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Techno-economic analysis of Bio-diesel production in the EU: a short summary for decision-makers

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FOREWORD

This paper has been prepared by IPTS in order to summarize in a short and concise document the crucial facts related to the elaboration, distribution and marketing of bio-diesel. It includes analyses related to the barriers hindering a deeper market penetration of this energy carrier, with particular emphasis on fiscal instruments.

The paper intends to be used to inform and foster the debate among the actors involved, in particular in view of the forthcoming Directive on Bio-Fuels promoted by DG TREN.

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SUMMARY

ABSTRACT

The present paper aims at presenting in a relative condensed format the crucial facts relative to the bio-diesel technique. It is meant for the reference of non-technical decision makers that require an overview of the techno-economic characteristics of this emerging approach towards a more sustainable transportation system.

Data have been extracted from a number of different sources. A basic reference for the techno-economic analysis has been the ATLAS database, but several other sources have been used also. These data have been gathered and harmonized for sake of comparability, and processed to provide an overview of the techno-economic of bio-diesel in section 3.

Several issues may be highlighted:

- The cost structure of bio-diesel production makes it so that the competitiveness of the bio-fuel crucially depends on the price of the biomass feedstock and the by-products obtained.
- Technological improvements may contribute to increase the market penetration possibilities of bio-diesel, but a mature bio-diesel economic sector is conditioned by a stable and cheap supply of feedstock.
- The competitiveness of bio-diesel also depends on the evolution of the prices of mineral fossil gasoil.
- These three parameters are highly volatile and difficult to predict. Policies to ensure price stability should be endeavored to favor a deeper penetration of bio-diesel crops.
- Bio-diesel is an energy carrier whose manufacturing and production at industrial scale is totally determined by non-energy EU policies, i.e. the agriculture policy (and, in particular, the set-aside schemes adopted and the corresponding subsidy implementation) as well as the fiscal policy.
- Bio-diesel blends, mixing bio-fuel and mineral fossil fuel are a viable way to foster a less carbon-intensive automotive sector.
- In the long-run, however, and considering the agricultural yields, biodiesel is not likely to supply a two-digit percentual share of the European automotive transportation needs.
- The set aside policy is a valuable instrument to introduce renewable fuels in the transportation market, but given the land required to supply the European demand, the competition with food-production crops would in principle impeach a massive market penetration.

1. TECHNICAL FUNDAMENTALS

1.1. WHAT IS BIO-DIESEL?

Liquid bio-fuels, primarily bio-diesel and bio-alcohol, are transportation fuels processed from agricultural crops and other renewable feedstock, that can be used instead of fossil fuels in internal explosion engines.

Bioalcohols:

- <u>Bioethanol/ETBE</u> is processed from wheat, sugar beet and sweet sorghum and is employed as gasoline substitutes or as an additive for it.
- <u>Biomethanol/MTBE</u> can be produced from ligno-cellulosic material from forestry (either dedicated crops or forest residuals) and agricultural wastes.

Bio-diesel is a mix of methyl esters, obtained from natural, renewable sources such as vegetable oils. The most common raw materials to manufacture bio-diesel are rape-seed, sunflower and soybeans, but also from waste oils (industry, kitchens, etc). Bio-diesel can be used alone or mixed in any ratio with petroleum diesel fuel. According to the share of bio-fuel in the blend, bio-diesel mixtures can be named as B100 (100% bio-diesel), B5 (5% bio-diesel and 95% diesel), B20…

Different bio-diesel types can be classified according to their source and manufacturing process:

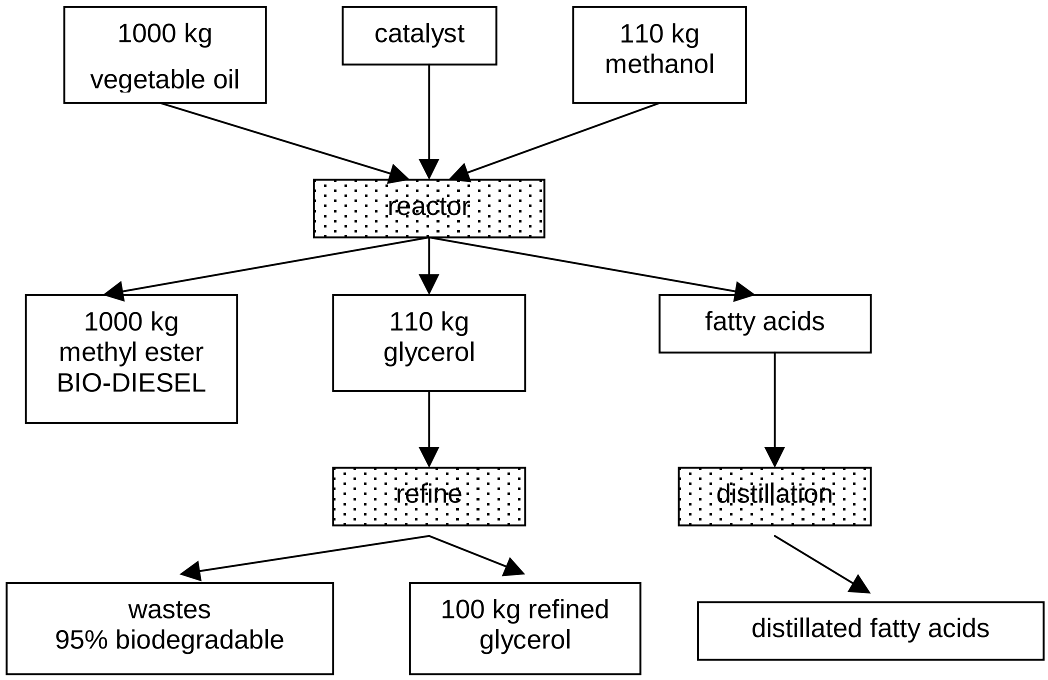
- <u>Esterificated oils:</u> They are produced through a reaction with methanol or ethanol in the presence of a catalyst to obtain the methyl or ethyl ester, depending on the alcohol employed oils of oleaginous seeds. This is the most common bio-diesel and it can be injected to Diesel engines either pure, or blended with petroleum gasoil.

