# Biofuels Worldwide

*After over 20 years of industrial development, the outlook for biofuels now looks bright. Recent developments indicate that the use of biofuels, previously confined to a handful of countries including Brazil and the United States, is "going global" and a world market may emerge. However, these prospects could eventually be limited by constraints relative to resources and costs. The future of biofuels probably depends on the development of new technologies to valorize lignocellulosic substances such as wood and straw.*

Driven by Brazil, the United States and, to a lesser extent, Europe, the prospects for biofuel development worldwide look bright.

## A Favorable Environment

Since the first biofuel programs were launched following the two oil shocks in the 1970s, the situation has changed considerably.

1. Biofuels have gained real credibility as fuels to supplement petroleum motor fuels. The energy policies of the early 1980s aimed to come up with solutions to replace oil and, in this respect, there were great hopes for biofuels. This vision was best illustrated by Brazil's Proalcohol Program for the development of ethanol. By now, it has become clear that biofuels will never be able to fully replace oil. They offer a solution to supplement gasoline or diesel fuel. They can be incorporated in blends, which is their strong point: unlike other alternative motor fuels (NGV, LPG), they can be used in existing motor fuel distribution networks without having to modify vehicles. This is especially true when, as in Europe, less than 5% is added.
2. Initially appreciated for their capability to reduce polluting tailpipe emissions, biofuels are now being developed for their good "track record" on the emission of greenhouse gases, especially in the transport sector, where the means of action appear more limited. With regard to polluting automobile emissions, substantial gains have been realized without resorting to biofuels, thanks to the generalization of catalytic converters, the improvement of petroleum motor fuels and more efficient engine combustion management.
3. Public authorities are renewing support for biofuels and setting very ambitious consumption goals. These include the following transport sector goals, calculated on energy basis: 5.75% by 2010 and 8% by 2020 in Europe; 4% by 2010 and 20% by 2030 in the United States. Reaching these goals would represent a real breakthrough, but the task is not easy. Judging by the technologies already in place, land use competition between the energy and food industries will have to be intelligently managed. In the effort to attain the 2010 or 2020 objectives, large volumes of coproducts will be inevitably generated and will have to be valorized.
4. Increasingly, the world of agriculture is equating biofuels with attractive new sales outlets. Given a trade environment characterized by tensions—for instance, at the WTO, where the countries from the South regularly denounce the farm support policies practiced in the North—finding new outlets for agricultural products is a priority. Biofuels represent a new outlet relatively protected from international competition. They are still traded in small volumes and do not really compete with petroleum products because they receive public support. Nevertheless, the situation could change; the European and American biofuel markets, for instance, are looking very attractive. Eventually, countries like Brazil (ethanol) and, to a lesser extent, Malaysia or Indonesia (palm oil) will try to export their low-priced production to these new and potentially lucrative outlets. In New York, an ethanol futures market (Nybot) opened last May, which may be a sign that a world ethanol market is emerging.

## The Characteristics of Biofuels

The two main types of biofuel are ethanol, used in gasoline engines, and vegetable oil methyl esters (VOME), with applications in diesel engines. Of the two, ethanol is the most prevalent. Brazil and the United States accounted for most of 2003 global production (about 19 Mt). In the same year, about 1.6 Mt of VOME were produced worldwide, primarily in Europe.

• Ethanol is made from two types of crop: sugar-producing crops (sugar cane, sugar beets) and amylaceous plants (wheat, corn). All of these production processes require a fermentation stage to convert the sugar to ethanol, as well as a more or less advanced distillation stage to separate the alcohol from water. Some processes generate large volumes of coproduct, the most virtuous being the production of ethanol from sugar cane: the principal coproduct, bagasse (sugar cane fiber), is valorized in energy form, particularly for distillation. When producing ethanol from sugar beets, 0.75 t of coproduct (mostly pulp) is obtained per tonne of ethanol. This coproduct is currently reused on the animal feed market. The production of ethanol from wheat or corn yields 1.2 t of residue per tonne of ethanol that can also be exploited on the animal feed market.

