Biofuels policy:
implications for food security and for the environment

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1. Definitions

Biofuels: liquid or gaseous fuels used primarily for transport produced from biomass. Biofuels comprise biogasoline, biodiesel and other liquid biofuels. Second generation biofuels refer to biofuels produced from wastes, residues, non-food cellulosic material and lingo-cellulosic material.

Biomass: biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste.

Price spike: a large, rapid, temporary rise or fall in price.

Price volatility: measures the relative rate at which a price of a commodity varies from one period to another. Under normal market conditions, however, a certain degree of price volatility is expected.

Excessive price volatility: occurs when price (averaged over a 60 day rolling window) exceeds the 95 or 99% price range quantiles.

Subsidy: according to the World Trade Organization's Agreement on Subsidies and Countervailing Measures, subsidies may take the following forms:

- Government provides direct transfer of funds or potential direct transfer of funds or liabilities;
- Revenue is foregone or not collected;
- Government provides goods or services or purchases goods;
- Government provides income or price support.

2. Production and use of biofuels

2.1 Industrial productions is still limited to first generation of biofuels, but research on advanced biofuels is progressing

Biofuels are liquid or gaseous combustible materials derived from biomass (plants, animals, microorganisms, or organic wastes) and used as a energy source for transport. They are usually classified into first, second and third generation biofuels. The two latter categories are also called "advanced" biofuels.

Table 1: Key characteristics of conventional and advanced fuels. ***Source*****: GSI, 2012.**

	FEEDSTOCK-TO-FUEL CONVERSION PROCESSES	FEEDSTOCKS	CROPS	LAND USE IMPACTS	WATER RESOURCE IMPACTS
Conventional biofuels (First generation)	• Fermentation • Transesterification • Hydrogenation	• Sugars • Starch • Vegetable oils • Animal fats • Used cooking oil	For ethanol: • Wheat • Corn • Potatoes • Beet • Sugarcane • Cassava For biodiesel and bio-jet: • Palm oil • Soybean • Rapeseed (canola) • Sunflower • Jatropha curcus • Camelina sativa	• Direct use of agricultural land • Indirect land use change • No land take for waste-based biofuels	• Restriction of physical access to water • Reduction of water available • Impoundment of water courses • Change in ground water depth • Less significant water take for waste-based biofuels
Advanced biofuels (Second/third generation)	• Bio-chemical • Thermochemical • Hybrid (biorefinery)	• Lignin • Cellulose • Hemi-cellulose	• Woody biomass • Grasses • Agricultural by-products • Waste streams • Algae • Seaweed	• Direct use of agricultural land • Indirect land use change • Possible use of marginal / semi-arid land • No land take for waste-based biofuels and some algae and seaweed	• Restriction of physical access to water • Reduction of water available • Impoundment of water courses • Change in ground water depth • Less significant water take for waste-based biofuels and some algae and seaweed

Sources: IEA, 2011a; FAO, 2011; Roundtable on Sustainable Biofuels, 2012; IISD-GSI analysis

First-generation biofuels are produced using conventional technology (e.g. fermentation, pyrolysis) by processing seeds, grains or whole plants from crops such as corn, sugar cane, rapeseed, wheat, sunflower seeds or oil palm. Bioethanol and biodiesel are the most common first-generation biofuels, followed by vegetable oil and biogas. They use well established and simple conversion technologies and represent the most reliable products that could be produced industrially on a medium time scale (IEA, 2010).

Ethanol is produced through a process of fermentation and distillation from sugar crops (sugar cane, sugar beet and sweet sorghum) or starch crops (corn, wheat, cassava, etc.). Although the basic production process from both types of crop is similar, the energy efficiency of the sugar-based ethanol process is much higher than that of starch-based ethanol due to the additional process steps involved in converting starches into sugar (IEA, 2010). Ethanol is often used in blends of up to 10% in conventional spark ignition engines but may also be used in blends of up to 100% in modified engines. In Brazil, for example, more than 90% of new car sales are equipped with flexible-fuel engines.

Biodiesel is produced from vegetable oil and animal fat through esterification. Major feedstocks are rapeseed, soybean, palm and sunflower, whereas animal fat and used cooking oil comprise a smaller part of the raw materials. During the production process several co-products are also delivered (such as bean cake, animal feed and glycerine), which can be used by several industries. Biodiesel can be blended with diesel or used in pure form in compression ignition engines with little or no modification to the engine (IEA, 2010).

Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2). It is produced by anaerobic digestion or fermentation breakdown of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material, and crops. The process is slow but efficient. Biogas reactors can also be coupled with ethanol production from corn or Triticale. The residues from ethanol production are fermented to produce biogas, which in turn can be used as an energy source for ethanol distillation (German National Academy of Sciences Leopoldina, 2012).

Advanced biofuels have the advantage of being produced from remnant non-food sources such as waste biomass, seed husks, stalks of wheat, corn stover, straw, wood, and algae. Most of current research focuses on processes convert these materials (20 to 45% by weight being highly stable cellulose and lignocelluloses) into fermentable sugars. A good deal of progress has been made at the research level in various processes such as hydrolysis and gasification, but they have not yet found widespread industrial application (German National Academy of Sciences Leopoldina, 2012; IEA 2010). Although advanced biofuels reduce the strain on food crops as they are able to make use of a greater proportion of the feedstock plant, this benefit could be reduced because in many cases other uses exist for agricultural co-products (*e.g.*, residues given to livestock as fodder or used to fertilize the soil). Advanced biofuels can be produced through several processes, including:

- biodiesel can be produced through biomass-to-liquid (BtL) technology: in this method, biomass is first converted into a syngas through pyrolysis and gasification. Then, Fischer-Tropsch synthesis is used to convert the syngas into biofuels;
- cellulosic ethanol is produced by first subjecting the biomass to a pre-treatment (mechanical, thermochemical or enzyme facilitated hydrolysis) in order to help the breakdown of cellulose and lignocellulose, followed by fermentation;
- renewable diesel (hydro-treated vegetable oil) is derived from fats and oils by catalytic hydrogenation. This process removes oxygen from the oil, so unlike the traditional yellow transesterified biodiesel, the product is a clear and colorless paraffin chemically identical conventional diesel requiring no modification or special precautions for the engine.

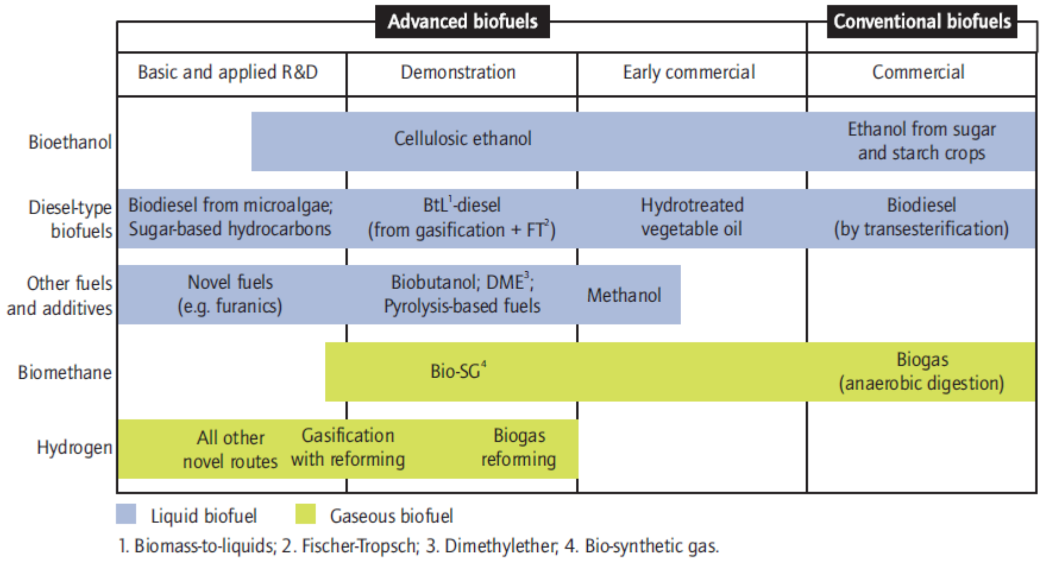


Figure 1: Commercialization status of main biofuel technologies. ***Source*****: IEA, 2011.**

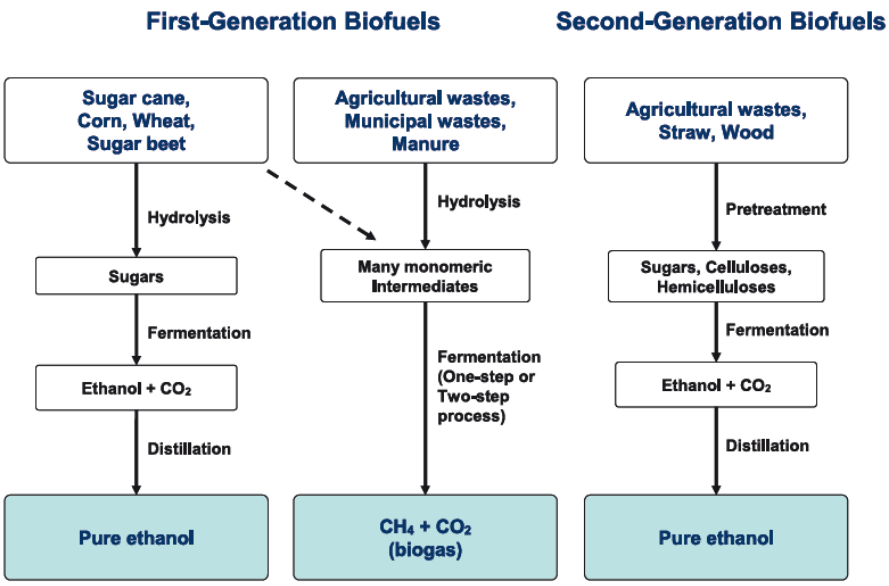


Figure 2: Routes to produce biogas and bioethanol.

