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First-generation biofuels: mixed results around the world

Population growth and improvements in purchasing power in several economic areas of the world are contributing to greater consumption of fossil energy and higher volatility in energy prices. At the same time, concerns in the face of the "climate change" are an incentive to reduce use in order to contribute to cutting greenhouse gas emissions (GHG) of anthropic origin. Both these trends have stimulated research in "greener" or "renewable" alternative energy sources, such as the wind, sun or biomass, over the last decade. Biofuels are one of these alternatives to fossil energies.

With this in mind, the majority of developed or emerging countries have introduced support policies for the production and use of biofuels. In many countries, these policies also aim to support agricultural activity and promote rural development.

This review based on economic analyses from the INRA-SAE2 department and competent bodies (ADEME, French Agency for the Energy Development and Control), the International Agency for Energy, FAO, IFPRI, OECD and so on, draws up an assessment of the biofuel sector on a worldwide scale, showing its implications in energy and environmental terms. It also takes an interest in the support measures granted by the public authorities in favour of this sector and analyses its implications in terms of global food safety.

Mixed results as far as energy and the environment are concerned

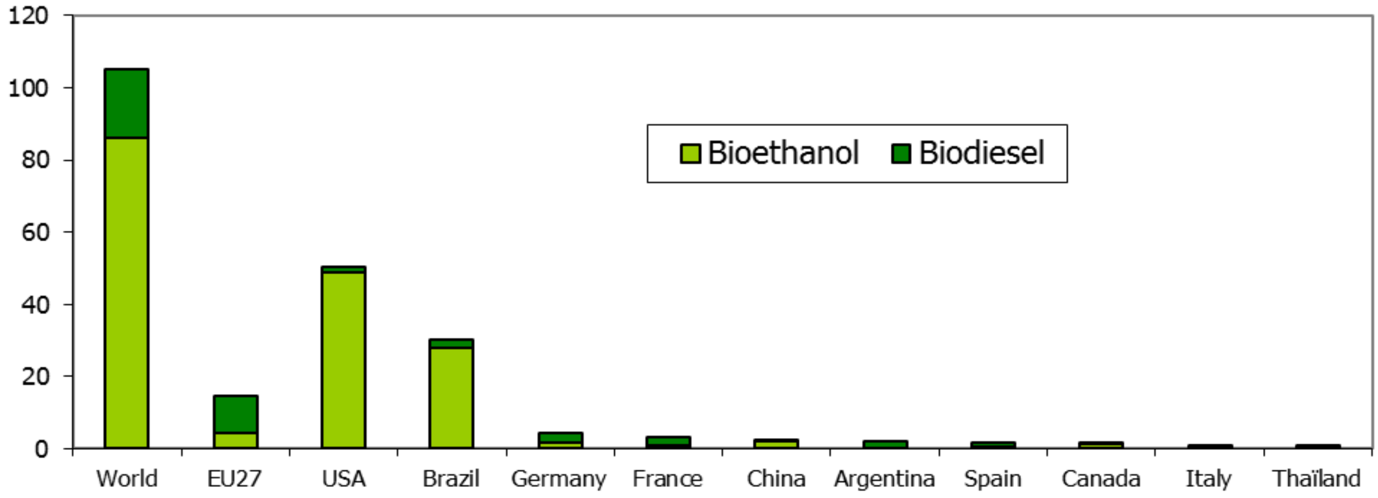
In international political debates on climate change and energy security, bio-energies first appeared as an attractive alternative. They could replace fossil fuels while emitting less GHG. Soaring oil prices further encouraged some States to invest in research and in promoting new sources of energy for transport, heating and electricity production. Today, liquid biofuels are the main source of replacement energy for the transport sector, which remains highly dependent on traditional fuel.

Biofuels (see box 1) were used from the beginning of the 20th century by figures like Nikolaus Otto, Rudolf Diesel or Henry Ford. At that time, they were ethanol, alcohol or various pure vegetable oils such as peanut oil. Plentiful, cheap petroleum reduced their interest, until the first two oil crises (1973 and 1979). As early as 1975, and unlike the European States, Brazil invested in a vast program of ethanol production.

