Biofuels Worlwide

The biofuels market is booming: after more than 20 years of industrial development, global biofuel production is growing fast. Willingness to reduce their oil dependence and necessity to promote low-carbon energies are the two main drivers for states to support biofuels development.

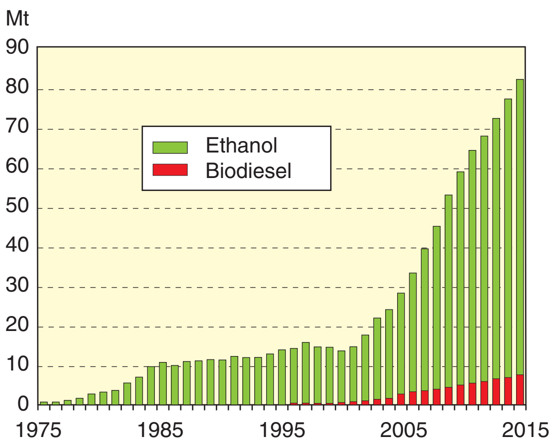
The production of biofuels worldwide is increasing sharply. The United States, Brazil and Europe account for most of this growth, although many other countries are also showing interest in motor fuels of vegetable origin.

Exponential growth

Today, biofuels are regarded as a real alternative to petroleum-based motor fuels, even if they probably can never fully replace them. For one thing, they reduce the chronic oil-dependence of the transport sector. They also reduce greenhouse gas emissions due to their mode of utilization. Since biofuels are blended with petroleum-based motor fuels, they are easier to introduce than gaseous replacement fuels: there is no need to install new distribution infrastructure or convert existing vehicles.

Every day, current events bring confirmation of this boom and motor fuels of vegetable origin are now to be found all over the world. In the last five years, global biofuel output grew at a rate of about 15% a year. More recently, the rate of increase has accelerated: 2005 biodiesel production was up by more than 60% year on year. In 2005, world biofuel output totaled 22 Mtoe (about 31 Mt), a figure that is expected to more than double by 2015 (Figure 1), in light of the growth targets set by many countries.

Fig. 1 Trend in world biofuel production



Source: F.O. Licht, Christoph Berg, presentation made at World Biofuels 2006, Seville, May 2006

Current production technologies

Two biofuels account for the bulk of production and utilization: **ethanol** in gasoline engines and **vegetable oil methyl esters (VOMEs)** in diesel engines. Ethanol is made from two types of crop: sugar-producing plants (sugar cane, sugar beets) and plants yielding amylaceous material (wheat, corn). Most of the world's ethanol is produced from sugar cane or corn. The other biofuels in existence today, the VOMEs, are derived from vegetable oils (e.g. rapeseed, sunflower, palm or soybean).

The world market is dominated by ethanol, mostly produced and consumed in the United States and Brazil. World consumption of VOMEs, which remains specific to Europe, is lower by a factor of ten. In 2005, world production of ethanol motor fuels amounted to 27 Mt (18 Mtoe) versus total biodiesel output of nearly 4 Mt (3.6 Mtoe)[1]. In 2006, ethanol production is expected to reach 40 Mt of which 80%, or almost 32 Mt (21 Mtoe), will be used for motor fuels. Biodiesel output is expected to exceed 5 Mt (4.5 Mtoe).

Biofuels: advantages and disadvantages

Environmental considerations

It has been fully demonstrated that replacing conventional motor fuels with biofuels reduces greenhouse gas emissions (GHGs) and the consumption of non-renewable energy. This is one of the main arguments in favor of using them on a large scale. When used pure, they can induce GHG emissions gains as high as 90% for those pathways with the highest efficiencies (i.e. the ones using sugar cane). The other technologies used to produce vegetable-oil-based biofuels yield gains that may be lower, but still remain positive (cf. the Panorama article entitled: *"Biofuels and their environmental performance"*). Furthermore, one may observe similar gains in terms of the consumption of fossil energy needed to produce these fuels. It has to be noted that IFP is also actively involved in studies undertaken to evaluate other environmental impacts of large-scale biofuel development, for example impacts on water resources.