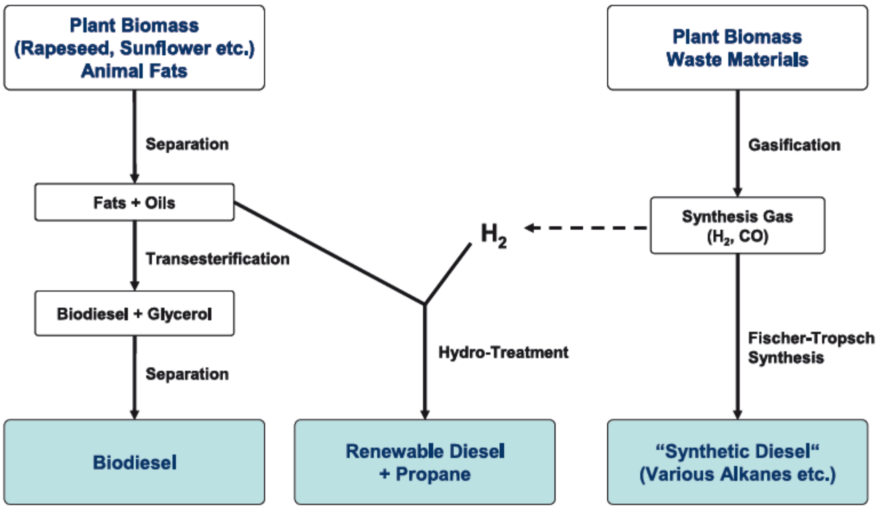


Figure 3: Routes to produce different types of biodiesel.

2.2 Production of biofuels is increasing rapidly

Total primary EU biofuels production amounted in 2009 to 14,5 million tonnes – 57% of which biodiesel and 20% biogasoline – and experienced threefold increase between 2005 and 2009. Globally, production grew from 16 to 100 billion litres in the period 2000–2010, while in the USA it will reach 57 billion litres by 2012 (15,2 billion gallons). Looking into the future, production is expected to double from 2007–09 to 2019, and demand to increase fourfold from 2008 to 2035 (IEA, 2010).

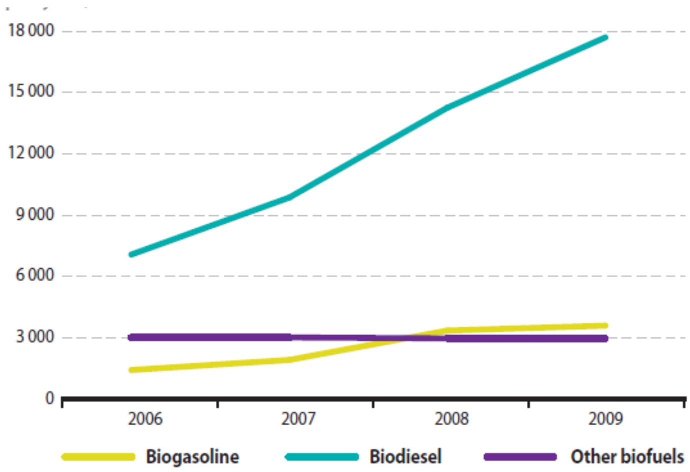


Figure 4: Biofuels production capacity in the EU (thousand tons per year). ***Source*****: Eurostat, 2012.**

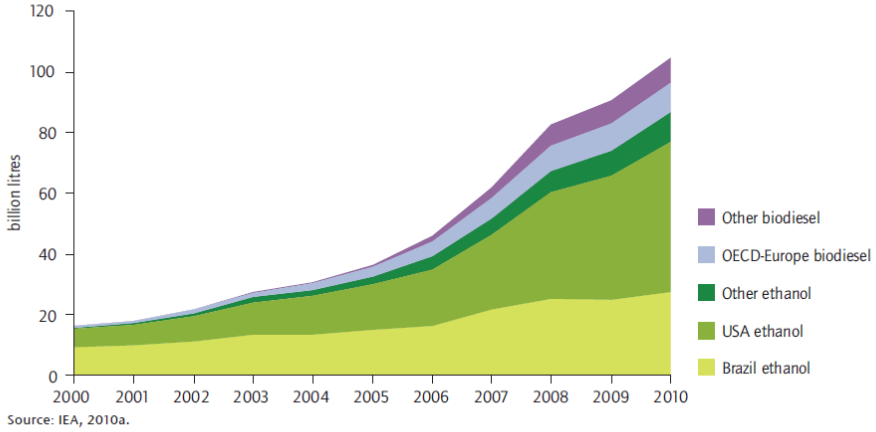


Figure 5: Global biofuels production (2000–2010). *Source*: EIA, 2011.

The currently low or modest penetration rates of biofuels are attained at the expense of comparatively large quantities of edible crops. In the EU, sixty-six percent of vegetable oils from crops are diverted to biofuels production. The main feedstock used is rapeseed (about 80%), with sunflower oil and soybean oil making up most of the rest. In the USA, biofuel industry already appropriates around 40% of the domestic corn production (equivalent to approximately 15% of the global corn production). Worldwide, it is estimated that crops used for biofuels occupy between 2 and 3% of all arable land (about 36 million ha in 2008). Projections of future land requirements vary from 35–166 million ha by 2020 if no additional policies to stimulate production are implemented, to 118–508 million ha if the goal of providing 10% of the global transport fuel demand with first generation biofuels in 2030 is actively pursued (UNEP, 2009).

In terms of feedstocks, by 2020, 44% of global ethanol is expected to be produced from coarse grains and 36% from sugar cane. Cellulosic ethanol production should represent only 5% of global production. More than 75% of global biodiesel production is expected to come from vegetable oil in 2020, while Jatropha should account for 7%. Biodiesel produced from non agricultural sources such as fat and tallow, as well as from waste oils and by-products of ethanol production, should represent about 15% of total biodiesel produced in the developed world over the period 2011-2020. Second generation biodiesel production is expected to start growing from 2018 in developed countries and to represent about 10% of global biodiesel in 2020 (OECD/FAO, 2012).

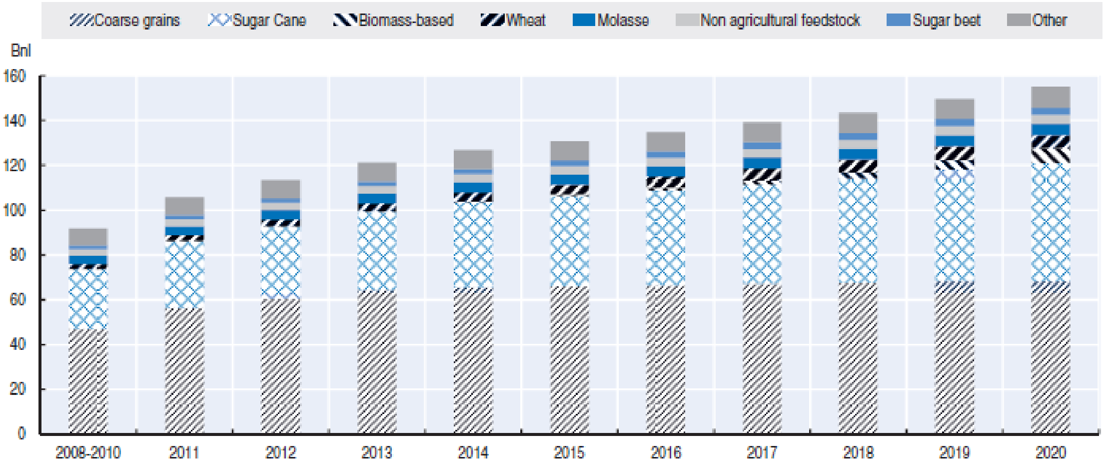


Figure 6: Evolution of global ethanol production by feedstocks used. *Source*: OECD/FAO, 2012.

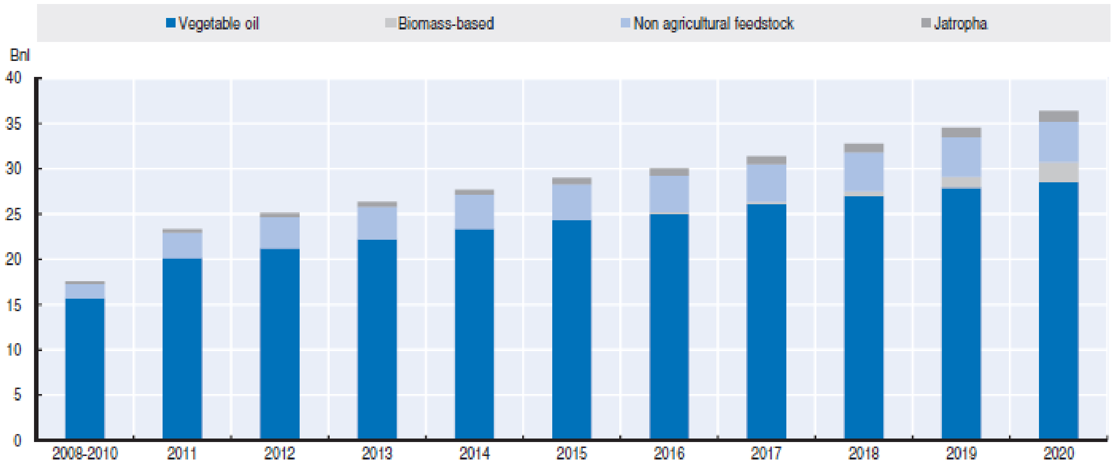


Figure 7: Evolution of global biodiesel production by feedstocks used. *Source*: OECD/FAO, 2012.