- <u>Non esterificated oils</u>: this kind of oil may be employed only in engines with special characteristics. Oils with a high acidity degree or other characteristics that could make it unacceptable for human consume could be integrated in this group also.

- <u>Waste vegetable oil</u> from recycled cooking oils can be used as bio-diesel, but before the “transesterification” process, they have to be pre-processed, including a cleaning and refining procedure because of the degradation undergone due to the high temperatures reached.

1.2. BIO-DIESEL PRODUCTION

The most common bio-diesel technology uses the so-called "transesterification" technique, a process that combines oils and fats with mono-alcohols in the presence of a base catalyst to form fatty acid esters (bio-diesel). Bio-diesel, glycerol, meals for livestock feeding, fertilizers, and other industrial/agricultural byproducts are obtained. Yields typically exceed 99% for most technologies. Bio-diesel fuel has to be filtered, and purified to meet fuel grade specifications required for its use as fuel for diesel engines.



Most of the alkyl esters produced today are obtained via a catalyzed reaction because it is the most economic for several reasons:

- Low temperature (65º C) and pressure (20 psi) processing.
- High conversion (98%) with minimal side reactions and reaction time.
- Direct conversion to methyl ester with no intermediate steps.
- Exotic materials of construction are not necessary.

1.3. BIO-DIESEL CHARACTERISTICS AND ENGINE PERFORMANCE

Bio-diesel obtained by means of an esterification process and diesel fuel oil from fossil sources have similar physico-chemical properties (density, viscosity, boiling temperature, specific energy content, etc). For this reason, it may be used in a standard diesel engine, the only possible modifications required are: a two-to-three degree retardation of injection timing and, because of the solvent characteristics of the fuel, the replacement of any natural rubber seals with synthetic material.

From the operational point of view, the use pure bio-diesel (B100) is reducing the fuel economy and power by 10 %, i.e 1.1 liters of B100 replace 1 liter of conventional fossil diesel.. However, such a decrease in fuel economy is not linear with the blended mix, and no efficiency losses are observed in B20 blends. Therefore, the fuel consumption ratio between conventional fossil diesel and blended diesel types with content of bio-diesel not more than 20 %, could be considered as 1:1. This fact is due to the complexity of the burning process in engine. Blended diesel benefits from the advantages of bio-additives like improved lubricity, which reduces the wear and tear of the engine. Bio-diesel blends are safer than conventional fossil diesel, because bio-diesel has got higher flash point than fossil diesel. Most operational disadvantages of pure bio-diesel do not arise when using blended types of diesel. Low temperatures can cloud and even coagulate any diesel fuel-oils, and this applies particularly to bio-diesel. Users of a 20 percent bio-diesel blend will experience a decrease of the cold flow of approximately 3 to 5°. Precautions beyond those already employed for petroleum diesel are not needed for fueling with 20 percent blends.

1.4. PRODUCTION OF RAW BIOMASS FOR BIO-DIESEL

Bio-diesel is predominantly produced in Europe from vegetable oils and specially from rape and sunflower. The production of vegetable oil (either for food and non-food purposes) is carried out with simple, traditional and efficient agricultural methods.

Rape crop occupies 85% of the set-aside surface dedicated to oil crops for non-food purposes and, it has a higher profitability per hectare with respect to sunflower. Thus, in this paper rape will be considered as the reference crop for the economic analysis.

Rape yield varies from 3.5 t/ha to 13 t/ha, but taking into account that rape for bio-diesel is cultivated on set-aside areas (which normally have lower yield), a yield average of 2.7 tons per hectare can be considered as a good standard. The detailed mass balance is the following:

- 1 ha rape provides 2.7 t seed
- 1000 kg seed provides in industrial plants
    - 360 kg oil and
    - 610 oil cake
    - 12 kg residual fat
    - 40 kg water

- 1000 kg oil provides (adding 110 kg methanol)
    - 1000 kg rape oil methyl ester

110 kg glycerol

(source IEA-Bionergy: Biodiesel and Environment in Austria)

1 ha rape (Central Europe climate) provides 972 kg oil or 972 kg or 1070 litre of bio-diesel

Even if rape-seed is the best option for bio-diesel production on central Europe, the climate of Mediterranean areas makes it necessary to consider another options. Among the oil crops for bio-diesel production considered in the Mediterranean area, sunflower has to be considered in first place. Sunflower is well adapted to drought conditions (it explores very deep layers not exploited by other crops), and needs little or no fertilizer and little work. For these reasons, and despite its lower yield, sunflower has to be studied from the techno-economic point of view.