In 2010, the world's two main biofuel producers (bioethanol, biodiesel) are the United States (50 billion litres, or 48% of world supply) and Brazil (29%). The European Union (EU) (mainly Germany, France and Spain) represents 14% of global supply (see graph 1), ahead of Asia (4%, especially in China and Thailand) and, more marginally, Canada and a few other countries (5%). Regarding more specifically the ethanol sector, two countries represent most of world production: the United States (54%, mainly from maize) and Brazil (34% mainly from sugar cane). As for the EU, it is much more focused on biodiesel production (mainly from rapeseed and sunflower oils), representing 53% of world supply (10 billion litres in 2010). The leading producers are Germany (15%), Brazil (12%), Argentina (11%), and France (11%) and, further behind, the United States (6%, chiefly from soya).

At the present time, "second-generation" or "advanced" biofuels remain at experimental state. Their production is chiefly located in North America, in the EU and to a lesser extent in a few emerging countries, such as Brazil, China, India and Thailand.

Graph 1: The top ten biofuel producers in the world in 2010 (in billion litres)



Source: Renewables, 2011

Worldwide, the share of renewable biofuels in final energy consumption was evaluated at 16% in 2009 (Renewables, 2011). Biofuels only contribute 6% of renewable energies. Many developed countries (EU, United States, Canada, Japan and so on) and emerging ones (Brazil, China, India and so on), are developing fuel production by setting minimum targets to be reached in terms of incorporating biofuels into traditional fuels (between 5% and 15%, according to the country, by 2020). This international development is the subject of lively debates, both in the scientific community and in society.

Frame 1: definitions

Biofuel is a fuel produced from non-fossil organic materials resulting from biomass. It is part of the range of energies referred to as renewable (water, wind, geothermal, wood, biogas and so on.) and presented as replacements for so-called primary energies (coal, natural gas, oil).

Today, the two **main sectors** of liquid biofuels are production of **bioethanol** by fermenting farm produce (wheat, corn, beet, sugar cane, and so on) and **biodiesel** from oils (among which rapeseed, sunflower and palm), and there is also a sector around biogas, bio-methane, which can replace the natural gas; charcoal is very little used. These various sectors produce **biofuels** known as "**first-generation**" ones.

There are also a second and a third generation. Unlike the first generation, the **second generation** uses the whole (leaves, straws, stalks or plants) of plants like miscanthus ("elephant grass") to produce biofuels. The **third generation**, or **algo-fuel**, is produced from seaweed which should, in theory, be more efficient than land plants are. The trend towards these new generations is mainly due to the fact that first-generation biofuels use crops intended for human or animal food.

Energy assessment

According to the methodologies used by the competent bodies for energy assessment of biofuels, it would appear to vary widely according to the type of product considered, the geographical location of production and the technologies used (FAO, 2008).

The calculation includes the (mainly fossil) energy used to produce the biofuel and the energy released when it is consumed. When the ratio of energy produced to energy used is equal to 1 that means that the biofuel does not contribute anything to the quantity of existing energy: its energy result is neutral. Therefore, the ratio must be higher than 1 in order for biofuel consumption to release more energy than that needed to produce it. At present, the values of this ratio estimated around the world are between 1 and 4 for biodiesel produced from sunflower, rapeseed or soya. It is less than 2 for bioethanol produced from maize. It is between 2 and 8 for bioethanol from sugar cane.

This variability in the ratio of energy used to energy released mostly results from variability in the "productivity" of the raw materials used. For example, sugar cane and sugar beet currently provide the best yields as regards ethanol production.

This variability feeds controversy as to the benefits expected of biofuels. This variability is increased by the fact that the co-products from biofuel production are not always included in the analyses (Bureau *et al*., 2010). There are several methods to include the negative environmental externalities of the products and co-products. As shown by the works of the French Agency for the Development and Control of Energy (ADEME, 2010), the choice of method has a significant influence on the quantitative results. The inclusion of the co-products is therefore a necessary prerequisite for an effective assessment of the energy results, as they can be re-used in various sectors, such as animal feed and industry as a whole.