2.3 Biofuels still account for a very low share of transport fuels

Despite the rapid grow in production over the last years, the share of biofuels in the volume of transport fuels is only 3,94% in the EU and 2% worldwide (2009). In terms of final energy consumption, biofuels account for just 0,6% of the global needs. The EU average masks a certain variability between countries, with counties such as Slovakia in one extreme (almost 9% biofuel penetration rate) and Bulgaria in the other (0,18%).

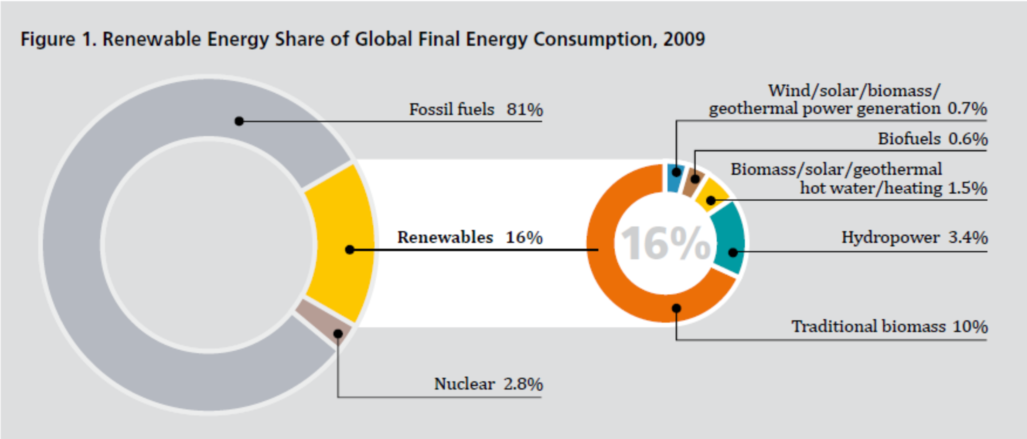


Figure 8: Renewable energy share of global energy consumption (2009). ***Source*****: REN21, 2011.**

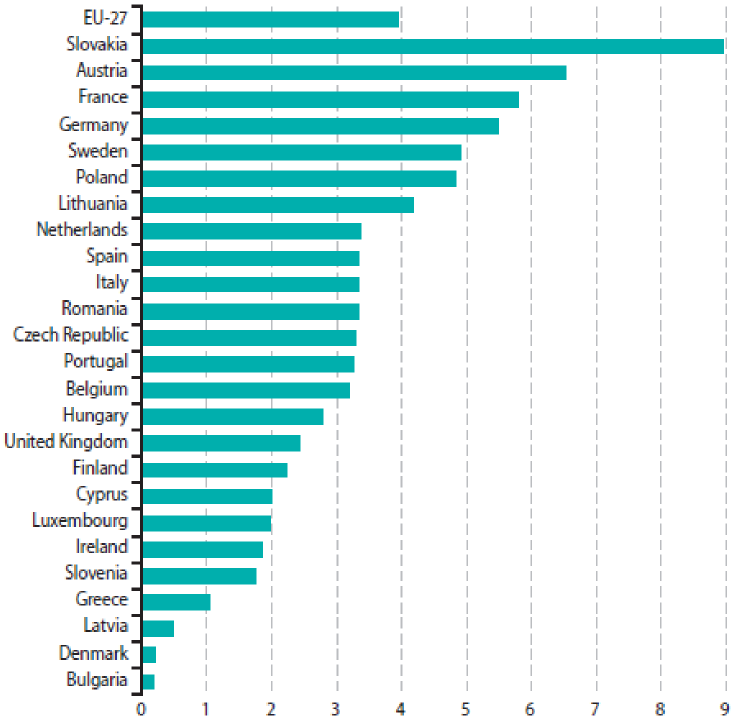


Figure 9: Share of biofuels in fuel consumption of transport (2009). ***Source*****: Eurostat, 2012.**

In the USA, biofuels are expected to account for about 9% of all transportation fuels in 2012. Brazil should also be highlighted since the biofuel penetration rate reached a staggering 21% in 2008 (equivalent to 12 million tons of oil) as a result of policies to promote ethanol production from sugar cane enacted in the 70s.

2.4 Biofuels are highly incentivized and subsidized

Directive 2009/28/EC introduced the so called 20-20-20 targets, by which the EU pledges to: (a) reduce greenhouse gas emissions at least 20% below 1990 levels; (b) produce 20% of the energy from renewable resources; and (c) reduce primary energy use in 20% compared with projected levels. In addition to these targets, the share of energy from renewable sources in the transport sector must amount to at least 10% of final energy consumption in the sector by 2020. Given that existing penetration rates of biofuels are around 4%, meeting this goal will require more than doubling current production figures. Biofuels need however to meet several sustainability criteria in order to fall under the Directive ruling. Greenhouse gas emission savings, for example, must be at least 35%, and they must reach 50% in 2017; in addition, biofuels shall not be produced using raw materials from land with high biodiversity value or with high carbon stock.

To increase production and reach proposed targets, countries have been directly and indirectly subsidizing biofuels. According to ActionAid, a non-governmental organization, the difference in price between conventional fuel and biofuels is will cost EU vehicle owners as much as €126 billion between 2010 and 2020.

Table 2: Value of government support to biofuels in selected countries (2010). ***Source*****: IEA, 2010.**

	2007	2008	2009
United States	4.9	6.6	8.1
Ethanol	*4.6*	*6.2*	*7.7*
Biodiesel	*0.3*	*0.4*	*0.4*
European Union	6.3	8.0	7.9
Ethanol	*1.3*	*2.0*	*2.1*
Biodiesel	*5.0*	*6.0*	*5.8*
Brazil	2.3	2.5	2.6
Ethanol	*2.3*	*2.5*	*2.6*
Biodiesel	*0.0*	*0.0*	*0.1*
China	0.3	0.6	0.5
Ethanol	*0.2*	*0.5*	*0.4*
Biodiesel	*0.1*	*0.1*	*0.1*

Table 3: Current government support measures for biofuels in selected countries. ***Source*****: IEA, 2010.**

3. Food prices, price volatility, and food security

3.1 Food prices are experiencing a sharp increase since mid April 2012

A drought affecting almost two-thirds of the contiguous USA – the largest moderate to extreme drought area since the 1950s – is driving up prices of internationally traded crops. Corn prices have already exceeded their 2008 and 2011 peaks, rising 23% during July alone. Wheat and soya bean prices have closely followed this trend. At the same time, grain harvest forecasts were revised downwards to 1810 million tons. In the EU, also as a result of abnormally hot and dry weather in central and southern Europe, Stratégie Grains – a monthly reference publication for cereal market analysis in Europe – amended its forecast for corn output by 7,1 million tonnes to 58.1 million, a 13% drop from 2011. Globally, grain stocks are expected to fall by 29 million tons by the end of 2012/13, and corn stocks in particular are forecast at a six-year low. The International Grains Council reports however that, "despite the possibility of further downgrades to crop estimates, food supplies remain ample and exports are likely to continue."

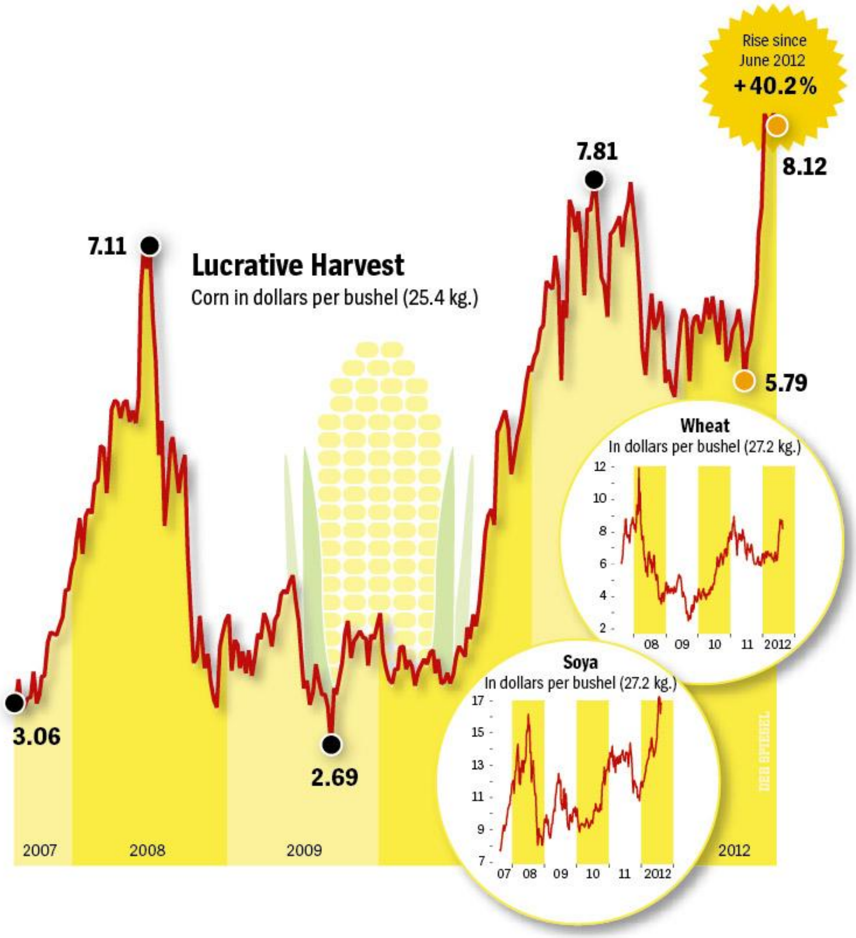
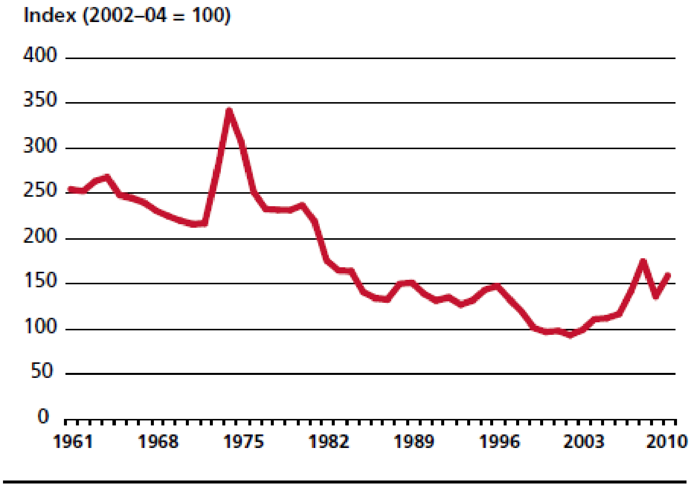


Figure 10: Skyrocketing prices for agricultural commodities. ***Source*****: Spiegel online (2012).**

When analysed from a longer term perspective, food prices declined consistently from the early 1960s until 2002, since when they started an upward trend. Still, when compared to record highs during the 1972-74 food crisis, food prices are still considerably lower.

