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Biofuels

With the prospect of a doubling by 2050 of world demand for energy, and at the very time when there are growing signs of a capping of the growth of the supply of hydrocarbons, various sources of alternative energy are being envisaged. In this context, biofuels appear to be an interesting complementary solution as they can be produced in a significant quantity from renewable resources in a manner limiting their final impact on the emission of greenhouse gases. The technological progress expected with so-called second or even third generation biofuels allows even greater advantages to be envisaged.

Assets of biofuels

Biofuels present the interest of forming a **renewable energy source**, the potential stock of which regenerates with the reproduction of the vegetal or animal matter from which they are extracted. That explains why biofuels were taken into consideration from the first days of cars : Nikolaus Otto designed his four-stroke engine in 1876 for it to run on ethanol, and Rudolf Diesel further developed the engine he had invented in 1896 for it to run on peanut oil.

In the 1930s, the use of petrol incorporating a proportion of alcohol was quite widespread in France: this proportion represented 6 million hectolitres in 1936, as against 9 million today for biofuels as a whole. Later on, in the 1950s, the strong drop in the price of petroleum products brought about the demise of this practice.

Also, even if they draw their energy power from carbon, biofuels contribute to the **fight against the emission of greenhouse gases** because the raw materials used in their production absorb carbon dioxide. Using their chlorophyll, plants for instance ingest approximately a sixth of atmospheric carbon dioxide. As for biofuels produced from animal raw materials, the absorption of carbon dioxide takes place via the plants animals feed on.

Lastly, biofuels contribute to the **energy independence** of the countries producing them from raw materials supplied by their own territory. The renewal capacity of raw materials plays in this respect the same role as a strategic reserve stock for fossil fuels.

What is a biofuel ?

A biofuel is a liquid hydrocarbon obtained from vegetal or animal raw materials by extracting the carbon chains these materials contain.

The word 'biocarburant' (biofuel), an offical designation used by the Act of 13 July 2005 laying down the guidelines of the energy policy, has been ratified by the general committee for terminology and neologies. It co-exists with other designations such as 'carburant vert' (green fuel), 'carburant végétal' (vegetal fuel) or 'agrocarburant' (agrifuel), which are of a more restricted scope, since they do not take account, for instance, of production from waste.

Sorghum : a way forward

The two biofuel production sectors

Biofuels can be mainly divided into two sectors, corresponding to the two main types of internal combustion engines: the alcohol sector for controlled-ignition engines running on petroleum, and the oil sector for Diesel compression-ignition engines running on gas oil.

*The **alcohol sector** comprises bioethanol and ETBE. **Bioethanol** is obtained by the fermentation of sugar extracted from plants, either directly, from sugar beet in Europe or from sugar cane in the Tropics, or indirectly, by conversion of the starch contained in cereal grains. **ETBE** (Ethyl Tertiary Butyl Ether) is the result of a chemical reaction between ethanol and isobutene, a petroleum refinery derivative.*

The incorporation of bioethanol or ETBE in petrol presents the advantage of raising the fuel octane index, thereby decreasing the risk of auto-ignition which damages the engine in the long run.

*The **oil sector** comprises on the one hand, **pure vegetable oils**, obtained in Europe from colza or sunflower seeds, and which may possibly be used directly by some Diesel engines in countries where this practice is authorised, such as Germany for instance and, on the other hand, **biodiesel or VOME** (Vegetable Oil Methyl Ester), resulting from the chemical reaction of vegetable oil with methanol produced from methane or other hydrocarbons.*

VOME has close chemical characteristics to gas oil, so it can be incorporated in this fuel without difficulty and even with some technical advantages, as VOME acts as a lubricant and allows a saving to be made on additives.

Worldwide, the production of biofuels is close to 1% of world consumption of petroleum in transportation. The production of bioethanol, three-quarters of which is accounted for by the United States and Brazil, is ten times higher than that of biodiesel, of which 90% is of European origin. Germany alone produces as much biodiesel as the rest of Europe.

An encouraging political framework

These advantages have encouraged public authorities worldwide to develop the use of biofuels. In the United States, the federal policy is based on national consumption goals, on subsidies to pump prices, and on direct aids to producers. In Brazil, the obligation to incorporate a minimum of ethanol in petrol is combined with a pump price subsidy, and aids for the purchase of fuel flexible vehicles that can run on pure or blended ethanol.

