiesel demand in this country is therefore likely to overestimate the actual responsiveness to crude oil prices. It should also be noted that in some countries a quota system applies to government support, again reducing price responsiveness in these countries

29. Background paper (OECD, 2008b) provides a detailed description of this application.

30. For details of nutrient and herbicide runoff modeling see Lankoski *et al.* (2006) or OECD (2008).

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