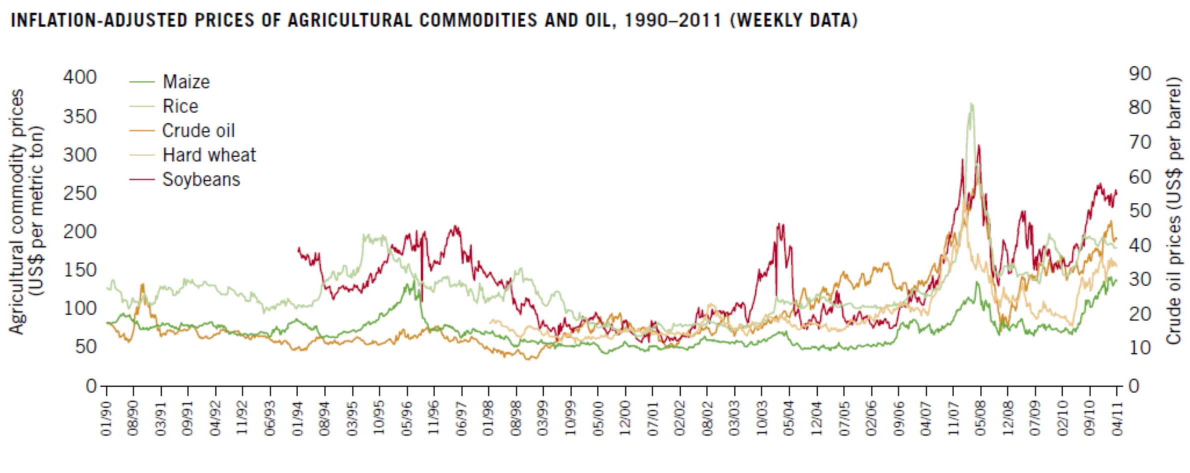


Note: FAO Food Price Index, adjusted for inflation, 1961–2010, calculated using international prices for cereals, oilseeds, meats, and dairy and sugar products. The official FAO Food Price Index has been calculated since only 1990; in this figure it has been extended back to 1961 using proxy price information. The index measures movements in international prices, not domestic prices. The United States gross domestic product deflator is used to express the Food Price Index in real rather than nominal terms.
Source: FAO.

Figure 11: FAO Food Price Index adjusted for inflation (1961–2010).

3.2 Food price volatility is becoming more common

Not only food prices are increasing, they are also becoming less stable are more prone to spikes, rendering predictions and food security budget estimates increasingly difficult. For hard wheat, for example, excessive price volatility increased from an average of 33 days a year between December 2001 and December 2006, to an average of 85 days a year between January 2007 and June 2011. Price peaks are of highest concern, and during the last five years alone there were two. The price of staples such as wheat more than doubled in 2007/8 and, after a short stabilization period, a further and even more pronounced spike occurred in 2010/2011.



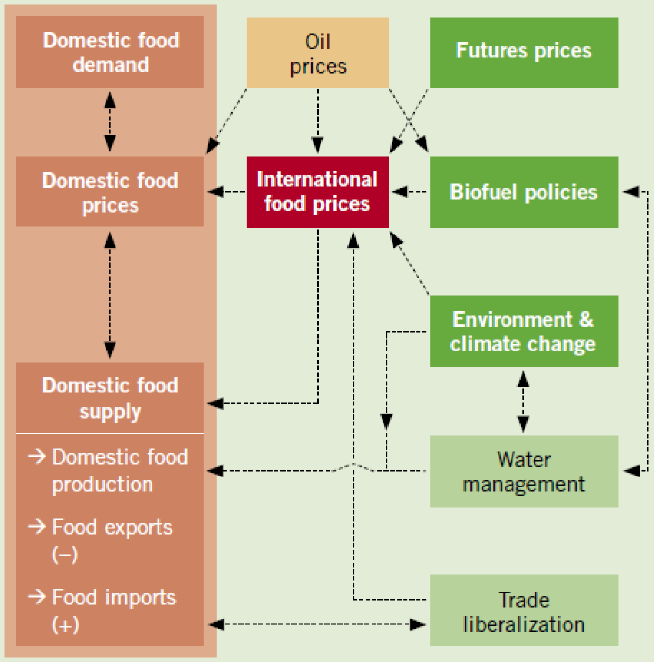
Source: FAO (2011a), International Grains Council (2009), and US Energy Information Administration (2011).
Note: Prices are adjusted for inflation using a consumer price index base year of 1982–84 (that is, 1982–84 = 100). Maize is U.S. No. 2 Yellow, wheat is U.S. No. 2 Hard Red Winter, rice is White Thai A1 Super, soybeans are U.S. No. 1 Yellow, and crude oil is the spot price for West Texas Intermediate at Cushing, Oklahoma.

Figure 12: Inflation-adjusted prices of agricultural commodities and oil (1990-2011).

3.3 Biofuel production, financial speculation, and climate change are to blame for peaks and swings in crop prices

World food prices are the result of complex set of long and short-term factors. Three of such factors explain most of the observed changes in food prices in 2007/08 and 2010/11:

- expanding biofuel production through rigid and ambitious mandates (cf. section ###);
- rise in financial speculation through commodity futures markets;
- increasingly frequent extreme weather events, probably as a result of climate change.



Source: Maximo Torero.
Note: Because of their impact on transportation and input costs, oil prices directly affect domestic and international food prices. They also indirectly affect international food prices by altering the competitiveness of biofuel production. Similarly, biofuel policies influence water management by creating competition between biofuel production and food production for access to water.

Figure 13: Key factors contributing to food price inflation and volatility.

It is now generally accepted that financial speculation has been exacerbating food price spikes. Particularly since the beginning of the 2008 crisis in financial markets, many investors worldwide decided to divert part of their assets to food derivatives markets. According to the Barclays Bank, such speculative cash amounted to $89 billion by June 2012. Even though derivatives markets are supposed to protect both producers and consumers by levering risks and stabilizing prices, the significant influx of money ended up inflating futures crop prices. Prices in the spot and futures markets tend however to an equilibrium as economic actors tend to minimize losses and maximize profits, so speculation in derivatives end up inflating real crop prices.

On top of these factors, price peaks and volatility were exacerbated by policy failures and market overreactions. For example, during the 2007/08 food crisis, 15 countries (among which major food exporters such as Russia), levied export restrictions in an attempt to limit price increases in their respective domestic markets and prevent shortages of supply. These restrictions however led to an abnormal decrease in supplies on the global market and heightened the crisis. Overall, the International Food Policy Research Institute estimated that trade restrictions accounted for as much as 30% of the increase in prices in the first half of 2008.

3.4 Food prices have a direct impact on food security and undernourishment

Food markets are relatively inelastic by nature – particularly grain supply, since it is usually limited to a single annual harvest. This means that even tough price inflation creates an incentive for farmers to become more efficient and increase production, outcomes take time to be felt. If needed, additional short-term supply must come from either domestic stocks or international sources. Grain markets are therefore quite vulnerable to relatively small shocks, especially when stocks are low. Price volatility also make revenues more unpredictable, and farmers may delay significant investments because of that.

Moreover, experience with the 2007/8 food crisis shows that domestic prices are in many cases tightly connected to world market prices. Poor countries and net food importers such as Malawi and Senegal were hardest hit because of their low reserves and lack of funds. Domestic prices in Malawi, for example, increased by 28% for rice, 26% for wheat and 26% for corn during that period.

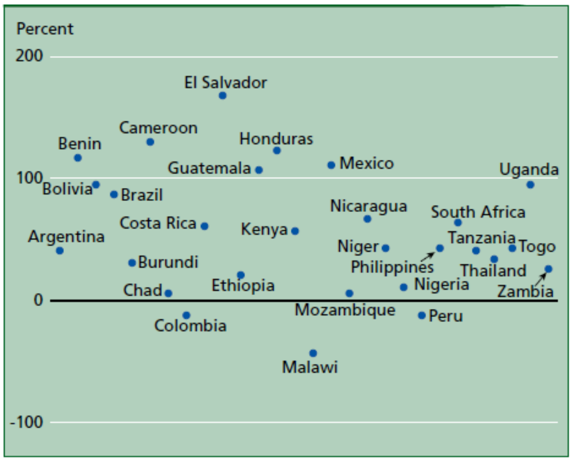


Figure 14: Increase in domestic corn prices after world price peaks (June 2010 – April 2011).

As a consequence, any factor that can trigger price swings or increases may have dramatic effects in terms of food security. Again, the poorest are the most vulnerable. The number of undernourished people augmented 8% in Africa between 2007 and 2008; worldwide, during that period, 100 million people were pushed into poverty. Later, in 2010/11, a famine affected 12 million people across the Horn of Africa again due to rises in food prices.