The location of biofuel production also plays a role in energy results. For the same type of production, productivity varies from one country to another. For example, the productivity of maize differs widely between the United States and China.

The technologies (cropping and production, transport of materials, technical performance of the industrial facilities) also play a role in energy results because they have an influence on the quantity of fossil fuels necessary to produce the biofuel. This is the case, for example, with bioethanol from sugar cane where the *bagasse* (a residue of the sugar cane process) is more or less extensively re-used according to the countries. In the bioethanol sector, the savings made on non-renewable energy consumption can reach 85%, depending on the technologies, compared with production of ordinary gasoline. The performance is even higher in the case of biodiesels (ADEME, 2010).

Environmental assessment

Today, there is an intense scientific debate around the results of first-generation biofuels in terms of reductions in GHG emissions. Many studies show that assessment of these results is highly sensitive to the impact of biofuel production on land use change (LUC). Each hectare of land that is cropped or not is characterised by a level of carbon stock (depending in particular on the type of land, the climate, previous uses and farming practices). Any change in land use consequently leads to a variation in the stock which can reduce (well) or increase (source) GHG (IFPRI, 2010 and 2011). Biofuels may be cropped on natural non-cropped environments (direct land use) or on land that is already cropped and move food production to another place (indirect land use).

The first GHG assessments of biofuels were highly positive. Most of the studies concluded that first-generation biofuels would induce a 20% to 60% reduction in GHG emissions compared with the classical fossil fuels (FAO, 2008). Moreover, these calculations did not take into account the major question of the change in land use in their calculation methodology. Most of the time, they used the product life cycle analysis method, consisting in recording all the emissions resulting from its production, processing, distribution and consumption (Bio Intelligence Department, 2010). In the case of biofuels, the chain to be considered must cover a wide spectrum going from agricultural production (including farming practices and inputs) to transformation into liquid biofuel and distribution (including transport and storage).

The article by Searchinger et al. (2008) was the first to underline the major role of land-use change (LUC) in GHG assessment of the biofuels. In particular, he was the first to show that when LUC is taken into account, the gap between the GHG assessment of first-generation biofuels and that of fossil fuels is significantly reduced. Land-use change induces emissions of 350 tons of CO_2 per converted hectare (with high variations). Consequently, the authors estimate the "carbon debt", meaning the number of years necessary for the emissions avoided by biofuel production to make up for the initial destocking. The latter would be up to 167 years for ethanol from American maize and 86 years for Malaysian palm oil (DG Tresor, 2010). The GHG assessment may even prove to be negative if direct or indirect LUC are taken into account in the case of disappearance of meadows, wetlands or primary forests (ADEME, 2010 and FAO, 2008).

A very recent critical review of some studies assessing the impact of direct and indirect LUC on the biofuel assessment (ADEME, 2012) shows that if we take LUC into account, two-thirds of the environmental assessments of first-generation biofuels (at world level) fail to meet the sustainability criteria set by the EU (35% reduction threshold in GHG emissions compared with those of the reference fossil fuel). Though the results of these studies vary according to criteria such as the crop studied, the type of fuel produced and the area of supply, the interest of biofuel becomes much less obvious in terms of reductions in GHG emissions.

A lively scientific debate continues on the environmental assessment of first-generation biofuels. There are various approaches to including land-use change, co-products and nitrous oxide emissions (FAO, 2008). In order to take better account of this complex debate, the European Commission will soon propose a new law on the assessment of indirect emissions of GHG from biofuels. The objective will be to distinguish low-pollution biofuels from those that pollute more.

Beyond the sole GHG assessment, some other environmental implications of biofuels are being debated, particularly with regard to land, water and biodiversity resources. Some crops used for biofuel production require more or less use of fertilizers, pesticides and water. Some crops like sugar cane, oil palm trees or maize have particularly high needs. According to some estimations (Bayramoglu et Chakir, 2010), biofuels represent 2% of the irrigation water taken worldwide in a context where the farming sector represents 70 % of the current consumption of fresh water. This rate should increase slightly in the future decade because of the expected increase in the production of biofuels (Havlik *et al.*, 2011).