(1) Source: FO Licht, 2006

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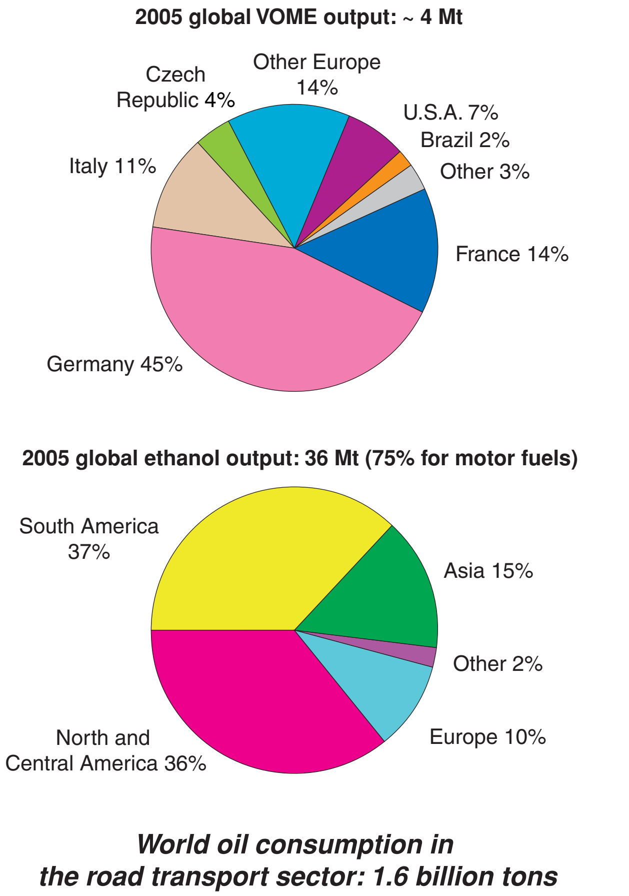
Fig. 2 Global biofuel production



Economic considerations

Biofuels offer another advantage in that the replacement of petroleum-based products reduces oil dependence and enables exploitation of domestic resources.

Their cost, although still high, is nearing that of conventional motor fuels, i.e. gasoline and diesel (cf. Table 1), as a result of the upward trend in the price per barrel (not taking taxes into account).

In Brazil, ethanol production costs are especially low and already competitive with those of petroleum-based motor fuels.

Table 1
Production costs for different motor fuels

	EtOH Europe	EtOH Brazil	EtOH USA	VOME Europe	Gasoline $60/bbl	Diesel $60 /bbl
€/l	0.4-0.6	0.2	0.3	0.35-0.65	0.32	0.36
€/GJ	19-29	10	14	10.5-20	9	10

Source: IEA/IFP: Price of motor fuels for France, exclusive of tax, December 2006, €1 = $1.3.

In most cases, biofuels still cannot be developed without public funding (the United States allocated an estimated $5-7 billion in 2006[2]). This is especially true now, given the high level of demand and the particularly elevated prices of ethanol in the United States and Brazil, and of VOMEs in Europe. In the United States, the ethanol price climbed to $3/gal in November 2006 ($0.6/l, or nearly $730/t, double the announced production cost). In Brazil, the ethanol price is in the vicinity of $0.4/l (nearly double the announced production cost). In Europe, the VOME price reached €700/t, due to an increase in the price of rapeseed oil (quoted at nearly $800/t in Rotterdam[3] in November 2006), while ethanol climbed to €0.6/l (€750/t or slightly over €1,100/toe).

For biofuels, like petroleum-based motor fuels, the cost of production depends heavily on the price of the raw material, which represents between 50 and 90% of the final cost. The price of wheat, corn, vegetable oils and rapeseed can vary greatly and substantially affect the relative competitiveness of biofuels compared to petroleum products. This is especially true in that the biofuels market can represent a major outlet for these raw materials: 20% of the corn produced in the United States is currently "burned" as ethanol, and 50% of the rape grown in Europe is transformed into biodiesel. In future, demand for biofuels will probably drive up the prices of these raw materials. For example, corn prices in the United States (December 2006) have reached a ten-year high (about $120/t), partly owing to the substantial development of the domestic ethanol market.