To examine how much rising food prices and increased price volatility made poor people worse off, IFPRI estimated the impact of price changes between 2006 and 2008 on the welfare of poor people in three countries—Bangladesh, Pakistan, and Vietnam:

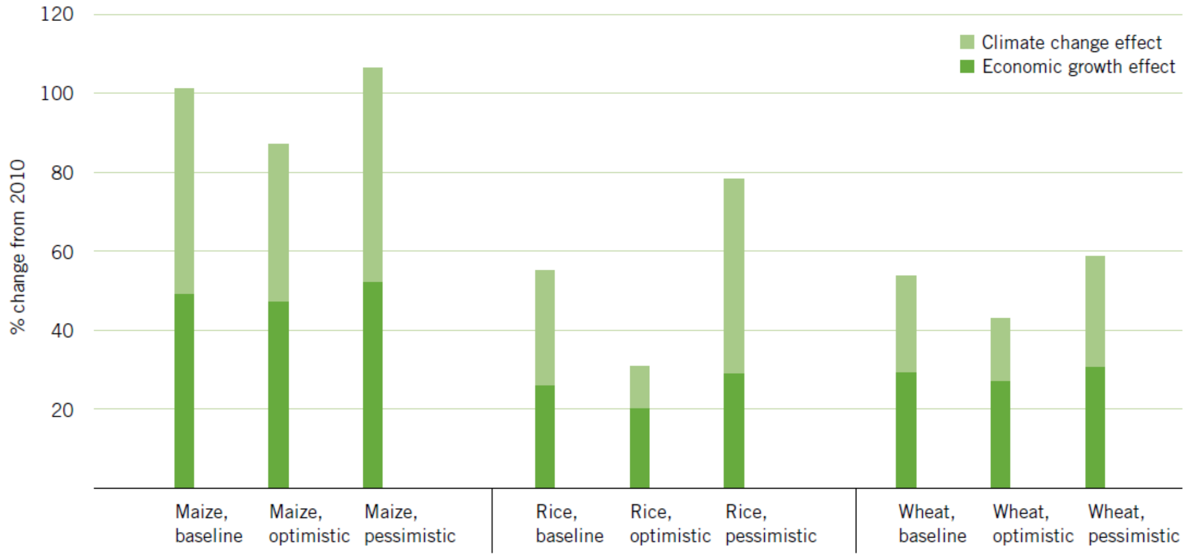
- → In both Bangladesh and Pakistan, increasing food prices left an estimated 80 percent of households worse off. In Vietnam, 51 percent of all households were likely worse off, whereas 64 percent of rural households in Vietnam may have been better off.
- → Among households that were worse off, the poorest households were estimated to experience the greatest losses in spending.
- → Households in Bangladesh lost an average of an estimated 11 percent of their household spending; households in Pakistan and Vietnam lost about 5 percent.
- → Increasing food prices caused poverty rates in Bangladesh and Pakistan to rise by an estimated 5 and 2 percent, respectively. In contrast, higher food prices could have reduced poverty in Vietnam by 8 percent because rice producers benefited from higher prices.
- → If countries were to fully compensate the poorest fifth of households for their losses stemming from higher food prices, the cost in Bangladesh would represent an estimated 1.3 percent of total national spending; in Pakistan, 0.67 percent; and in Vietnam, 0.31 percent.

Source: Robles (2010).
Note: These estimates are at the microeconomic level and incorporate first-round and substitution effects. The study simulates the real price change of the most important food items in each country between the first quarter of 2006 and the first quarter of 2008.

Figure 15: Estimating the effects of rising food prices and excessive volatility on the poor.

3.5 Food demand and food prices are expected to grow

World population is currently around 7 billion people, of which about 1 billion are undernourished, and increases annually by 1%. Meeting this growing food demand and delivering an European standard of living to people worldwide has been estimated to require a 100% increase in food production until 2050. However, arable land is estimated to increase just by 5%. Such an intense pressure on the food system is very likely to lead to even higher and more volatile food prices compared to those we already experience nowadays. According to the International Food Policy Research Institute, between 2010 and 2050 corn prices are expected to increase by 44% in the optimistic scenario or 52% in the pessimistic scenario just as a consequence of the demographic and economic pressures. If the influence of climate change is also accounted for, price increases are expected to reach magnitudes between 88 and 106%.



Source: Nelson et al. (2010).
Note: The study for this graph considers three combinations of income and population growth: a baseline scenario (with moderate income and population growth), a pessimistic scenario (with low income growth and high population growth), and an optimistic scenario (with high income growth and low population growth). Each of these three income/population scenarios is then combined with four plausible climate scenarios that range from slightly to substantially wetter and hotter on average, as well as with an implausible scenario of perfect mitigation (a continuation of today's climate into the future). The climate change effect presented in the graph is the mean of the four climate change scenarios.

Figure 16: World food price increases under various climate change scenarios (2010–2050). ***Source*****: IFPRI, 2011.**

4. Producing biofuels in a *full world*

"Full world" is the expression introduced by Herman Daly to refer to a human economy where remaining natural capital, and not human capital, is the limiting factor in economic development. The question therefore arises whether it is sustainable to devote large areas of cropland to produce biofuels given the sheer pressure ecosystems are already subject to. In terms of climate change, energy return on input and return on investment, it is also important to assess whether the promotion of biofuels is a rational choice, or whether investments in alternative energy sources or carbon sinks ought to be preferred.

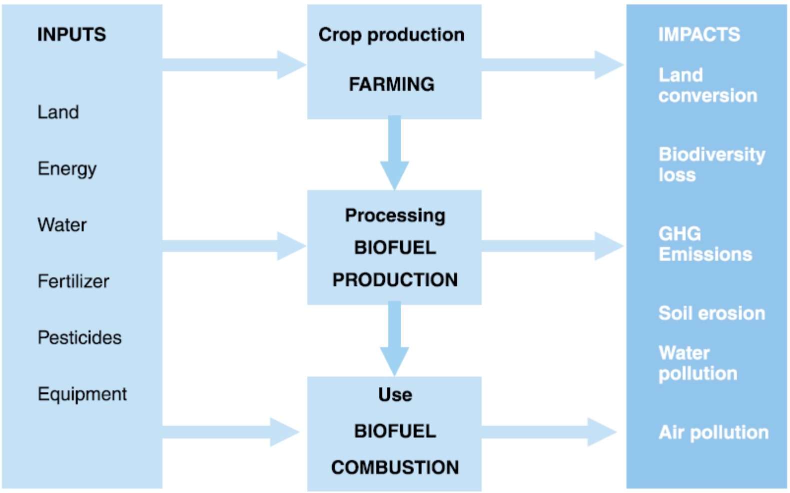


Figure 17: Environmental impacts of biofuels production. *Source*: UNEP, 2009.

4.1 Production of biofuels inflates food prices

The fixed biofuel mandates established by several countries aimed at making their production more appealing, yet this policy aggravates the price inelasticity of demand thereby exacerbating agricultural price fluctuations (FAO et al., 2011; FAO, 2011). Biofuels also influence food prices by strengthening the link between food markets and energy markets. Food costs are naturally dependent on energy prices by way of electricity and fuel consumption (either directly in machinery and irrigation systems or embodied in any equipment, fertilizers, etc.), but the sheer scale and inherent volatility of the energy market may be critical if the linkage becomes too strong. For example, if a crop's value is higher in the energy market than in the food market, farmers will be tempted to divert their harvest to the production of biofuels (IFPRI and Welthungerhilfe, 2012). Although there is no consensus on the exact scale of biofuels interference in food prices (particularly corn) because of methodological difficulties, the effect is estimated to range between 12 and 75% (GSI, 2012).

ORGANIZATION (STUDY)	WEIGHTING (PERCENTAGE) ASSIGNED TO BIOFUELS	FOOD BASKET ANALYZED AND METHODOLOGY
The World Bank (Mitchel, 2008)	70–75 per cent	Ad hoc approach not adopting a structural model but attempting to identify key factors affecting food commodity prices focusing on maize, wheat, rice, oilseeds and on the Index of food commodity prices since 2002 (reflecting export prices)
IMF (Lipsky, 2008)	70 per cent of the increase in maize prices and 40 per cent of the increase in soybean prices	Based on IMF research into 2007 price rises with no further explanation of research methodology available
International Food Policy Research Institute (Rosegrant, 2008)	25–30 per cent	Partial equilibrium model (IMPACT Model) analyzing the interactions among agricultural commodity supply focusing on maize, wheat, sugar, oils and cassava
U.S. Federal Reserve (Baier, Clements, Griffiths,& Ihrig, 2009)	12 per cent	Estimated direct effects using simple supply and demand equations then added indirect affects to the equations with focus on corn, sugar, barley and soybean prices. Findings: increase in world biofuel production accounts for 12 per cent of the rise in IMF food price index from June 2006 to June 2008. U.S. biofuel policy accounts for 60 per cent of this effect, Brazil accounts for 14 per cent and the EU accounts for 15 per cent
U.S. Congressional Budget Office (CBO, 2009)	Between 28 per cent and 47 per cent of the increase in U.S. maize prices	Analyzed maize prices between April 2007 and April 2008 in attributing price increases to increased ethanol production

Source: GSI synthesis

Figure 18: Contribution of biofuels expansion to food price rises on the global market in 2006–2008. Source: GSI, 2012.

Interesting insights were also proposed by a quantitative model developed by the New England Complex Systems Institute (2012). The model is able to replicate FAO's Food Price Index over the last eight years and predicts a new price peak – even higher than recent peaks – to occur immediately. The peak is anticipated and magnified by the drought, but it would still take place by the end of 2012 as a result of speculative activities and corn-to-ethanol conversion. In contrast, if speculation were to be curbed urgently, the rise in prices due to the drought would be considerably smaller and smoother. The model further predicts that should the mandatory ethanol quota be eliminated, a sudden price drop would take place.