As regards biodiversity, the development effects of biofuel production are not easily quantifiable and have received little scientific validation. While planting new crops dedicated to the biofuel sector may have a positive effect in some areas of the world (Africa), it may also be a source of ecosystem degradation (loss of local habitats, indigenous species, resources and so on.). These effects are different according to the area, the crop, the intensity of the production model and use of inputs and resources (The Royal Society, 2008). In tropical areas like, for instance, Malaysia and Indonesia, the fast development of biofuels based on palm oil induced major deforestation of the ombrophilous forests and a loss of diversity in wild species, such as certain populations of large apes and tigers (CNUE/FAO, 2007). Of course, countries importing palm oil for the production of biodiesel are concerned by these developments.

In the longer term, several solutions are already adopted or being envisaged to control pressure on natural resources from biofuels. Improvements in yields, the development of integrated farm management ("Good agricultural practices") and the adoption of high-performance infrastructures all contribute to this (FAO, 2008 and FAO, 2012). In France, the adoption, among farmers and industrialists in the biofuel sector, of formalized contracts with technical specifications that are as yet to be defined, could lead to the adoption of more virtuous practices on the environmental level (Bamière *et al.*, 2010).

Internationally, the development of second-generation biofuel production remains prone to lower profitability, high processing costs ((Babcock *et al.*, 2011) and a lack of commercial outlets (Bocquého and Jacquet, 2010). Yet second-generation biofuels have several qualities: higher yield in biomass per hectare, lesser use of lands and more limited GHG emissions. They represent a major opportunity, given the high availability of potentially-usable waste (assessed between 2.3 and 2.8 Gt, (IFP, 2010): cellulose waste, residue from forestry and processing industries and the organic part of municipal waste.

Expensive support policies

Usually biofuels, like other renewable resources, are not yet able to compete with fossil fuels without any support from public authorities (see figure 1). In some fuel-price contexts, only the bioethanol can do that.

Most producing countries have implemented policies to support the production and/or use of biofuels, via to various systems; these policies apply to all the stages in the chain: production (premium for planting crops dedicated to biofuels), processing (subsidies for investments), marketing (tax credits, bonds of incorporation and so on) and consumption (tax exemptions, subsidies for the purchase of vehicles using mixtures).

Within the EU, the main measures (see frame 3) are completed by application of specific customs duties on biofuel imports. Bioethanol is categorized as farm produce and benefits from higher protection than biodiesel which is categorized as an industrial product. In addition to this, the bilateral or regional agreements and preferential treatments adopted between the EU and developing countries allow the admission of biofuels produced in these countries with customs duties close to zero (French Cour des Comptes, 2012).

Even if it is difficult to isolate the specific effects of these measures from the effects of other factors, it seems that they are incentives, given that the biodiesel production community was multiplied by six between 2003 and 2010 (and by eight for bioethanol). Public intervention in this sector may also be justified because biofuels generate gains for society. However, the rules of the World Trade Organization (WTO) apply to such support and recently resulted in the abolition of direct payments for production of biofuels granted to European and American farmers.

In certain countries, in particular the United States, development of biofuels has been a means of increasing the traditional outlets and influencing price dynamics positively. Regardless of the potential cost of support policies, an increasing number of developing countries (chiefly emerging nations) intend to develop their biofuels production. They consider that increasing demand in this sector could contribute to increasing the prices of raw materials which are falling in real terms. The development of biofuels could also facilitate access to energy in rural areas. Agriculture could then drive wider rural development (FAO, 2008).