Rain-fed lands in Mediterranean countries have yields between 0.750 t/ha and 1.230 t/ha. In this case, a yield average of 1 t/ha is considered as a reasonable standard. The mass balance for this crop is the following:

- 1 ha sunflower 1 t seed
- 1000 kg seed provides in industrial plants 400 kg oil
- 1000 kg oil provides (adding 110 kg methanol)

  1000 kg rape oil methyl ester

  110 kg glycerol

  (source European Energy Crops InterNetwork)

1 ha sunflower (Mediterranean climate) provides 400 kg oil or 470 litre of bio-diesel

1.5. ENERGY BALANCE

An entire fuel-cycle energy balance assessment should include not only the energy contents of bio-diesel and the energy consumed in its manufacture process, but also the energy absorbed/released by all the necessary processes to obtain the final product. Studies carried out for the bio-diesel demonstrate that the energy global balance, including the extraction processes, refining and esterification, is positive.

The overall energy balance depends on the use given to the rape straw. It maybe cut and utilized as an energy source or, alternatively, either left and ploughed in soil. The fuel cycle energy balance (for rape-seed crops) is shown in the following table for both cases:

***Table 1**. Energy balance for bio-diesel from rape-seed in MJ/ha*

Energy yield (+) or cost(-)	**Oilseed rape, straw ploughed in MJ/ha**	**Oilseed rape, straw utilized MJ/ha**
Bio-diesel/ bioethanol	54346	54346
Cake/bran	1316	1316
Straw	0	60000
Total	**55662**	**115662**
Agricultural fuel	-4687	-4945
Fertilizers	-7190	-7190
Agrochemicals	-337	-337
Seed	-35	-35
Packaging	-282	-282
Transport	-723	-1122
Processing	-17251	-17251
Total	**-30505**	**-31162**
Balance	**25157**	**84500**

(source: British Association for Biofuels and Oils)

The crop growing and the processing of the raw seeds to produce bio-diesel. In order to economically optimize the overall process, seed pressing and should be carried out close to the crop growing area. This would reduce the transportation energy requirements. The bio-diesel fuel may then be transported to local distribution centers, leaving the by-products to be taken to centralized refining plants, where economies of scale are necessary.

In addition, the use of the dry residuals and straw from the crop, as well as the crushed seed, still containing 5 to 10% oil, may also be burnt to produce electricity. This possibility has not been accounted for, though, in the present techno-economic analysis.

An energy balance for bio-diesel from sunflower would give similar figures. An hectare of sunflower produces less bio-diesel but on the other hand more straw is obtained and less fertilizers and agro-chemicals are needed.

1.6. EMISSIONS AND OTHER ENVIRONMENTAL POSITIVE EFFECTS

The main advantage of bio-diesel as a renewable energy is that its production and use of biodiese provide important reductions in emissions of CO_2. This is not, however, the unique advantage. Indeed, reductions in the emissions of sulfur oxides, particulates and carbon monoxide are also obtained. On the other hand, it also induces a slight increase in nitrogen oxides.

It goes without saying that the benefits (and disadvantages) of the use of this bio-fuel are completely scalable depending on the type of blend used (B100, B20, …). These depend also on the engine performance, as well as the engine type. The possibility of mixing in any ratio with mineral fossil diesel oil is a significant advantage to consider also.

Specific figures for the potential emission reductions per pollutant are given in the following.

Carbon dioxide (CO_2) Every ton of fossil fuel that is burnt adds 2.81 tons of CO_2 to the atmosphere, together with a further half ton generated during the refining process. The specific carbon contents of bio-diesel ton burnt is slightly lower, about 2.4 tons of CO_2 per ton, and it can be assumed that it will be entirely recaptured next year by crops growing in fields to produce more vegetable oil starting material, as well as absorbed through the carbon cycle (e.g. as glycerol and solid wastes), thus net bio-diesel carbon dioxide emissions are zero.

Sulphur oxides (SOx) Every ton of fossil fuel that is burnt adds 180 kg of sulfur oxides to the atmosphere, adding to the formation of acid rain. Bio-diesel contains no sulfur, other than any which may be absorbed from the (polluted) atmosphere or from field dressings applied during growth.

Nitrogen oxides (NOx) NOx emissions from bio-diesel may increase or decrease with respect to those from fossil mineral diesel oil depending on the engine family and even the testing procedures. NOx emissions from pure (100%) bio-diesel increase on average by 6 percent. However, bio-diesel’s lack of sulfur allows the use of NOx control technologies that cannot be used with conventional diesel. So, bio-diesel NOx emissions can be effectively managed and efficiently eliminated as a concern of the fuel’s use.

Carbon Monoxide (CO). The advantage of bio-diesel is that it contains additional (11%) oxygen molecules, which improve the burning efficiency of the fuel. This inhibits the production of monoxides, resulting in a 20 to 40% reduction in emissions.

Particulate matter (PM) Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from bio-diesel are about 40 percent lower than overall particulate matter emissions from diesel.

Bio-degradability. Fossil oil degrades only 50% in the first 21 days after a spill while bio-diesel is 98% harmlessly broken down in the same period.