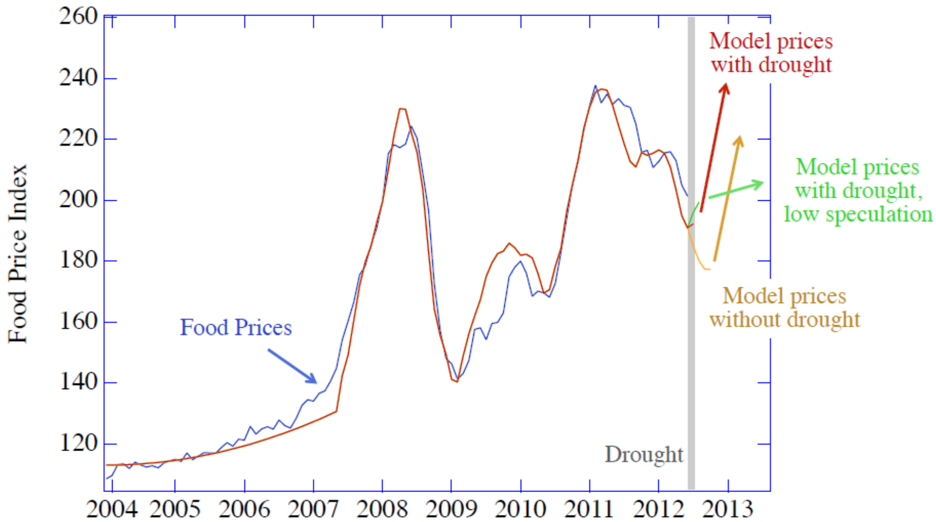


Figure 19: Food prices and model simulations. ***Source*****: NECSI, 2012.**

The Institute for European Environmental Policy has also developed their own models in an attempt to estimate the specific impact of biofuel demand driven by EU policies on commodity prices in 2020. Wheat prices are expected to increase between 1 and 13%, sugar (beet/cane) prices could rise between 2 and 21%, and corn between 8 and 22%. Prices of oil seeds and vegetables oils, in turn, could inflate 8 to 20% and 5 to 36%, respectively (IEEP, 2012).

In addition to their influence on food security via food prices, fuel crop plantations may have a direct effect on people's livelihoods and food security. Recently, the UN Special Rapporteur on the right to food, Olivier De Schutter, and the UN Special Rapporteur on the rights of indigenous peoples, James Anaya, reported on moves to convert 1–2 million ha of rainforest and small-scale farming plots to an export-led crop and agrofuel plantation in the Meruake region of Indonesia, potentially affecting the food security of 50 thousand people. Examples like this are multiplying across the world, particularly where indigenous peoples and poor communities cannot express their concerns.

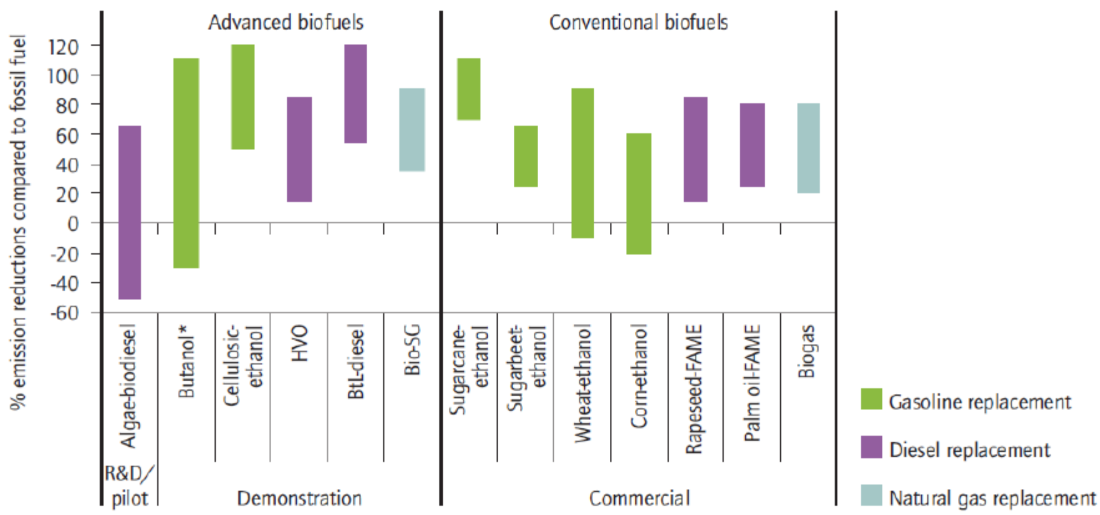
4.2 Induced land use changes make first generation biofuels a feasible option to curb GHG only in limited circumstances

Reduction of GHG emissions has been pointed out as the main reason underlying the strong incentives in place for the production of biofuels. Yet, from a GHG emissions perspective, well-to-wheel analyses suggest that shifting to biofuels is a rational option only in a limited number of cases.

For first generation biofuels, the highest GHG savings (as compared to fossil fuels emissions) are obtained when producing ethanol from sugar cane. Savings range from 70 to more than 100%. Bioethanol made from corn can save up to 60% but may also increase emissions in 5%.

GHG emissions from biodiesel production face even higher uncertainties, particularly if palm oil is used. In this case, savings of 80% might be achieve, or a negative balance (*i.e.*, higher emissions than if fossil fuels were used) up to -2070% could result (IEA, 2011). High savings depend on high yields, whereas increased emissions take place when production occurs on converted natural land and the associated mobilisation of carbon stocks is accounted for. In this sense, palm oil expansion in Southeast Asia is particularly worrying. In Indonesia, two-thirds take place on converted rainforests, of which one quarter contained peat soil with a high carbon content. Not surprisingly, 432 years are needed to compensate for the released carbon (Ravindranath et al., 2009). If current trends continue, in 2030 the total rainforest area of Indonesia will have been reduced by 29% as compared to 2005, and would only cover about 49% of its original area from 1990 (UNEP, 2009).

In terms of GHG emissions, the best commercial option seem to be ethanol derived from sugarcane. Other options could offer substantial savings but real figures are highly dependent on factors such as the biofuel energy content, crop productivity, feedstock type, conversion technology process, and depreciation time (UNEP, 2009). Selected second generation biofuels – currently in pilot or demonstration phases – could offer in some cases an advantage over first generation biofuels. For example, BtL biodiesel and cellulosic ethanol both allow savings in the range of ~50 to 120%.



*Emission savings of more than 100 per cent are possible through use of co-products. Bio-SG = bio-synthetic gas; BtL = biomass-to-liquids; FAME = fatty acid methyl esters; HVO = hydrotreated vegetable oil

Figure 20: Greenhouse gas savings of biofuels compared to fossil fuels exclusive of indirect land use change impacts. *Source*: IEA, 2011.

One of the key challenges of life cycle assessments is however how to account for indirect land use changes. Contrarily to direct land use changes, which can be observed and measured, biofuel production might trigger unintentional land use changes elsewhere. As current production of biofuels requires large tracts of land that could otherwise be used for food production, it is very likely that as a consequence agricultural activities will expand to previously wild or set aside areas in order to cope with rising food demand. As long as the global cropland required for agricultural based consumption grows, such indirect land use displacements cannot be avoided.

These land conversions may have extremely negative consequences in terms of GHG emissions. For example, the conversion of forest peatland to palm oil releases 3452 ton CO_2/ha and requires 423 years to offset the resulting carbon debt (UNEP, 2009). In a comprehensive assessment, Ravindranath et al. (2009) developed six global scenarios of land conversion over a 30 year period required to replace 10% of diesel and gasoline consumption with biofuels (*i.e.*, achieve a 10% penetration rate). Annual CO_2 emissions in 2030 for the baseline scenario (fossil fuels only; no biodiesel use) are estimated at 0,84 billion ton. Biofuels could reduce this figure as much as 0,17 to 0,76 billion tons (20–90%), but they would be exceeded by emissions caused by land use changes estimated at 0,75 to 1,83 billion ton. A worse balance would be achieved if the emissions released in cultivation, transportation, and processing of the biofuels are also taken into account, thereby reducing the amount of CO_2 substitution by biofuels by 20-90%.

In the EU, it was estimated that the additional use of conventional biofuels required to meet the blending mandates by 2020 would result in indirect land use changes ranging from 4,7 to 7,9 million ha. Overall, the policy would lead to an uplift of GHG emissions between 31,3 and 64,6 million ton of CO_2 equivalent (GSI, 2012). A model developed by the International Food Policy Research Institute points into the same direction and shows that few biofuels are able to comply with the sustainability criteria set by the European Commission. The certification of biofuels according such criteria proves very difficult in part because there is no international consensus about a methodology able to estimate indirect land use changes and associated GHG emissions. In sum, there is presently a substantial risk of sacrificing the ecological sustainability of ecosystems while aggravating, instead of mitigating, climate change.