Ethanol can be used pure, in a blend or in its ether form (ETBE), obtained in reaction with refinery isobutene. If it used pure or in a very high concentration (*e.g.* 85% or E85), then vehicle modifications are necessary (injection systems, engine adjustment systems, compatibility of plastics and gaskets, special cold-start strategies for pure ethanol). A number of car manufacturers (GM, Ford, DaimlerChrysler, PSA and Renault) have commercialized vehicles that run on E85 or gasoline *e.g.* in Brazil or in the United States. On the other hand, no such modifications are required at lower content levels. Ethanol can be used in concentrations of 5 to 10%, as it is in the United States.

Generally, ethanol is incorporated in blends in relatively low contents (5 to 10%). Technical difficulties can arise: in the presence of trace quantities of water, for example, the gasoline and alcohol phases may separate. This phenomenon is known as demixtion. The addition of pure ethanol to gasoline will increase its propensity to evaporate (by augmenting the vapor pressure). Using ETBE eliminates these disadvantages.

• VOME are produced from vegetable oils made from rapeseed, sunflower, soybean or palm, among other source plants. When seeds are ground to produce the oil, a solid residue called "cake" is obtained (1 to 1.5 t of cake/t of oil). Generally, it goes to make animal feed. Unsuitable for direct use in modern diesel engines, vegetable oils need to be transformed by means of transesterification with an alcohol (currently methanol) to obtain vegetable oil methyl esters and glycerin (0.1 t of glycerin/tonne of VOME). Clearly, glycerin plays a significant role in valorizing this technology. If VOME are to be produced on a large scale, special attention must be paid to trends in the glycerin market, which is relatively small: about 0.8 Mt/year of glycerin is produced worldwide, of which 100 000 t are a by-product of VOME production.

Like ethanol, VOME can be used pure or blended. Vehicles must be modified if they are used pure, which inhibits the expansion of this biofuel. VOME are mostly incorporated in blends in concentrations ranging from a few percentage points to 30%.

## Advantages and Disadvantages

The advantages of biofuels are well known. They provide an alternative to petroleum fuels in the transport sector and offer better environmental performance. With respect to the latter, the main reason for using biofuels is that they reduce greenhouse gas (GHG) emissions. Biofuels can deliver gains of 60 to 90% for the most efficient technologies (sugar cane). Similar gains are obtained with respect to fossil fuel consumption, compared to petroleum-based motor fuels (the energy balance accounts for all stages in the life cycle of the biofuel).

Their biggest disadvantages relate to the availability of resources and the costs of the technologies involved.

As a rule, biofuel technologies post fairly low energy efficiencies per hectare: 1 toe/ha for VOME produced from rapeseed or sunflowers, 1 to 2 toe/ha for ethanol produced from wheat or corn, and 3 to 4 toe/ha for ethanol ex-sugarbeet or ex-sugarcane. Owing to a number of agricultural constraints, it is impossible to grow all species in all soil types under identical conditions. Therefore, one result of large-scale biofuel development will be competition between the energy and food sectors over land occupancy. It will be necessary to find the best trade-offs. Since large volumes of coproduct will be generated, their outlets are likely to reach saturation.

Finally, the cost of producing biofuel is higher than the price of fossil fuels (exclusive of tax), even if the high barrel price is narrowing the gap (cf. Table 1). In Brazil, the cost of ethanol is quite low and already competitive with petroleum motor fuels.

Table 1
Price comparison for motor fuels

| Ethanol Europe | Ethanol Brazil | Ethanol US | VOME Europe | Petroleum motor fuels $25/bbl | Petroleum motor fuels $50/bbl |
|---|---|---|---|---|---|
| €0.4-0.6/l | €0.23/l | $0.3/l | €0.35-0.65/l | $0.2/l | $0.4/l |
| €19-29/GJ | €11/GJ | $14/GJ | €10.5-20/GJ | $6/GJ | $12/GJ |

*Source: IEA/IFP*

Biofuel development still needs appropriate support from public authorities.