Another disadvantage of biofuels is that, for key existing pathways, the per-hectare yield is relatively low: 1 toe/ha for VOMEs made from rapeseed oil or sunflower oil, 1-2 toe/ha for ethanol ex-wheat or ex-corn, and 3-4 toe/ha for ethanol ex-sugar beet or ex-sugar cane. Moreover, agronomic constraints are such that it is not possible to cultivate all species on all types of soil under the same conditions. As a result, if biofuels were to be developed on a large scale using existing pathways, this sector would eventually find itself competing with the food industry for the use of land. Given the abundance of co-products, sales outlets are likely to reach the saturation point, which would eventually make the production of biofuels more costly. To replace 10% of gasoline and diesel consumption in Europe and in the United States, about 20-25% of all arable land in these parts of the world would have to be mobilized. These numbers clearly indicate the limits of existing biofuel technologies and the need for new options in this field if the goal is to reach even more ambitious replacement targets. One pathway that is receiving a great deal of attention is the valorization of

(2) *Biofuels at what cost? Government support for ethanol and biodiesel in the United States, D. Koplow, October 2006.*

(3) *In comparison, oil priced at $70/bbl is equivalent to about $500/t.*

lignocellulosic materials (cf. Panorama article: *"New biofuel technologies"*), which broadens the range of exploitable raw materials, thereby increasing the potential rate of replacement (cf. Panorama article: *"Potential biomass mobilization for biofuel production worldwide, in Europe and in France"*).

Biofuel markets worldwide

Mature markets

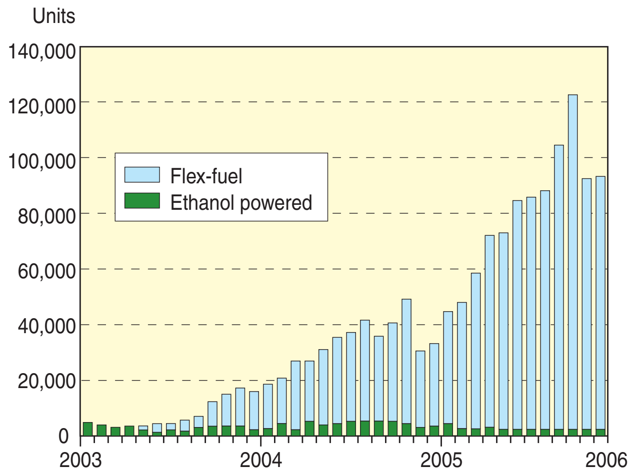
Three large geographic areas currently dominate the biofuels market: the United States, Brazil and Europe.

Ethanol accounts for the bulk of global production, with Brazil and the United States representing two very different business environments.

In **Brazil**, ethanol consumption has seen three key periods: growth between 1975 and 1990 led by the governmental alcohol incentive program, relative stagnation between 1990 and the early 2000s due to the oil countershock, and renewed growth from the early 2000s and the present in connection with the rising price of oil on international markets and, more locally, with the introduction of flex fuel vehicles (FFVs). Here, it is important to stress that the introduction of FFVs in the early 2000s had a decisive effect on the consumption of ethanol motor fuels (Figure 3).

FFVs gave Brazilian consumers at the pump a chance to decide whether they wanted a gasoline containing 20-25% ethanol (a percentage set by the government) or pure ethanol, after they have checked the prices on offer. This flexibility has consumer appeal: in 2005, FFVs accounted for nearly 70% of all vehicles equipped with spark ignition engines.

Fig. 3 Sale of new vehicles running on ethanol in Brazil



Source: ANFAVEA.