In table 2 gas-oil combustion emissions are compared to bio-diesel emissions, considering gas-oil emissions as 100%.

Table 2 *Bio-diesel emissions compared to conventional fossil diesel*

Emission Type	B100	B20
Total Unburned Hydrocarbons	-93%	-30%
Carbon monoxide	-43.2 %	-12.6 %
Hydrocarbons	-56.3 %	-11.0 %
Particulates	-55.4 %	-18.0 %
Nitrous oxides	+5.8 %	+1.2 %
Air toxics	-60 % / -90 %	-12 % / -20 %
Mutagenicity	-80 % / -90 %	-20 %

Source: *US Department of Energy*

In addition to the above stated data, pure bio-diesel could reduce the cancer risk by 94 %. The B20 is reducing the cancer risk by 27 %. The overall effect on CO2 emissions highly depend on the type of process selected to manufacture the bio-diesel oil. It could well range between 95% and 80% of CO2 savings with respect to the use of conventional diesel.

2. EUROPEAN UNION POLICIES CONCERNING BIO-DIESEL

2.1. ENERGY POLICY FOR RENEWABLE ENERGY AND BIO-DIESEL

The increasing emissions of greenhouse gases (due to increasing demand and use of fossil fuels, basically) and their possible impact on the world climate is a reason of growing concern. This issue has led to a number of political commitments and considerations with the aim to reduce the overall emissions of green-house gases and especially of $C0_2$. In the context of the Rio Conference and the Kyoto Protocol the EU has committed itself to reduce CO_2 emissions by the year 2000 by 8.1% in relation to the level of 1990.

Back to 1996, the White book on "Energy Policy for the European Union" of 1996 anticipated that, in spite of the increasing energy efficiency gains, final energy demand (and therefore also primary energy consumption) would have uninterruptedly increased in the EU. Dependency on imported energy was supposed also to increase in the next decades, unless dramatic developments in the renewable energy sector occur. By that time, in a relative low-oil price scenario, it was relatively more difficult to anticipate dramatic changes in the supply to to the transportation sector. These prospects have been modified to some extent by the oil shock prices of 1999-2000, but the essential conclusions remain basically unchanged.

Putting together these baseline projections with the necessity to curb carbon emissions down, it becomes urgent to implement policy measures able to reduce the carbon intensity of some sectors, notably the road transportation sector. In this respect, bioenergy could well start to play a larger role in the fuel mix. Biomass burning (with or without processing) releases to the atmosphere only as much $C0_2$ as has been bound by the plants while growing. Roughly speaking (and depending on the type of fuel and the engine efficiency changes) the utilization of 1 kg of bio-diesel leads to the reduction of some 3 kg of CO_2. In addition, using bio-fuels offers other environmental benefits, for example in improving the lubricating characteristics of diesel fuels and removing completely the presence of sulfur compounds in the exhaust mix.

The **White Paper for Renewable Energy Resources** adopted in November 1997 introduced some indicative targets for a more sustainable energy system in the European Union. The main objective envisaged was to double (from 6% to 12%) the share of renewable energy resources in the total energy consumption of the EU by 2010. Bionergy, of course, was supposed to play a crucial role in this renewable share expansion. Beyond environmental benefits, a range of other factors argue for greater exploitation of bioenergy carriers, in particular within the traffic sector, which heavily depends on high-grade fuels, suitable for the operation of existing fleets. While the number of technologies and/or energy sources can be used for stationary energy plants, the possibilities for the transport sector are rather limited, being in practice locked in around the explosion engine. Bio-fuels are the only renewable sources of energy which can be used in this sector without a dramatic technological change, i.e. making use of the existing transportation fleets based on internal explosion engines (either Otto or Diesel).

The last policy paper produced by DG TREN, the **Green Paper** "**Towards an European Strategy for The Security of Energy Supply"**, delineates a long-term energy strategy for the Union. According to this policy paper, a rebalance is required to complement its supply policy by clear action in favor of a demand-side management policy. The paper courageously puts into evidence the narrow margins for manoeuvre, give the high dependence on external resources, the cost structure of the energy sector and the severe environmental constraints. Supply side measures are therefore expected to be almost useless if not complemented with action addressing efficiency measures and demand management closer to the final consumer.

This twofold aspect of the policy portfolio addressed by the Green Paper is to be outlined:

- With regard to demand-side, the Green Paper is calling for a real change in consumer behaviour, and highlights the value of taxation measures to steer demand towards better-controlled consumption that is more respectful with the environment.

- With regard to supply-side, the development of options leading to a change towards less carbon-intensive technological *filières* is a crucial priority, given to the constraints imposed by the fight against global warming. The development of new and renewable energies (including bio-fuels) is recognized as a necessary key to foster such a change.

Amongst final energy demand sectors, transportation is a crucial sector first because of its increasing share in the final consumption mix (over 30% of total final energy consumption), and second because of its concentration on liquid fossil fuels. Transportation policy is therefore a priority area for energy efficiency. Road traffic is of particular importance as it accounts for about 84% of overall CO_2 emissions from transport. Concerning novel road transportation schemes**,** it is expected that new generation fuels will start the market penetration in captive fleets and urban transport, simply to minimize logistic and distribution problems. These fuels would be derived from a larger variety of primary energy vectors, including biofuels.