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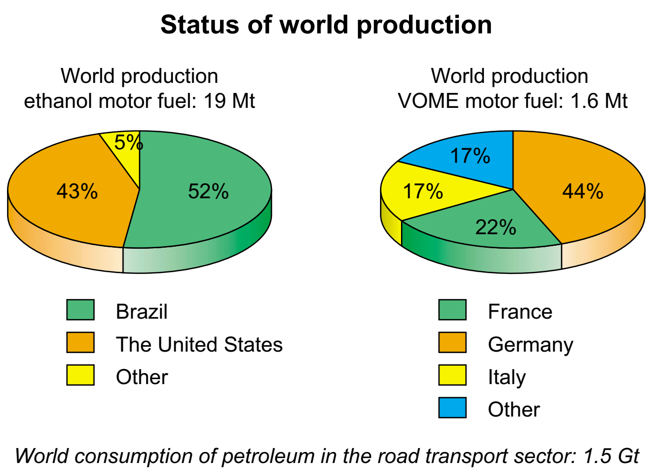
World biofuel production volumes are given in Figure 1.

Fig. 1 World biofuel production volume




In **Brazil**, the Proalcohol Program, rolled out by the government in the wake of the oil crises of the 1970s, was key to developing ethanol production from sugarcane. Between 1973 and 1990, various measures were implemented under this program. The national oil company (Petrobras) guaranteed purchased volume for ethanol. The Government underwrote the price of ethanol, encouraged investment in new units by means of preferential interest rates and subsidized the purchase of vehicles running on pure ethanol. The countershock of 1986 and the fact that Petrobras was very successful in discovering oil fields partially undermined the main argument in favor of developing the technology, which was to avoid being dependent on oil imports.

Following the drop in oil prices in 1986, it was no longer feasible for the Government to support the purchase price of ethanol: the difference between the price of gasoline and that of ethanol was too great. Trends on the sugar market, which was looking more attractive to sugarcane producers, also played a significant role. In the 1990s, the program underwent a major overhaul. The Government planned to encourage the use of blends by withdrawing public subsidies for the purchase of vehicles running on pure ethanol. In 1997 and 1999, it "opened up" the ethanol market and ended price guarantees. The volumes consumed were guaranteed in part, for the government required that 22-24% of ethanol be added to gasoline. Finally, the sale of ethanol was almost entirely exempted from tax.

The Brazilian automobile fleet still numbers nearly 3 million cars that run exclusively on ethanol and about 16 million vehicles that burn a gasoline-ethanol blend. The Government has also introduced a tax deduction to help underwrite the purchase of fuel flexible vehicles (FFVs) able to run alternatively on pure ethanol or a blend. As those vehicles meet a real success, most of the car manufacturer including PSA and Renault are now proposing to sell FFV. Consumption of ethanol as a motor fuel totaled about 10 Mt in 2003 (nearly 40% of national gasoline consumption).

Ethanol production in Brazil is expanding fast. Sugarcane producers are seeking more profitable outlets than the export of sugar, now that world sugar prices are depressed. It is important to remember that trends on the global sugar market have a heavy impact on the ethanol market. Special attention should be paid to the outcome of a case brought before the WTO by Brazil, Thailand and Australia concerning subsidies granted to sugar crop producers in Europe.

In Brazil, a dynamic ethanol market is attracting foreign investors, including the largest European sugar corporations. There are plans to build about 14 new units in the state of Sao Paulo alone. The goal is to export ethanol on a new global market in biofuels. To this end, the first ethanol export terminal (capacity: 32 000 t) was built in the port of Santos this year.