Brazil's consumption of ethanol motor fuel totaled nearly 12 Mt in 2005. In 2004, about 60% of the ethanol consumed was sold as a blend (22% ethanol and 78% gasoline) and the other 40% as pure ethanol. The percentage of alcohol used in motor fuels corresponded to almost 40% of national gasoline consumption and about 15% of total motor fuel consumption. In Brazil, the boom in ethanol production is even attracting foreign investors. The objective is to export ethanol on the new global market for biofuels. A number of projects are underway to build infrastructure, including port terminals and pipelines. The prime target market is Japan, whose government is considering imposing ethanol (contents of 3 to 10%) in gasoline products and whose production capacity is very limited. The United States and Europe are also potential export markets, although these countries subject ethanol imports to customs duties of approximately $0.2/l, which limits their economic advantage.

The **United States** ranks Number Two worldwide for the consumption of ethanol motor fuel. Production (mostly ex-corn) reached about 12 Mt in 2005 with growth reaching about 30% year on year and 100% over the last five years. Ethanol does not represent a very significant part of US motor fuel consumption, i.e. about 1.5% of volumes consumed in the road transport sector. The situation is comparable in Europe, where biofuels covered 1.2% of motor fuel demand in 2005. But the sharp increase in consumption observed in recent years should persist, especially in the wake of the new push given by the US government in the final draft of the Energy Policy Act passed during the summer of 2005, and considering the fact that US energy policy is increasingly geared to reducing oil dependence on the Middle East. The Energy Policy Act includes an ambitious biofuel promotion plan aimed to boost output from nearly 12 Mt in 2005 to 22.5 Mt in 2012 by imposing mandatory incorporation measures. As soon as possible, the United States would like to develop second-generation technologies using lignocellulosic materials. The Department of Energy very recently announced that it was reviewing bids for an initial installation to produce ethanol from this type of biomass, scheduled to come onstream in 2012.

Europe has fallen behind Brazil and the United States, which have both implemented large-scale programs. In 2005, Europe failed reach its objective to replace 2% of the petroleum-based motor fuels consumed in the transport sector. Biofuels only represented 1.2% of total road transport consumption (4.2 Mt including 80% VOMEs). In 2005, most of Europe's ethanol was produced in Spain, Sweden, Germany and France. In 2005, Europe developed distillation of its wine surpluses, which represented the bulk of growth for the year. Ethanol imports grew substantially in the United Kingdom, Germany and Sweden. Most of these imports came from other European countries, but also from Brazil. In Europe, except for Sweden, and unlike the United States or Brazil, ethanol is not incorporated directly but transformed into ETBE (obtained by reacting isobutene, a liquefied petroleum gas, with ethanol) before being blended with gasoline. One reason for this regional particularity is the obligation to properly account for motor fuel properties such as volatility, since pure ethanol makes ethanol/gasoline blends more volatile. Another advantage of this practice is that it avoids demixtion (separation of the alcohol and "gasoline" phases) in the presence of traces of water.

On the other hand, **Europe** dominates the global market for **VOMEs**. On the European motor fuel market, diesel consumption is increasingly dominant (60% of total motor fuel consumption). This helps explain why VOME, rather than ethanol, is developing rapidly. VOME production in Europe has risen very substantially in the last ten years, exceeding 3 Mt in 2005. For the last five years, the annual growth rate has averaged 35%. France, Germany and Italy accounted for most of this growth. Some of the countries that have recently joined the European Union, including the Czech Republic and Poland, already possess available capacity and aim to become key market players. For more information about the regional situation, see the Panorama article: *"Biofuels in Europe"*.

Brazil is not exclusively interested in ethanol. In 2003, it launched a domestic program to promote the use of VOME-based motor fuels in order to curb diesel imports and ensure local development in disadvantaged areas. Soybeans will probably be the principal source of vegetable oil for this program—Brazil is the world's Number Two producer of soybeans—although other sources, such as the castor bean, are also under consideration. Brazil is planning a 2% blend, to be made mandatory by 2008.

In 2007, Brazil is also hoping to launch a new diesel fuel named H-Bio on the domestic market. H-Bio is obtained by refining a blend containing 90% crude and 10% vegetable oil (soybean oil). Brazil is one of the top three world soybean producers along with the United States, which ranks first, and Argentina, and it is the leading producer of soybean oil. According to Petrobras, the development of H-Bio could reduce domestic diesel imports by 25% by 2008.