The market for transportation bio-fuels in the European Union is still relatively small. In 1998, it amounted about 0.15% of the total consumption of mineral oils as fuel. Barriers for a deeper market penetration are due to their relatively high costs. The price differential with fossil fuel currently varies from 1.5 to 4 times for products before tax, depending on the type of bio-fuel considered. It seems that, from this point of view, bio-diesel is closer to the competitive threshold, and this is why particular attention is put on it. It seems, though, that a firm development of biofuels (and, in particular bio-diesel) may take place only if several conditions apply:

- First, Member States governments (as ultimate responsible for energy policy in their countries) should make a firm commitment to achieving the ambitious and realistic objective of the White Paper for 2010, namely, 7% of bio-fuels and a target of 20% for 2020 for all fuel substitutes.
- The gap between the prices of bio-fuels and competing products should be reduced by measures which, initially, could be of a fiscal nature.
- Oil companies should undertake to organize large-scale distribution by way of voluntary agreements rather than Community regulations.

2.2. AGRICULTURAL POLICY AND BIO-DIESEL: NON-FOOD PRODUCTIONS

The Common Agricultural Policy Reform on 1992 established crop specific per hectare payments to compensate the reduction or abolition of institutional prices. These payments are based on historic regional yields, and paid in general on the condition that producers set aside a defined percentage of the land for which it was requested.

The reference set-aside share is currently 10%, but the applied set-aside rates has been adapted each year taking into account the forecast market development. Furthermore farmers are allowed flexibility in the management of their set-aside obligation: they may use the set-aside land to grow crops whose final destination is non-food/feed use ("non-food crops"), and still receive the corresponding compensatory payments. Oilseeds are the main raw materials concerned by this scheme (for chemical uses and bio-fuels): almost 90% of non-food production area on set-aside in the EU corresponds to oilseeds.

Within **Agenda 2000**, there is no specific proposal for a non-food agricultural policy as such. But by closing the gap between internal prices and world prices, it aims to put at the disposal of food/non-food agro-industries more competitive raw materials.

Under Agenda 2000, the level of direct payments is the same for cereals, oilseeds and set-aside. Given that the cultivation of non-food crops under set-aside scheme remains possible, food and non-food crops are put on an equal footing. The slight reduction of set-aside payments under Agenda 2000 will not, as such have any effect. The determinant factor is the **relative profit margin**.

Producers subject to the set-aside obligation will have in principle a choice between two possibilities: setting land aside or growing crops for non-food uses on it. A key factor determining their choice will be the income they expect from each of the two alternatives.

In the case of set-aside the income is given by the difference between the regional set-aside payment per hectare and the cost maintaining the land set aside.

In the case of crop production for non-food uses they will receive in addition to the set-aside payment a market revenue for the crop cultivated. On the other side they have the costs of producing the crop. Since land and in general also machinery are available, these costs will normally be the variable costs of production.

Market revenue will depend on the quantities produced per hectare and on the price that can be obtained from the crop when it is sold for non-food uses. In the case of bio-fuels, the prices processors are prepared to pay to farmers are not too high. In fact, these prices are based on the price of competing mineral fuels and would not be attractive without any additional support measures. Partial or total exemption of hydrocarbon taxes applicable to bio-fuels a measure which is often applied in this context.

With a compulsory set-aside rate fixed at 0%, farmers will have no more reason to grow and sell rape-seed for diester production at lower prices. When selling rape-seed to the crusher, the farmer will not accept a lower price than the one he expects for food and feed market. The question is how far the processor will be able to pay such a price. This will depend on the price he can get for his product on the fuel market as well as on his own production costs. Under these conditions the main risk barrier to the development of bio-diesel across Europe is the uncertainty surrounding feedstock availability. Farmers will be hesitant to tie-up their greatest resource-land for a number of years with a crop whose market is in itself somewhat uncertain.

The possibility of **growing non-food crops under compulsory set-aside scheme is an opportunity for bio-diesel development, but is not an appropriate instrument to promote non-food production**. The sustainable development of non-food crops and consequently bio-diesel industry, cannot be based on a set-aside rate which can vary from year to year according to the market situation for food commodities

In this context, more than the opportunity provided by compulsory set-aside scheme, **tax exemption is a key condition for the relative profitability of liquid bio-fuels**. In absence of compulsory set-aside this condition becomes even more important.

2.3. CURRENT RTD IN EUROPE

Most current RTD activities through EU countries are pilot demonstration projects that are being implemented in several cities. Some examples are given below (main source ATLAS database).

France

The AGRICE research group was established in 1994, coordinating research projects on Agriculture, Industry and Environment. Activities are coordinated with the INRA (National Institute for Research in Agronomy), IFP (French Institute of Petroleum), and many private companies (TOTAL, Rhône Poulenc) and professional associations. The French agency for Energy Management (ADEME) has been appointed to ensure the coordination and management of this group. AGRICE's mission is to develop research partnerships for new market outlets for agricultural products such as liquid and solid bio-fuels, biodegradable products with the objectives of protecting the environment while increasing energy independence, and increasing farmer income while reducing the amount of fallow land. One of the top priorities of the sector is to be able to reduce the production cost of liquid bio-fuels by 0.152 ECU/l (0.2 $/l) before 2005.