The first target market is Japan, where the government is presently examining the possibility of making it mandatory to add ethanol to gasoline (between 3 and 10%) and where production capacity is very low. The United States and Europe also represent prospective markets, although they currently levy a customs tax on imported ethanol (about $0.2/l) that limits the economic benefit.

Brazil is not only interested in ethanol. In 2003, it launched a national program for the use of VOME. Brazil is the world's number two producer of soybeans, so the latter will probably constitute its main source of vegetable oil although other sources, including the castor bean, are also under scrutiny. Brazil is considering a 2% blend. Another particularity: ethanol may be substituted for methanol in VOME production to obtain a vegetable oil ethyl ester (VOEE) instead of a VOME.

**The United States** is the second largest consumer of ethanol in motor fuel. The production of ethanol (mainly from corn) amounted to about 8.4 Mt in 2003 with growth reaching about 30% this past year and about 90% in the last five years. This uptrend is expected to last: 15 new distilleries were to be built in 2004. The total volume of ethanol produced in the United States is expected to reach 11.2 Mt in 2004, thus exceeding Brazilian output.

The use of ethanol is regulated, for the most part, by two legal texts: the Clean Air Act of 1970, amended in 1990, and the Energy Policy Act of 1978, amended in 1998.

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The amended Clean Air Act of 1990 imposed mandatory minimum oxygen content levels (2 and 2.7% by weight) in gasoline commercialized in areas where air quality does not meet federal standards. Until very recently, refiners used MTBE to achieve this purpose. For public health reasons, the use of this product has been banned in some states, including California in 2003. Ethanol was then substituted for MTBE, one of the biggest reasons why 2003 demand rose so substantially. Moreover, we should note that a waiver to existing volatility specifications was issued so that gasohol (10% ethanol-90% gasoline, obtained by splash blending) could be used in this situation.

At the same time, the Energy Policy Act provided a tax exemption for ethanol. Introduced in 1978 and renewed ever since, this exemption was extended to 2007 for the 10, 7.7 and 5.7% blends, but scaled down in three stages to 53, 52 and 51 cts/gallon of ethanol (14, 13.7 and 13.5 cts/l) respectively in 2001, 2003 and 2005. By way of an indication, the gasoline tax currently approximates 40 cts/gallon (10.6 cts/l). Many states provide additional tax relief, in some cases amounting to 20 cts/gallon (5.3 cts/l).

In addition, political support for biofuels has been increasing. The US agricultural policy implemented in 2002 provided financial aid measures applicable to biofuels and a budget that could exceed $150 million/year during the period 2003/2006 (Title IX, Farm Bill of 2002). President Bush's Energy Bill, which stalled in Congress in 2004, included an important biofuel promotion project with an ambitious goal: boost production from 9 Mt in 2005 to 15 Mt in 2012. It also called for the mandatory use of ethanol in blends.

The United States, the world's leading soybean producer, also began to show interest in VOME. Long absent from regulatory texts concerning biofuels, VOME are now clearly mentioned and number among the alternative fuels that public fleet managers in particular can afford: the users of VOME, like other alternative fuels, are entitled to financial aid. Today, about 400 vehicle fleets burn biofuels containing VOME, generally at a 20% content (B20).

A VOME quality standard was also drafted. It is without any constraint relative to the iodine index (which measures the degree of saturation of the ester), unlike the European standard, which specifies that the iodine index must remain below 120. The reason is that the United States would like to exploit its soybean production, and soybean esters are associated with a high iodine index (about 135). This European specification will be a barrier to the future use of soybean oil esters, hence to their import.

In some states, including the biggest soybean producers, isolated initiatives have been taken. For example, Minnesota passed a law in March 2002 stating that VOME would have to be incorporated in all diesel fuel sold in the state, in 2% blends, by no later than June 30, 2005 provided that the requisite production units are constructed in the meantime.