Another particularity is that Brazil is planning to use ethanol to produce vegetable oil ethyl esters (VOEEs) instead of methanol to produce VOMEs.

The **United States** is also starting to focus on VOMEs which, for many years, were not mentioned in the legal texts regulating the use of biofuels. Today, they are clearly identified as one of the alternatives to diesel fuels for heavy vehicles available to fleet managers, in particular. Financial incentives are granted for using these or other alternative fuels to replace petroleum-based products. Currently, the most commonly used type of VOME is a 20% blend (B20). As of January 1, 2005, a tax exemption of at least one cent/liter per percentage point was granted for VOME blends, so the exemption for the B20 comes to 20 cents a liter. Biodiesel production in the United States is growing quickly: inferior to 100,000 t in 2004, it reached about 250,000 t in 2005 and should come close to 850,000 t in 2006. This sharp uptrend should continue, at least in the next few years. In September 2006, US biodiesel production capacity was estimated to be nearly 2 Mt and is expected to rise by nearly 5 Mt over the next 18 months. Once these plans have been carried out, the United States should become the leading VOME producer worldwide. In the US, the standard regulating VOME quality does not contain any restrictions bearing on the iodine index, which is used to measure the degree of saturation of the ester, in contrast to the European standard (the index must not exceed 120). This enables the world's top soybean producer to make biodiesel from soybeans (the iodine index for soybean-based esters is high, about 135).

Emerging markets

In a new development, **many other countries** are planning to implement ambitious domestic biofuel programs as the price per barrel returns to high levels on the world energy market. In Latin America, Paraguay, Argentina, Colombia, Costa Rica and Guatemala are following the Brazilian example. China and India are also setting up programs to encourage the use of biofuels, especially blends containing 5 to 10% ethanol.

In **China**, the Number Two corn producer worldwide, ethanol is usually made from corn. The use of ethanol as a motor fuel was introduced by the tenth five-year plan for environmental protection (2001-2005), which called for the replacement of conventional petroleum-based motor fuels with a blend containing about 90% gasoline and 10% ethanol in nine provinces (Jilin, Heilongjiang, Henan, Anhui, Liaoning, Hebei, Hubei, Shandong and Jiangsu) by year-end 2005. Four units produce the ethanol for this program, with output of about 1 Mt/year. Other ethanol production units are in the planning stages. China has also signed a technical cooperation agreement with Brazil and is considering the importation of Brazilian alcohol.

India, the second-largest global producer of sugar cane after Brazil, is also planning to develop the use of ethanol in 5% blends. In 2003, it had planned to make the use of 5% blends mandatory nationwide. This target could not be attained: crops were adversely affected by unfavorable weather conditions and the construction of infrastructure to produce anhydrous ethanol was delayed. Even so, nine states and three regions made it compulsory to use gasoline containing 5%

ethanol, provided that ethanol of adequate quality was available in sufficient quantities at a price competitive with petroleum-based motor fuels. Domestic capacity for the production of ethanol suitable for blends (anhydrous ethanol) comes to at about 500,000 t/year. India has entered into a technical cooperation agreement with Brazil bearing on the production of anhydrous ethanol and the optimization of its use in vehicles.

Malaysia and **Indonesia**, major palm oil producers, are supporting the use of biodiesel by setting targets to replace between 2 and 5% of diesel consumption by 2008-2010. Malaysia is seeking to boost biodiesel production for export, to Europe in particular.

Although **China** consumes between 60 and 70 Mt of diesel a year, of which about one-third is imported, its production of biodiesel remains symbolic. With output estimated to be 100,000 t/year, Chinese biodiesel is made from "recycled" cooking oil and dedicated oilseed crops (jatropha, etc.).

India is also planning to produce biodiesel, mostly from jatropha oil. A committee is currently studying ways and means. The goal is to reach the testing stage for new blends (up to 20%) by 2011.

The importance of tax incentives

In all of the countries aiming to develop biofuels, favorable tax measures have had a major impact at two levels: an impact on motor fuels, via full or partial tax relief, and on agricultural policy. The measures taken vary greatly from one geographic area to the next.