Belgium

The Flemish technology agency VITO has financed and coordinated demonstration projects for the use of 100% bio-diesel in light duty vehicles. TEC Hainaut has performed experiments using bio-diesel in public buses. Successful tests were made with 20% bio-diesel and 80% fossil diesel and 100% bio-diesel.

Spain

There is an on-going experimental program to demonstrate the technical viability of using rape-seed bio-diesel in public transport in Vitoria, with the involvement of central, regional and local government and financial support from the EU Altener Programme.

There is also a similar experimental program in Zaragoza to demonstrate, in this case, the technical viability of using sunflower bio-diesel, with the involvement of the university and electric utilities. Similar programs using sunflower-based bio-diesel are on-going in Madrid and Valladolid with the involvement of central government and an oil company. The project will operate four buses running with a B30 blend over one year. These projects are all supported by the EU Altener Programme.

The Netherlands

Demonstration projects for rape-seed bio-diesel and bioethanol are under way in the cities of Rotterdam and Groningen, respectively. There is also a demonstration project to demonstrate the viability of bio-diesel as a fuel in marine engines.

United Kingdom

There are a number of projects demonstrating the use of bio-diesel in the UK in a variety of vehicle types. There are no projects demonstrating the use of any other bio-fuels. Bio-alcohol research in the UK being basicallyf ocusing at pre-commercial research, concerned with the finding of novel appropriate crops for the conversion of biomass. No industrial scale plant has yet been built. Research has been carried out into the life-cycle energy use and environmental impacts associated with the production and use of a variety of alternative fuels for transport.

3. TECHNO-ECONOMIC ANALYSIS

3.1. BIO-DIESEL PRODUCTION ECONOMIC BALANCE

It should be pointed out that several (non-technological) limiting factors have stopped until now the development of the bio-diesel industry[1]. These limiting factors are feedstock prices, bio-diesel production costs, oil prices and taxation of energy products. They will be discussed in the following paragraphs.

3.1.1 Feedstock prices

No matter the technological process adopted for the bio-diesel manufacturing, the largest portion of the cost to produce bio-diesel is the feedstock cost. Rape-seed used in bio-diesel sector covers around half of the non-food area under set-aside scheme, so special emphasis will be put to analyze costs and performance of this crop as a key energy raw material.

In recent years, total production costs of bio-diesel have fallen, despite a progressive increase in the price paid for rape-seed. The decreasing trend in bio-diesel production costs is expected to continue. Experience with bio-fuel seems to indicate that once a stage production is reached, costs tends to fall overtime due to technical progress.

In this context, the cost of producing feedstock has been the major obstacle to economic feasibility of bio-diesel since the final price of bio-diesel crucially depends on the rape-seed price in international markets.

According to FAPRI[2] and OECD outlook projections[3], whereas the short-term will remain characterised by very low prices induced by excess supply, the medium-term prospects for world oilseed prices indicate that a graduate and moderate price recovery can be reasonably expected. According to this, rape-seed prices would increase from 214 Euro/t in 2000/01 to 242 Euro/t in 2007/08.

In order to consider bio-diesel as a real choice for farmers, the final price paid for non-food rape-seed must be the same as the food rape-seed price. It seems reasonable to establish 214 Euro/t as a price of reference for the next years

[1] All techno-economic analyses in the present chapter are based on the assumption of parity between fuel efficiency of conventional fossil diesel and bio-diesel. This pre-condition signifies that techno-economic analysis actually assesses blended types of diesel with bio-diesel content not more than 20 %, but not pure (B100) bio-diesel.

[2] Food and Agricultural Research Institute. University of Missouri.

[3] Prospects for Agricultural Markets 2000-2007. European Commission. Directorate General for Agriculture. November 2000.

3.1.2. Bio-diesel production costs

The estimated costs for bio-fuels, under a situation of tax exemption, can be broken down into fixed and variable costs. Fixed costs have been estimated for extracting oil from seed and for processing this oil into bio-diesel. These includes manufacture, capital (considering depreciation) and staff costs.

The typical cost of a bio-diesel manufacturing plant may range, according to different sources, around 100 Keuro/'000 t/y. This parameter is not likely to undergo significant reductions in the future. Assuming a discount factor of 10% and an economic plat lifetime of 15 years, this would yield a capital cost annualized of around 0.012 Euro/lt.

Glycerol and protein meal for livestock feeding are by-products that help to offset the cost bio-diesel production. These by-products selling is considered as fixed income.

Rape-seed price (Pr) is considered hereafter as a variable. The manufacture of 1l bio-diesel needs 2.23 kg rape-seed.

Table 3 *Bio-diesel cost production depending on rape-seed price in Euro/l*

Fixed costs	
Manufacture costs	0.147
Capital costs (annualized)	0.012
Staff and overhead costs	0.005
Fixed income	
By-products income	0.084
TOTAL fixed factors	**0.080**
Variable costs	
1 l of bio-diesel requires 2.23 kg of rape-seed	**Pr*2.23**
TOTAL PRODUCTION COSTS	**0.08 + Pr*2.23**

Pr: rape-seed price

SOURCE: EC ATLAS Database, US National Renewable Energy Laboratory (NREL)

IPTS data gathering & elaboration

By assuming the reference rape-seed price of 0.214 Euro/kg, a net cost of 0.557 Euro/l is obtained. This corresponds, by adding the revenue obtained by selling the by-products, to a brute cost of 0.668 Euro/l.