Finally, the American administration has approved a tax break amounting to 1 ct/percentage point contained in the blend, effective January 1, 2005. For the B20 blend, which will be the most common, the tax exemption will amount to 20 cents. This subsidy should eventually boost production from about 85 kt today to 350 kt (30 Mgal to 124 Mgal).

**Europe** appears to be lagging in comparison with the programs, including some on a large scale, underway in Brazil and the United States. In the last 20 years, only France has remained relatively consistent in implementing this type of policy. Since 2000, however, Germany has taken the lead for VOME while Spain and Poland have moved into the forefront for ethanol.

Contrary to the situation in Brazil or the United States, the European motor fuels consumption has been increasingly dominated by diesel fuel (in Europe, 60% of the total). One reason is the rapid development of VOME, rather than ethanol.

In Europe, VOME production has been growing fast in the last ten years, reaching 1.5 Mt in 2003. Annual growth over the period 1992-2003 averaged 35%. This tendancy should also be seen in 2004, as the production level can be estimated beetwen 1.7 and 2 Mt. France, Germany and Italy accounted for most of this growth.

In 2003, Germany became Europe's top producer of VOME (715 000 t) as well as the top consumer.

France, European leader until 2001, produced 357 000 tonnes in 2003, thus exceeding the quota fixed by the public authorities. It exported the surplus to Germany and Italy. The production quota, set at 317 500 t/year, was revised upwards in 2004 (+70 000 t). It also has been announced that a new 160 000 t/year unit will be built in Sète to feed refineries located in the south of France implementing the IFP's new process: *esterfip H*. Biofuels was one of the strong points of the climate plan introduced by the French government, which approved construction of four new units. It can be added that in 2005, a new 130 000 t quota of biofuels should be granted (100 000 t of éthanol and 30 000 t of VOME).

Number three, Italy produced nearly 273 000 t of VOME in 2003 (growth up 30% over 2002). About 25% of this total served for heating.

Last but not least, several countries that have recently joined the European Union—especially the Czech Republic (current production: about 70 000 t) and Poland—already have the capacity and seem determined to become major players.

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In 2003, European ethanol production remained concentrated in France, Spain, Poland, and, to a lesser extent, Sweden. Practices in Europe (except Sweden) differ from in the United States and Brazil: ethanol is not generally used directly, but transformed into ETBE then blended with gasoline. This European particularity is partly due to compliance requirements relative to motor fuel properties such as volatility (the use of pure ethanol makes the ethanol/gasoline blend more volatile). It also helps avoid demixtion in the presence of traces of water (separation of the alcohol phase and "gasoline" phase).

A longtime European leader in ethanol production, France has been overtaken by Spain and Poland as shown in Table 2 below.

Table 2
Ethanol production in Europe in 2003

| | Ethanol | | ETBE | |
|---|---|---|---|---|
| | In tonnes | In toe | In tonnes | In toe |
| Spain | 180 000 | 115 200 | 383 400 | 329 724 |
| France | 77 200 | 49 408 | 164 250 | 141 255 |
| Sweden | 52 300 | 33 472 | — | — |
| Poland | 131 640 | 84 250 | 280 390 | 241 135 |
| Czech Republic | 5 000 | 3 200 | — | — |
| Total | 446 140 | 285 530 | 828 040 | 712 114 |

*Source: Observ'er*

As we can see, Spain is Europe's most dynamic producer, with one company, Abengoa, as the driving force behind this trend. Spanish capacity has been estimated at about 500 million l/year (400 kt/year). The ethanol is mainly produced from wheat and barley.

Sweden now consumes more ethanol than it produces. This has been true since the E5 biofuel was virtually generalized in early 2003 and the E85 was developed at some fifty service stations. Eventually, national consumption is expected to reach 200 000 m$^3$ (or 158 kt). The difference between production and consumption is essentially covered by imports from Brazil or Spain.

Finally, Germany is finally shifting to ethanol. Three distilleries are either under construction or have already been brought onstream, which should bring domestic capacity to nearly 500 000 t/year and make it the number one European producer.