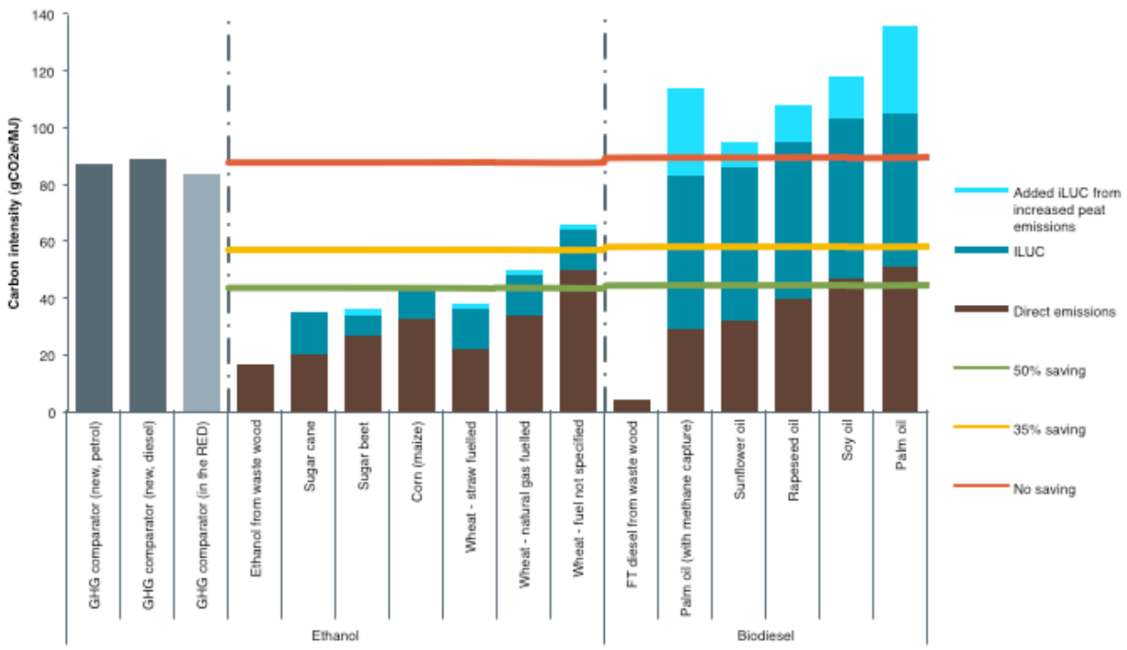


Figure 21: Emissions from different biofuel pathways based on the IFPRI/MIRAGE model. ***Source*****: ICCT, 2011.**

4.3 From an energy return perspective, biofuels are mostly outcompeted by other renewables

Photosynthesis is a very inefficient process. Plants transform into biomass only about 0,5% of all the energy absorbed by Earth's terrestrial vegetated surface. A good way to compare the efficiency of energy production between different production processes is by analysing the energy return on investment (EROI). EROI is the ratio of the amount of usable energy returned from a particular energy resource to the amount of energy spent to obtain that energy resource. When applied to bioenergy production, EROI generally only considers the energy input from fossil fuels and not from other sources of energy (*e.g.*, heat from burning wood or sugar-cane straw).

Compared to other commercially viable energies, including renewables, most biofuels have relatively low EROI. For example, the EROI of wind turbine electricity generation is 18, of photovoltaic electricity is seven, but usually falls well below three for most bioenergy alternatives. Even ethanol production from sugar cane in the tropics, with an EROI of eight, can only be reached when bagasse is used as the main energy source for ethanol distillation. This option is generally not sustainable as the bagasse should be plowed under in order to replenish the carbon stock in the soil. In terms of area efficiency (*i.e.*, the energy production per unit of area), again photovoltaics and solar thermal collectors are mostly 10 times more efficient than plant photosynthesis (German National Academy of Sciences Leopoldina, 2012).

As useful as EROI can be, it should not be the only nor the main criteria for policy making. GHG (already analysed) and price considerations are other important factors. Moreover, not every type of fuel may be replaced by electricity producing alternatives with higher EROI. Airplanes for example require energy densities that can nowadays only be achieved by certain liquid fuels. As such, even if biofuels could be considered a second-best alternative, their production might still be needed.

	EROI	Area efficiency (W m^{-2}) (year's average) [e)]
Firewood (Germany)	10 [a)]	< 0.2
Biodiesel from rapeseed (Germany)	< 2 [a)]	< 0.2
Bioethanol from maize (USA)	1.5 [a)]	< 0.3
Bioethanol from sugar beet (Germany)	3.5 [a)]	< 0.4
Bioethanol from sugar cane (Brazil)	8 [a,b)]	< 0.5
Bioethanol from Triticale/maize (Germany) (combined production)(Chapter 2.11)	8 [a)]	< 0.3
Bioethanol[a)] methane[a)] and electricity from lignocellulose (Chapter 2.11)	3	< 0.5
Bioethanol from switch grass (USA)	5.4 [a)]	< 0.2
Bio-butanol	< 1 [a)]	
Biodiesel from algae (Chapter 1.17)	< 1 [a)]	
Biogas from maize silage (Germany)	4.8 [a)]	< 1.1
Biogas from maize silage (Germany) (electricity)	1.4	< 0.4
Photovoltaic (Germany) (electricity)	7	> 5
Photovoltaic (Brazil) (electricity)		> 10
Wind turbine (Germany) (electricity)	18	2 – 3 [c)]
Nuclear power (electricity)	10 – 20 [d)]	
Hydropower (electricity)	100	

a) Combustion energy

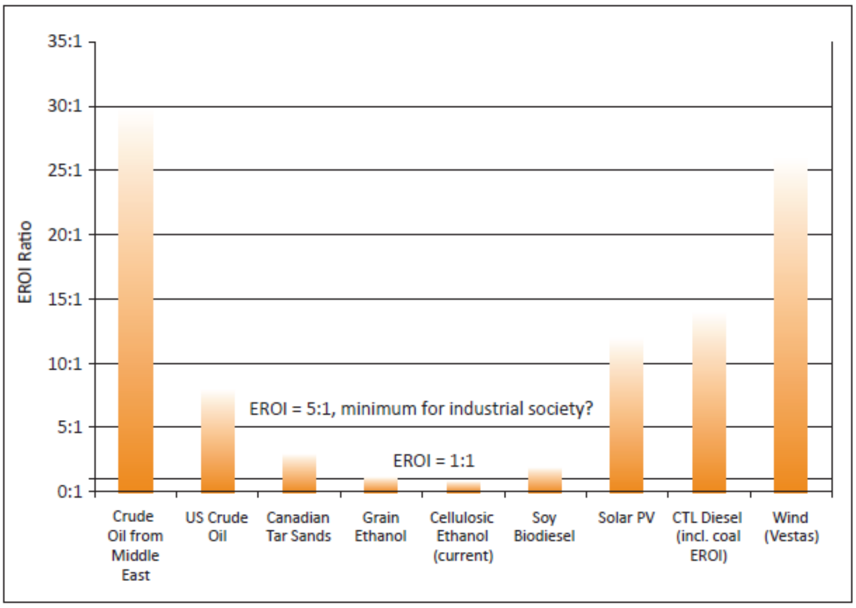
b) This high EROI is reached only when bagasse (the residue from sugar cane after it has been crushed to extract the juice) is used as the main energy source for distillation, which is not sustainable because of the resulting loss in soil carbon (Chapter 1.12).

c) Land based standard wind farms; the land between the turbines may be used for agricultural or other purposes.

d) EROI estimates for nuclear power as low as 1 and as high as 50 can be found in the literature.[70] The estimates are problematic because of the still poorly developed database for the costs of deconstruction and making good the damage caused by catastrophes.

e) Average power during 365 days and 24 hours a day

Figure 22: Energy return on investment and area efficiencies of selected fuels and renewables energies. *Source*: German National Academy of Sciences Leopoldina, 2012.



Note: EROI measurements are not standardized; the shading indicates ranges from various studies. Abbreviations: PV = photovoltaic; CTL = coal-to-liquids; Vestas = Vestas Wind Systems.

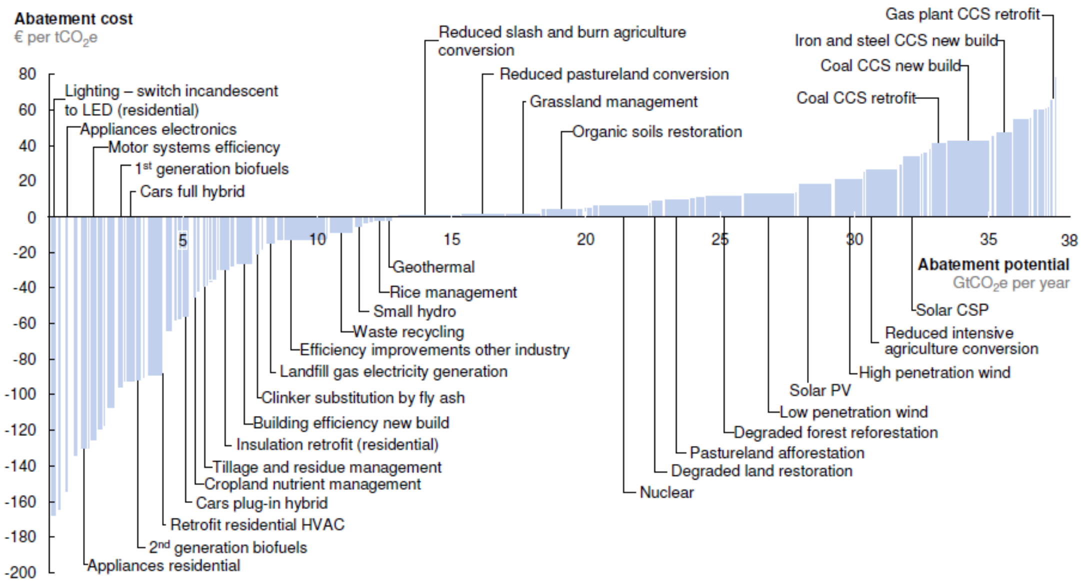
Figure 23: EROI of different types of energy. *Source*: Fridley, 2010.

Another aspect should be taken into consideration. Globally, it has been estimated that humans appropriate 23,8% of potential net primary productivity (Haberl et al., 2007), but in countries like Germany, the figure may rise to as much as 75% (German National Academy of Sciences Leopoldina, 2012). This implies that the fraction of primary production used by human society is in some places already larger that that used by other living beings. An extension of intensive agriculture for biofuels production must acknowledge this aspect.

4.4 Production costs of biofuels are expected to decrease and to become increasingly competitive compared to fossil fuels

According to Mckinsey (2010), biofuels (either first or second generation) are, from a cost perspective, a cost effective option to curb GHG emissions. Mckinsey's marginal cost abatement curve position biofuels in the section yielding a profit for society, even if GHG savings are not large. It is not clear, however, if the effects of indirect land use changes were taken into consideration.