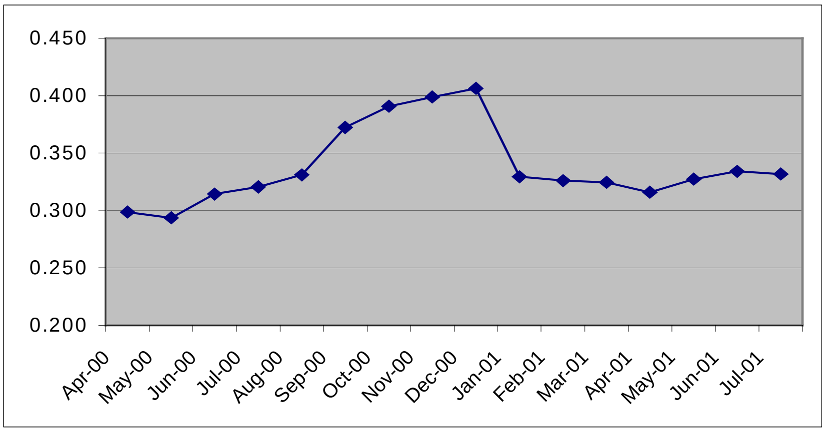
Two salient facts have to be underlined with respect to this cost structure. First of all, the large share in the final cost attributable to the procurement costs of biomass. In the case presented above, the share of the rape-seed cost in the final product is about 70%. Other reports quoted by the US NREL quote a raw material cost share up to 90% of the total cost. This of course heavily depends on the assumptions made (and the record observed) for price of raw biomass. The second salient fact is that the selling of by-products is a significant source of income that contributes to make the whole process competitive. With the assumptions made here, this amounts about 15% of the gross production costs. Other reports deliver for this figure even 35% of the gross production cost.

3.1.3. Oil prices

Low production prices of oils (specially automotive gas oil) are another crucial handicap for the development of bio-diesel. In this sense, the continuous increase in oil prices approaches bio-diesel cost production to gas oil ones, converting this difference from a handicap to an opportunity for bio-diesel.

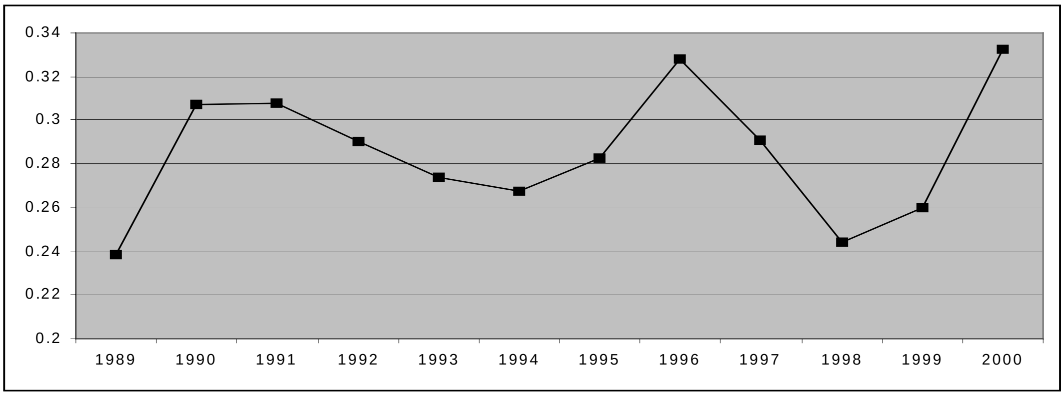
The evolution of gas oil prices in the European Union is shown in the figure 1.

Figure 1 *Automotive gas oil consumer prices net of duties and taxes in Euro/l. Weighted average for EU.*



Source: European Commission Directorate General for Energy and Transport. Oil Bulletin

Figure 2 *Price of diesel (commercial use) Euro/l (excl. taxes)*



Source: Enerdata Data Base

3.1.4. Taxation of energy products

There is no harmonized European policy on bio-fuels. Each Member State implements its own domestic regulations, inside a Community framework for the taxation of energy products.

There are, though, **minimum levels of taxation** applicable to automotive gas oil are: ECU 343 per 1000 liters on 1 January 2000 and ECU 393 per 1000 liters on 1 January 2002.

The minimum levels of taxation are modified depending on whether these motor fuels are used for certain industrial or commercial purposes. The proposal refers to: agriculture and forestry; stationary motors; plant and machinery used in construction, civil engineering and public works; vehicles intended for use off the public roadway; passenger transport and captive fleets which provide services to public bodies.

Member States may apply **total or partial exemptions** or reductions in the level of taxation to energy products used under fiscal control in the field of pilot projects for the technological development of more environmentally-friendly products or in relation to fuels from renewable sources, bio-fuels, among other possibilities.

3.2. BIO-DIESEL TAXATION LEVEL SCENARIOS

In the following paragraphs different tax level scenarios will be discussed. Current bio-diesel production costs (see 3.1.2.) will be considered first. Then, a scenario assuming production costs reduced by 0.152 Euro/l, according to the RTD priorities stated in the EC ATLAS report. Finally a possible tax linked to CO_2 emissions applied to fossil diesel fuel will be calculated as well as the cost of the avoided emissions due to fossil diesel replacement by bio-diesel.