In the European Union, the Directive 2003/30/EEC of 8 May 2003 on the promotion of the use of biofuels has imposed on the Member States a minimum percentage of biofuels, in energy content terms, in the total quantity of petroleum and gas oil marketed in their market: 2% in 2005 and 5.75% in 2010. The European Commission, in its proposal for a Directive of January 2008 on the promotion of the use of energy produced from renewable sources, targets a rate of 10% in 2020. Article 4 of the programme Act of 13 July 2005, laying down the guidelines of the energy policy, has set for France even more ambitious goals, strengthened by Article 48 of the agricultural outline Act of 5 January 2006: 5.75% in 2008,7% in 2010, and 10% in 2015.

As regards tax measures, since 1992 biofuels have enjoyed a partial exemption from the TIPP (taxe intérieure de consommation sur les produits pétroliers – domestic tax on petroleum products). In addition, a tax was introduced in 2005 on fuel distributors not reaching the incorporation goals (general tax on polluting activities – TGAP). As for the use of pure vegetable oils, they enjoy a total remission of tax when such use is authorised.

The technological conditions for the production of biofuels are evolving very rapidly, with the result that a first and second generation of biofuels are already distinguished, and a third generation is even sometimes mentioned.

Limits of the first generation

The first generation corresponds to direct production from agricultural produce. Its implementation **raises three problems:**

– ***Potential competition for the use of arable land between food produce and energy productions.*** This difficulty arises in very different terms depending on countries. In Europe, the development of biofuels has been devised with a view to the exploitation of fallow land; but other countries that have opted for less conditional support strategies, such as the United States and Brazil, have been confronted with the overly great success of these strategies in the wake of the continuous rise in the price of petroleum. Worldwide, the dilemma appears all the more difficult to overcome as demographic growth and economic development are creating new needs for both food and energy; the search for a solution requires, at the very least, a technological advance leading to productions with a far higher efficiency;

Ethanol production plant

– ***The energy budget of first generation productions is close to balance, above all for the alcohol sector.*** It depends largely on the way of assessing the fossil energy saving represented by agricultural wastes being used as animal feed;

– ***The balance in terms of greenhouse gas emissions appears less favourable when the production and distribution conditions are taken into account.*** Apart from the possible deforestation undertaken to seek new agricultural land or aside from the release

of carbon dioxide resulting from land adapting to a change of crops, attacks have thus been levelled against the negative impact of the use of nitrogen fertilisers emitting nitrous oxide, and rejections inherent in any industrial conversion. In addition, all the inputs of the production and then of the distribution of biofuels, down to the energy maintaining the employee workforce of the sector, themselves generate additional emissions of carbon dioxide; convergent studies, distinguishing the agricultural species used, appear to demonstrate that the alcohol sector is less well placed than the oil sector.

The advances of the second generation

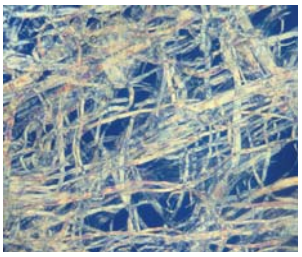
The second generation of biofuels is supposed to take better account of these difficulties, in accordance with three development avenues:

– Search for ***sources with higher efficiency***, that can be exploited without encroaching as much on food-producing agricultural land: it can be a matter of short rotation woods (poplars in Europe, *Jatropha curcas* in arid zones) or annual herbaceous plants (fibre sorghum); a great deal of hope is placed in algae potentially very rich in oil. Waste also forms a potential source of biomass not competing with food: whey, animal fats or used frying oils are already being recycled industrially into biodiesel;

– ***More effective use of sources*****,** by aiming to extract the very last drop of their energy content: the extraction of biofuel from seeds or pulp can therefore be combined with the recycling of plant waste to obtain the energy necessary for this extraction; the use of this recycling of wastes substantially improves the balance in terms of greenhouse gas emissions since it replaces fossil fuel inputs by fuels having previously absorbed carbon dioxide; this approach is already used in Brazil to produce ethanol;

– ***Use of extraction technologies more effective per se***: the goal is to convert biomass, regardless of its vegetal or organic origin. This is aimed in particular at sources rich in lignocellulose (straw, stalks, trunks), including in the form of waste (shavings). Biomass to liquid (BtL) conversion is spoken of, which uses different pathways - thermochemical or biochemical - depending on whether biomass is broken down by enzymes or chemically.

➢ Biodiesel is obtained following a *gasification* step and then by converting the synthesis gas



Cellulose seen under a microscope

obtained into a wax, via the Fischer-Tropsch process, named after two German engineers who developed the process in 1920; a last step then submits this wax to a hydrocracking (*) process to obtain biodiesel. Another thermochemical method produces oil directly by *pyrolysis* (destruction by heat), this oil then being refined to extract biodiesel.