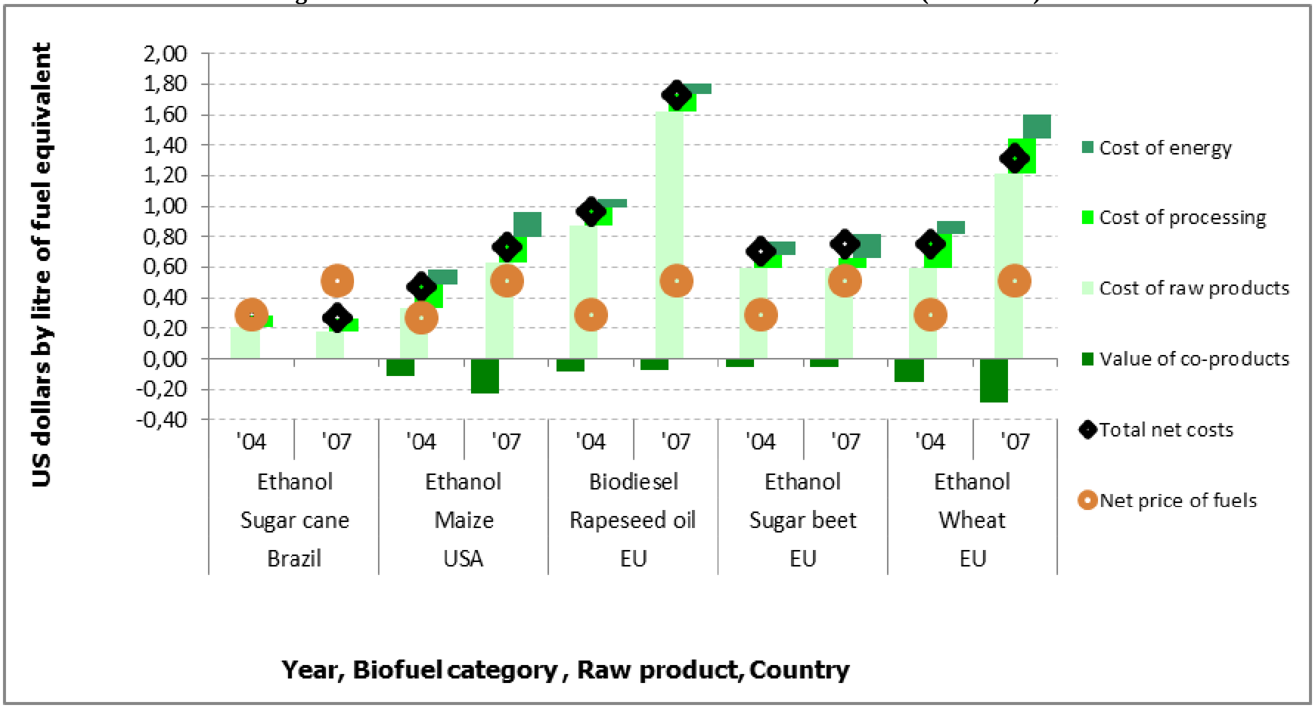
However, certain studies at INRA have stressed that the support measures adopted in favour of biofuels are not necessarily the most effective to support farm activity and farmers' income (Gohin, 2007).

New tensions on food markets

The growing power of the biofuel market is creating new demand for farm produce, and particularly for maize, sugar and oil crops. In 2008-2010, the biofuel sector used 11% of global production of secondary cereals, 21% of sugar production and 11% of vegetable oil production (OCDE-FAO, 2011). In the United States, 30% of maize production was used for ethanol, whereas Brazil used 50% of its production of sugar cane for its biofuels (FAO, 2009). In the EU, 60% of rapeseed oil production was transformed into biodiesel. Given the current trends in the biofuels sector and the statutory rules planned by the various producing countries by 2020, this increase in demand for raw materials for biofuel production should keep on going during the next ten years (IFPRI, 2011).

Figure 1 presents the prospects drawn up by the European Commission and the Food and Agriculture Policy Research Institute (FAPRI) in terms of production, consumption and exchanges of biofuels in the world's main producing countries, as well as the corresponding quantities of agricultural raw materials. According to these projections, American production of ethanol should progress more slowly (from 49 billion to 58 billion litres, that is to say +20% between 2010 and 2020) than domestic consumption (from 48 billion to 69 billion litres, or +40%), thus weighing down on the trade balance. At the same time, American production of biodiesel should be multiplied by 1.7 (from 2 to 4 billion litres), that is to say also at a slower rate than consumption (from 1.7 to 3.8 billion litres); here, too, there should be a deterioration in the balance of trade (FAPRI-ISU, 2011).