In Europe, biofuel utilization and taxation are regulated by several EC legal texts:

• The European directive 98/70/EC on motor fuel quality authorizes the incorporation of up to 5% ethanol and up to 15% ETBE in gasoline (reference directive: 85/538/EC) and up to 5% VOME in diesel fuel, for regular sale at the filling station. Higher contents are perfectly compatible with existing engines; in this case, all pertinent information must be clearly posted at the pump.

• A directive (2003/30/EC) promoting biofuels contains biofuel consumption objectives for the transport sector: at least 2% by 2005 and 5.75% by 2010 (percentages measured in energy) of its total consumption of gasoline and diesel fuel. Not mandatory, these goals provided as indications; nevertheless, member states must keep the Commission informed on the measures taken to reach them.

A directive (2003/96/EC) on taxation allows member states to grant biofuels a partial or full exemption from excise taxes.

Each country continues to exercise responsibility in the area of motor fuel taxation. To date, a number of member states have obtained biofuel tax exemption waivers that can range from 30 to 100% of the excise taxes levied on petroleum motor fuels.

A new development on the world energy scene, marked by a return to a high price per barrel, many other countries are planning to launch ambitious national programs to promote biofuels.

In **India**, it became mandatory (effective January 1, 2003) to incorporate 5% ethanol in gasoline in nine states and four regions under federal control, but the program has been delayed by dissension over the price of ethanol among market players (distilleries, oil companies).

**Thailand** has fixed a production target of 90 kt of ethanol. Of the 8 distilleries scheduled to help achieve this goal, only one is in service.

In 2001, **China** introduced a program to commercialize ethanol for use in 10% blends. In 2003, the domestic production of ethanol, mainly from corn, totaled 1 Mt.

In **Asia**, several producers of palm and coconut oil including **Malaysia**, **Indonesia** and the **Philippines** are planning to scale up their VOME production.

**Australia's** goal is to produce 280 kt of ethanol by 2010 for use in blends containing no more than 10%. This would represent about 2% of national gasoline consumption at that date. This plan is accompanied by public support measures to boost investment and subsidize domestic production (about €0.22/l).

In **Colombia**, all cities with over 500 000 inhabitants will be required to use a 10% ethanol blend, effective 2006. The construction of 9 new distilleries is planned to cover new demand, estimated at 720 kt. The ethanol will be produced from sugarcane.

In **Central America**, El Salvador, Guatemala, Honduras, Nicaragua and Costa Rica have implemented an ambitious policy to promote ethanol blends produced from sugarcane: 720 kt by 2010, including 320 kt for export.

Last but not least, **Canada** has set an ethanol consumption goal of 1.3 Mt by 2010. It will allow blends containing up to 10% ethanol.

## Outlook

R&D work is underway to develop new solutions to the problems represented by production costs, restricted land volume (competition with food crops) and the management of coproduct volumes. These solutions will focus on lignocellulosic substances (wood, straw), a resource that is more plentiful and cheaper to use than food crops. Two alternatives are being considered: the first, used to produce ethanol, has been under development in recent years especially in North America; the second, using the Fischer Tropsch method to make synthesis diesel fuel, figures prominently in European plans. The FT process, which holds out promise as a technology of the future, is the object of several research projects including at IFP in partnership with the French atomic energy agency (CEA).

Moreover, these two technologies could be combined at a single industrial facility, a sort of biorefinery at which ethanol process wastes could serve to supply the gasification-FT synthesis process. Like present-day refineries, this unit would generate two motor fuels, a “gasoline type” and a “diesel type”. This option allows also the production of a “bio-jetfuel” that can feed the air transport sector, that giving thus an opportunity to reduce the greenhouse gas emission of in a sector where there are very few alternatives to petroleum fuels.

*Stéphane His*
*stephane.his@ifp.fr*

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