➢ Biodiesel can also be obtained via the biochemical pathway by *enzymatic hydrolysis*, first to extract cellulose from its matrix of lignin, a substance rigidifying the vegetal extracts composing biomass, and then to decompose cellulose into simple sugars, similar to those of beetroot, that can then be converted directly by fermentation into alcohol. For this purpose, research is studying the properties of the enzymes of some filamentous fungi that grow on tree trunks.

These three development avenues can be pursued in parallel or combine their advantages. For instance, the development of a biodiesel sector using algae, efficiently recycling wastes into fuels, can very well co-exist with a BtL production chain based on hearty coppice species.

The ambivalence of the third generation concept

The first two development avenues, namely the use of new vegetal or animal sources, or their fuller exploitation by the recycling of wastes into fuels, correspond to an improvement of the production processes of first generation biodiesels. These avenues are already beginning to be the subject of industrial implementation by the roll-out of new production capacities.

On the other hand, **BtL conversion corresponds to a genuine technological breakthrough,** and still supposes research to allow its large-scale industrial exploitation. In France, this research is being conducted as part of the 'National research programme on bioenergies (PNRB)' launched in 2005 by the National research agency (ANR), delegated to the Agency for the environment and energy control (ADEME), and mainly bringing into play the IFP and CEA; their challenge today consists in succeeding in

(*) Hydrocracking is a chemical operation carried out under hydrogen pressure, which allows the long molecular chains of heavy hydrocarbons to be split to obtain lighter hydrocarbons.

building and operating pilot plants.

This research has a prospect of coming to fruition at relatively distant dates. For instance, the thermochemical process for the production of biodiesel by biomass gasification could lead to industrial exploitation at a significant level around 2020, while the large scale production of bioethanol by enzymatic hydrolysis, already possible today, would require an even longer length of time to lower its costs. Hence the temptation of some analysts to place these BtL sectors in a **third generation** biofuels prospect.

Bach up energy

Full substitution of biofuels for fossil fuels is not envisageable, in the first place because the production processes, even of the second generation, will never allow the necessary volumes to be reached quantity-wise. Also, while the exclusive use of a biofuel in an engine is not theoretically impossible, it runs into various difficulties in practice.

• Ignition when the engine is cold is the main difficulty facing an **engine built to run on ethanol.** Since 2003, Brazil has nevertheless been demonstrating that flex-fuel cars can overcome this problem using a device that injects a bit of petrol on starting. In exchange for this adjustment, bioethanol can be used as the sole fuel.

In France, flex-fuel vehicles have been available since 2006, but with a blend limited to 85% bioethanol; the composition of E85 fuel varies in fact depending on the time of year, to adjust the quantity of petrol to respond to cold igntion.

In a conventional engine, bioethanol can be used only as a petrol additive, as the incorporation of alcohol raises various difficulties related in particular to volatility and to the risk of demixing (separation of the petroleum and alcohol phases) in the presence of humidity. Tests demonstrate that the engine operates normally until a 10% incorporation rate, the rate that applies in the United States; in the European Community, this rate is limited by the Directive 98/70/EEC of 13 October 1998 relating to the quality of petrol and diesel fuels, to 5% for bioethanol (*) and to 15% for ETBE; in France, the proportion effectively incorporated varies between 2% and 5%.

• The need for adaptation is lesser for the **operation of a Diesel engine with biodiesel**. The main difficulty in this case is carbon deposit which depends on the quality of the oil. Germany authorises the use of pure vegetable oils as fuels, under the sole responsibility of vehicle owners. In France, Article 49 of the agricultural outline Act of 5 January 2006 authorises, from 1 January 2007, the sale of pure vegetable oil with a view to its use as an agricultural fuel or to supply professional fishing ships.

In practice, vegetable oil, in the form of VOME, is above all consumed in gas oil, incorporated in a proportion that the European standard EN590 limits to 5%.

A clear strategic direction

Even as a back-up energy, biofuels are going to play an essential role in the adjustment to the growth in world demand for energy. However, the tensions over food supply and the attention paid to pollution risks, the depletion of water resources or biodiversity loss, underscore the absolute necessity to develop the second generation sectors.

This synthesis assesses the situation, acting as a departure point to an analysis requiring deeper investigations. The OPECST will in any case follow up developments in this field, particularly as part of the mission to assess the national research strategy on energy that was entrusted to it by the Act of 13 July 2005 laying down the energy policy guidelines.

(*) This Directive has been in the process of being amended since 2007. The Commission proposes to raise this rate to 10%.