Fig 1: Production cost of the main biofuels sectors in the world (2004-2007)



Source: OECD-FAO Agricultural Outlook 2008-2017

In Brazil, production of ethanol should double (from 27 to 55 billion litres), whereas consumption is likely to increase by 60% (from 25 to 40 billion litres). This country should improve its position as a net exporter and see its trade surplus multiplied by six. The quantities of sugar cane used for manufacturing Brazilian ethanol could increase by 80% over that time. According to the projections of the FAPRI, Canada, China and India should record an increase in their ethanol production, respectively by 20%, 30% and 90% between 2010 and 2020.

At EU level, at the same time, production should rise from 6 to 18 billion litres for ethanol and from 10 to 18 billion litres for biodiesel. Consumption should increase as quickly, going up from 8 to 24 billion litres for ethanol and from 13 to 21 billion litres for biodiesel (IT, 2011). The EU deficit should therefore be confirmed. These trends induce a significant increase in the quantities of cereals used for energy purposes, and to a lesser extent in the oil produced from oil crops (FAPRI-ISU, 2011 and IT, 2011).

Food security in question

Demographic growth, the change in diets (giving more places to animal proteins) and the increase in consumer's purchasing power in many emerging countries are three key factors which combine to drive a steady increase in world demand (OECD/FAO, in 2011). In this context, the development of biofuels is an additional factor, among others (speculation on agricultural commodity markets, the climate, etc.), which tends to weigh on changes in international prices (Voituriez, 2009).

The current rise in foodstuff prices observed in the statistics of the FAO weakens the situation of populations in some thirty African countries, in particular net importers of farm produce. It quite particularly concerns rural populations and the poorest farmers (Pisani and Chatellier, 2010). Some of these countries have an added weakness in that they are reliant on imports of cereals and petroleum products (FPA, 2012) at the same time. Among these African countries, thirteen covering a total population of 242 million inhabitants are considered by the FAO as poorly endowed in energy; in 2010 they had a trade deficit on fuels of more than 5% of their GDP. This situation will become even more delicate in the future given the links of interdependence between foodstuff prices and those of the energy. In about twenty other African countries, the situation is considered less dramatic because they benefit from considerable hydroelectric, geothermal and solar potential.
For these latter countries, development of biofuels may take place and give a positive balance of trade.

Frame 2: bioenergy policies in the EU

The EU policy known as the "Energy-Climate Package" sets the main objectives of the Member States regarding energy and adaptation to climate change through to 2020.That is to say: i) bring the share of renewable energies up to 20% of total energy consumption for all the Member States (Directive 2009/28/EC), by raising the share of renewable energies up to 10% in energy consumption of the transportation sector; ii) reduce greenhouse gas emissions compared with 1990 (Directive 2009/29/CE and decision n°406/2009/EC), with an objective of a 10% reduction in greenhouse gas emissions during the cycle of production of the fuels used in transportation (Directive 2009/30/EC and Regulation°443/2009); iii) and increase energy efficiency by 20% , in particular by reducing energy consumption in the building and transport sector (Decision n° 406/2009/EC).

In November 2010, the European Commission adopted an "Energy 2020" plan which defines five priorities for a more sustainable energy system in the economic and environmental sense. This system plans to favour energy savings in the transportation sector, as well as to start a European research project on second-generation biofuels.

The common agricultural policy (CAP) favoured the development of crops (mainly rapeseed and sunflower) intended for the production of biofuels. The 2003 CAP reform allowed farmers to take advantage of the opportunities offered by the production of biofuels. Until 2010, financial support could be granted for the reconversion of land traditionally allocated to food production to energy production. Besides this, until 2008, farmers could use the lands lying fallow for crops others than food, among which those of biofuels (for example rapeseed for diester). Within the framework of the CAP second pillar (Regulation (IT) n° 74/2009), funds were co-financed and investment subsidies were granted for the modernization of farms and renewable energy production infrastructures (biomass and others).