When considered from a pure production cost perspective, biofuels are in most cases more appealing than their fossil fuel counterparts, particularly as technologies are expected to mature and bring costs down. Ethanol produced from sugar cane is the currently cheapest option, costing between 60 and 75% of the gasoline equivalent. Advanced biofuels generally involve higher capital expenditures than first generation biofuels, but their raw materials (such as ligno-cellulosic feedstocks and biomass from domestic waste) are usually cheaper than the feedstocks used for conventional biofuels. Advanced biofuels like those produced through BtL processes have therefore the potential to become cost-competitive in the long-run. Whether or not this will happen depends on the interplay between a complex series of factors, including future biomass feedstock prices and the extent to which upscaling and technological learning is able to lower production costs (IEA, 2010).



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Figure 24: Global abatement cost curve beyond business as usual – 2030. Source: Mckinsey, 2010.

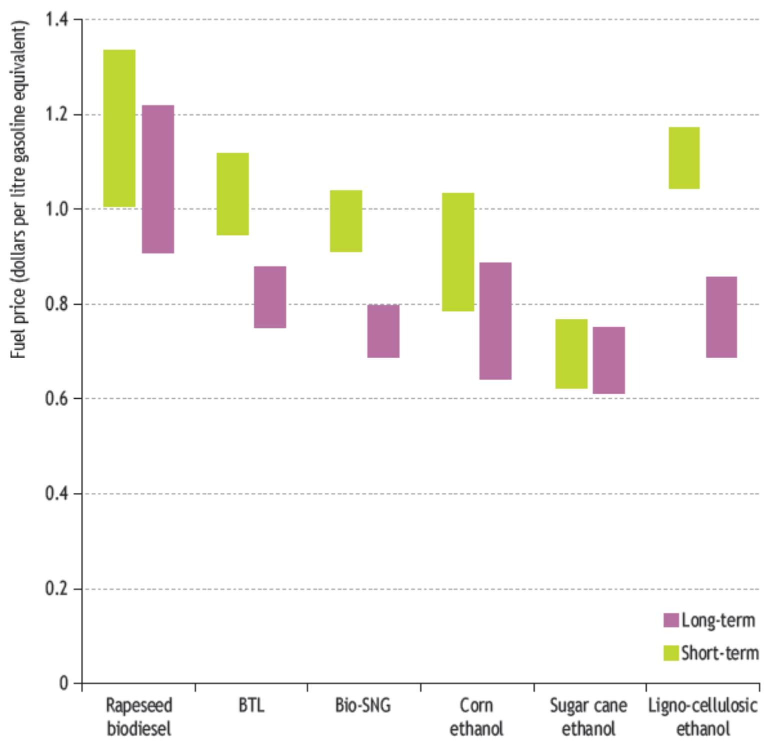


Figure 25: Indicative cost ranges of selected biofuels vs. fuel prices. *Source*: IEA, 2010.

5. Recommendations and conclusions

5.1 Recommendations by selected organizations and individuals

The director-general of the Food and Agriculture Organization, José Graziano da Silva, has recently published a text in Financial Times (09/08/2012) stating:
"With world prices of cereals rising, the competition between the food, feed and fuel sectors for crops such as maize, sugar and oilseeds is likely to intensify. One way to alleviate some of the tension would be to lower or temporarily suspend the mandates on biofuels. (…) An immediate, temporary suspension of that mandate would give some respite to the market and allow more of the crop to be channelled towards food and feed uses."

The Special Rapporteur on the right to food, Olivier De Schutter (2011), has urged governments to remove support schemes for the production of biofuels:
"Several countries subsidize the production and consumption of ethanol or biodiesel. Such policies achieve generally very little for the environment, and they increase the tension between supply and demand on agricultural markets. They also send a signal to financial actors that they will reward by speculating on farmland and on agricultural commodities. The Special Rapporteur on the right to food (…) has noted that 'the current path in the development of agrofuels for transport is not sustainable, and that if such development goes unchecked, further violations of the right to food will result. Pending the adoption of an international consensus on this issue, any new large-scale investment into the production of agrofuels for transportation should be authorized by government authorities only when its detailed and multi-stakeholder assessment is positive in terms of its implications, both at the domestic and international levels, for the right to food, social conditions and issues related to land tenure, including the displacement of farmers and the indirect environmental impact this might cause in terms of land use. All measures encouraging a market for agrofuels (blending mandates, subsidies and tax breaks) should be revised, since such measures encourage speculation by non-commercial investors, who anticipate that the price of agricultural commodities will remain at high levels and rise further as a result of the growing demand for agricultural commodities on international markets, linked to the creation of this artificial market' (A/HRC/9/23, para. 31)."

A number of international organizations (FAO, IFAD, IMF, OECD, UNCTAD, WFP, World Bank, WTO, IFPRI and UN HLTF) released in 2011 the report "Price Volatility in Food and Agricultural Markets: Policy Responses" recommending:
"G20 governments [to] remove provisions of current national policies that subsidize (or mandate) biofuels production or consumption. At the same time, governments should:

- *Open international markets so that renewable fuels and feed stocks can be produced where it is economically, environmentally and socially feasible to do so, and traded more freely;*
- *Accelerate scientific research on alternative paths to reduced carbon emissions and to improved sustainability and energy security;*
- *Encourage more efficient energy use, including in agriculture itself, without drawing on finite resources, including those needed for food production.*

Failing a removal of support, G20 governments should develop contingency plans to adjust (at least temporarily) policies that stimulate biofuel production or consumption (in particular mandatory obligations) when global markets are under pressure and food supplies are endangered."

A panel of international scientists and economists issued by the end of 2011 a Statement on Biofuels and Land Use recommending:
"Peer-reviewed research over the last several years, including studies commissioned by the European Commission, indicates that conventional biofuels can directly or indirectly result in substantial GHG emissions through the conversion of forests and grasslands to croplands or pasture to accommodate biofuel production. Increased demand for crops to make fuel results in higher global commodity prices that can induce farmers in other countries to plow up new ground, including sensitive, high-carbon ecosystems such as tropical forests in South America and Southeast Asia or peatland in Southeast Asia. The conditions for this to occur are not relegated to the future, but are already in place. The [Renewable Energy and Fuel Quality Directives] do not currently account for these emissions in their lifecycle analysis or elsewhere, giving biofuels credit for greater carbon savings than actually achieved. (…)Without addressing land use change, the European Union's target for renewable energy in transport may fail to deliver genuine carbon savings in the real world. It could end up as merely an exercise on paper that promotes widespread deforestation and higher food prices."

In 2012, the German National Academy of Sciences Leopoldina published a detailed report on biofuels where recommends:

- *"Promotion of bioenergy should be limited to those forms of bioenergy that: (a) do not reduce food availability or spur food-price increases due to competition for limited resources such as land or water; (b) do not have large adverse impacts on ecosystems and biodiversity; and (c) have a substantially (> 60–70 per cent) better GHG balance than the energy carriers they replace.*
- *To find the best solutions, further research is required on the measurement of land-use related GHG emissions and on consequential comprehensive GHG life-cycle assessments of different production systems for agriculture, food, and bioenergy. Consequential life-cycle assessments have to be based on models, which are able to reliably calculate the total change in global GHG emissions due to bioenergy deployment.*
- *A combined optimization of food and bioenergy production, e.g. through use of animal manures for biogas production or energy capture from biogenic wastes or agricultural residues holds promise for a significant bioenergy production. The production of bioethanol from starch and sugars is not recommended for Germany because of the associated climate and ecological risks. Importing bioethanol produced from these sources is also problematic for the same reasons. However, combination of bioethanol and biogas production in small, decentralized reactors operating mainly on agricultural wastes does appear to be an option, as long as there is optimal exploitation of internal energy fluxes and all ecological aspects are respected.*
- *Production of biogas from agricultural and municipal wastes deserves to be developed further; from the perspective of waste disposal, alternatives such as direct combustion or pyrolysis should also be included.*

- *Until now biomass, was mainly used for heating (most of the wood) and for electricity production (most of the biogas) rather than for transport. This is of concern since transport fuels are in the long run most difficult to replace. Therefore, the conversion of biomass should concentrate on biofuels for heavy good vehicles, airplanes and large ships that probably, also in the future, can not be powered by electricity."*

A main report prepared by the International Food Policy Research Institute in 2011 concluded:
"The [EU] mandate policy should be flexible enough to deal with a redirection of the policy when new information is made available, but also to tackle short-term variations of agricultural prices. Indeed, the biofuel demand, driven by a mandate, is putting an additional inelastic demand on a market (agricultural products) known for its short-term rigidity in terms of both supply and demand and, therefore, its large price fluctuations. Since a mandatory policy forbids market mechanisms to take place, the biofuel demand will increase price volatility and will have very unintended consequences for poor consumers. Even if not related to the land use effect directly, this channel should not be neglected and must be incorporated in the development of a flexible biofuel policy."

In the Global Hunger Index 2011, prepared by IFPRI and Welthungerhilfe:
"Biofuel subsidies should be curtailed in order to minimize biofuels' contribution to volatility in food markets. It also means that biofuel mandates should be removed to avoid policy-driven conflicts between food and nonfood use of natural resources for agricultural commodities. At the very least, mandate levels should be made flexible so that they are negatively correlated with observed gaps between supply and demand. (...)
To reduce incentives for excessive speculation in food commodities three measures should be introduced: (1) improved documentation through strengthened reporting obligations for commodity exchange, index trading, and over-the-counter transactions (including information about market players, their products, and their scale), (2) increased capital deposit requirements (margins) when each futures transaction is made, to deter momentum-based speculators, and (3) stricter position and price limits (and phasing out of existing position limit waivers for index traders). The recommended measures would reduce the speed of transactions and simultaneously increase the transparency of the market."

5.2 Conclusions

6. References

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