In **Brazil**, the most important changes were as follows:

- Tax incentives specific to the purchase of vehicles running on pure ethanol were withdrawn to encourage the development of blends.
- The ethanol market has "opened up" since 1997 and 1999, putting an end to guaranteed prices.
- The government set mandatory levels (20-25%) for the ethanol content in gasoline that partially guarantee the volumes consumed.
- The sale of ethanol has been almost totally exempted from tax.

In **the United States**, the use of ethanol is subject to two key regulatory texts: the Clean Air Act of 1970, modified in 1990, and the Energy Policy Act of 1978, regularly amended or added to since it was passed. Under the Clean Air Act, gasoline for sale must contain a minimum oxygen content (2% and 2.7% by weight) in areas where air quality is not up to federal standards. Until recently, refiners used MTBE to achieve this objective, but a number of states (e.g. California in 2003) have banned MTBE for public health reasons. The replacement of the latter with ethanol helps explain the upsurge of demand in recent years. Moreover, derogating from volatility standards made it possible to use gazohol (10% ethanol added to 90% gasoline by means of splash blending).

In parallel, the Energy Policy Act set forth the tax incentives granted to ethanol. The exemption granted since 1978, regularly renewed, was extended until 2007 for 10%, 7.7% and 5.7% blends. The tax exemption for ethanol was reduced in three stages to 53, 52 and 51 cents/gallon (14, 13.7 and 13.5 cents/l) in 2001, 2003 and 2005, respectively. By way of an indication, the gasoline tax is currently about 40 cents/gallon (10.6 cents/l). In addition to these tax deductions, many states offer further exemptions, which in some instances amount to about 20 cents/gallon (5.3 cents/liter).

These incentives are supplemented by other measures. The 2002 Farm Bill subsidized biofuels in different ways. The total amount of subsidies could exceed $150 million/year for the period 2003-2006 (Title IX of the bill).

In the **European Union**, biofuel utilization and taxation is regulated by several Community texts:

- Directive 98/70/EC authorizes the addition of up to 5% ethanol to gasoline for standard distribution; Directive 85/538/EC permits the addition of up to 15% ETBE to gasoline for standard distribution; Directive 85/538/EC permits incorporating 5% VOME into diesel fuel for standard distribution.
- Directive 2003/30/EC promotes biofuels by setting higher targets for biofuel consumption in the transport sector. It imposes a biofuel content of 5.75% (measured in terms of energy) in gasoline and diesel for the transport sector by 2010.
- Directive 2003/96/EC, which bears on taxation, allows member states to exempt biofuels partially or fully from excise taxes.

Each country is responsible for the taxation of motor fuels. Many member states are introducing tax relief for biofuels equivalent to 30 to 100% of the excise taxes levied on petroleum-based motor fuels.

In the European Union, the Common Agricultural Policy has an impact on the economics of biofuel technologies. Two examples illustrate this point:

- The fallow land system allows the use of set-aside land for non-food purposes.
- A subsidy of €45/hectare is granted for energy crops grown on non-fallow land (the current ceiling of 1.5 Mha is expected to burrent ceiling of 1.5 Mha is expected to be raised to 2 Mha).

Biofuels Worlwide

Finally, at year-end 2005, the European Commission issued a biomass action plan in which biofuels figure prominently.

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Outlook

Based on the growth forecasts for production capacity and on the consumption targets in the geographic areas mainly concerned by the use of biofuels, namely the European Union, the United States and Brazil, global biofuel consumption could reach a total of 60 Mtoe by 2015. This would represent slightly more than 3% of world motor fuel consumption in 2015, compared to 1.3% today.

To take production levels higher, it will be necessary to turn to second-generation biofuels based on lignocellulosic materials (wood, straw). One might think that lignocellulosic biomass, more abundant, would not to compete with biomass derived from food crops. Two main options are possible: the first yields ethanol and the second is used to produce synthetic diesel motor fuel using the Fischer-Tropsch process. The second can also be used to produce biokerosene, offering an opportunity to reduce greenhouse gas emissions in the air transport sector, which still has few alternatives to petroleum-based products.

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