The production of second-generation biofuels will not necessarily eliminate the existing competition in land use between crops intended for food purposes or for energy purposes. This competition will depend on the potential for expanding arable areas at world level and on productivity gains, a point on which there is no consensus as to the long-term trends.

Table1: Projections for biofuel markets (multiplying coefficients between 2010 and 2020)[1]

	EU		**USA***	**Argentina***	**Brazil***	**Canada***	**China***	**India***
	*	**						
Production								
Ethanol	2,6	2,8	1,1		2,0	1,2	1,3	1,9
Biodiesel	1,2	1,7	1,7	1,3	1,2			
Consumption								
Ethanol	2,5	2,8	1,4		1,6			1,4
Biodiesel	1,2	1,8	2,1	1,5	1,1			
Adverse Trade Balance								
Ethanol	1,8	2,7	13,6			1,9		
Biodiesel	1,4	2,9	1,3					
Favourable Trade Balance								
Ethanol					5,7		0,6	3,5
Biodiesel				1,2	1,4			
Raw materials used*								
Ethanol	Wheat 3,2 Maize 2,5 Barley8,8	2,9 4 3	Maize 1,1		Cane 1,8	Wheat1,4 Maize 1,2	Wheat1,3 Maize 1,3	
Biodiesel	Oils of : Rape 1,2 Soya 1,2 Sunflower1,1		Soya 1,2 Others Oils 2,2	Soya 1,2	Soya 1,1			

[1] example: The American production of ethanol would be multiplied by 1.1 – or increase by 10% - between 2010 and 2020.

* Data from the FAPRI-ISU, 2011.

** Data from the European Commission, 2011.

A potential impact on price volatility

In the food sector, the low elasticity of demand in relation to prices, the sensitivity of demand to sanitary factors, the rigidity of short-term supply and dependence of supply on external factors (climate) are the main vectors of price volatility. Agricultural markets are therefore frequently subject to predictable variations in prices (OCDE-FAO, 2011).

In this framework, the production of biofuels and, as a consequence, demand for agricultural raw materials from the biofuel sector is highly dependent on the price of fossil fuels. The development of biofuels, which is largely governed by the regulations (incorporation requirements), may contribute to an increase in price volatility (Gohin *and* Tréguer, 2010; Babcock *and* Fabiosa, 2011). Further to the 2009 world economic crisis and to the momentary drop in energy prices, the rate of expansion of the biofuel sector has slowed down and prices have fallen (by 6% for ethanol and 26% for biodiesel).

This mechanism of market interdependence also applies to non-food production, as underlined in the works by Havlik *et al.*, (2010) concerning forestry products. The demand for forest products is traditionally guided by factors linked to demand for construction products, consumption or fuels. Studies conducted in the French forestry sector (Lecocq *et al.*, 2011) show that the growing use of forest biomass to produce biofuels (or, more widely, renewable energies) could induce an additional increase in annual harvesting of 12 million m^3 within 5 years (that is to say a third more than at present). These volumes remain much lower than potential availability, estimated at 80 million m^3 a year (CEMAGREF, 2007).

Internationally, the numerous studies currently underway do not allow any final conclusions as to the energy and environmental balance of biofuels. The results of these works are contrasted and much debated, according to the considered geographical areas, the raw materials and the technologies used. The arguments between experts essentially concern the degree of precision of the calculation methodologies and the spectrum they cover. At all events, the benefits of the first-generation biofuels sector are the subject of controversy, all the more so given the public funds dedicated to their expansion. The major increase in international food prices and their greater volatility raises questions as to the strategies to be preferred in the long term. The benefits of this sector must therefore be analysed in the broad context of world food supply security which outweighs the purely economic interest of the main producing countries. The arrival of second-generation biofuels comes up against a problem of economic profitability. It is nevertheless carrying great hopes in terms of improving (energy and environmental) assessments and reducing competition between food and non-food outlets (International Energy Agency, 2010).

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For further information

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