3.2.1. Bio-diesel taxation level scenarios at current costs

The EU Commission intends to develop a market share for bio-fuel and recommends time-limited exemptions or reduction of taxes on bio-fuels to 0-10% of normal amounts the first 10 years, then to increase stepwise. The following table compares the final bio-diesel price with gasoil, depending on the tax level applied. The scenarios considered are total exemption, a partial exemption of 10% of gas-oil taxation and full gas oil taxation.

It has been considered:

- Current production costs: 0.08 + 2.23*rape-seed price
- Gas oil prices as an average of the past twelve months.
- Taxes: minimum full level of taxation applicable to motor fuels 0.393 Euro/l.
- Rape-seed price is considered fixed to 0.214 Euro/kg

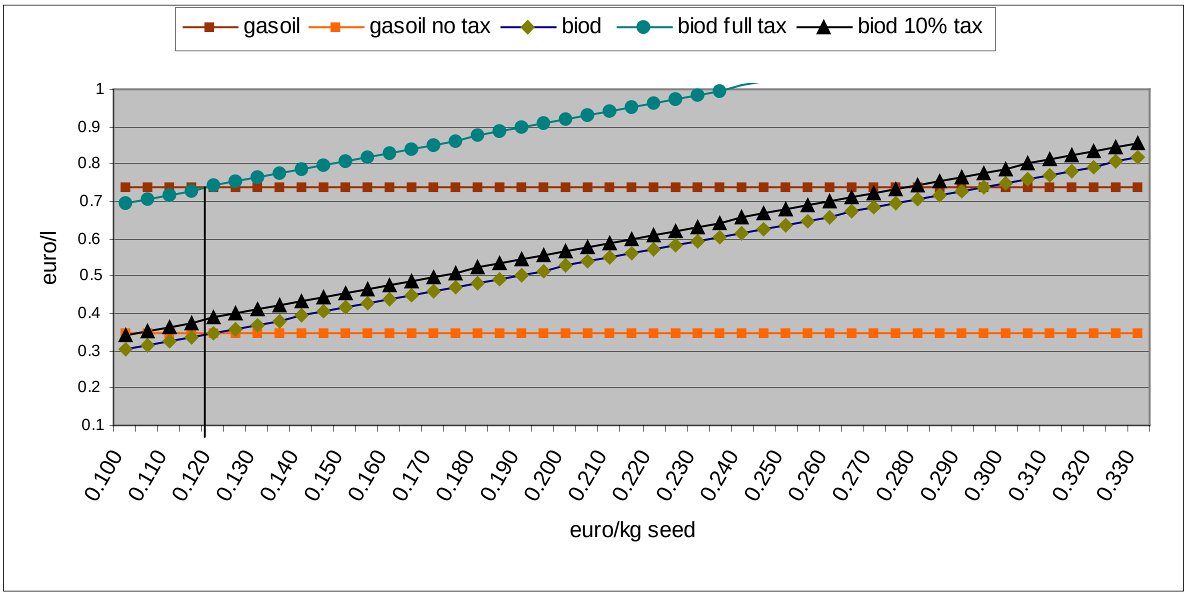
Table 4 *Bio-diesel taxation level scenarios at current costs*

Euro/l	BIO-DIESEL 0.214 Euro/kg seed Total Exemption	BIO-DIESEL 0.214 Euro/kg seed 10% level of full gas oil taxation	BIO-DIESEL 0.214 Euro/kg seed full gas oil taxation	GAS OIL average july-00 july-01 price full gas oil taxation
Production cost	0.557	0.557	0.557	0.346
Taxes	0	0.0393	0.393	0.393
TOTAL	0.557	0.597	0.950	0.739

This figure indicates that a final cost of bio-diesel lower than gas-oil can occur only within scenarios of total or partial hydrocarbon exemption.

In the following figure the same scenarios are represented depending on rape-seed prices.

***Figure 3** Bio-diesel taxation level scenarios at current costs, depending on rape-seed price*



Some results may be outlined from Figure 3:

- To produce bio-diesel at the same price as gas-oil, considering current costs, would only be possible at very low rape-seed prices: 0.120 Euro/kg, which is almost half a price expected for the year 2007. This is not a probable scenario if we consider that farmer's income should always be maintained.
- Considering total tax exemption, price paid for rape-seed could reach 0.295 Euro/kg.

3.2.2. Bio-diesel taxation level scenarios lowering costs

One of the top priorities of RTD identified by ATLAS (according to the ADEME paper) is to reduce the production cost of liquid bio-fuel by at least 0.2 $/l (0.152 Euro/l) before 2005. Assuming this target as a reasonable cost reduction (and assuming that the cost curve is still linear in the price range considered for the raw material), it is obvious that this cost reduction necessitates both lower production costs and higher prices of the by-products. Under these circumstances, bio-diesel cost, depending on rape-seed price, is compared with gas-oil price In Figure 4.

It has been considered:

- Bio-diesel "low costs" obtained reducing by 0.152 Euro/l current production costs: 0.08 - 0.152+ Pr*2.23
- Gas oil prices as an average of the past twelve months.
- Taxes: minimum full level of taxation applicable to motor fuels 0.393 Euro/l.

__Figure 4__ Bio-diesel taxation level scenarios at lower production costs, depending on rape-seed price

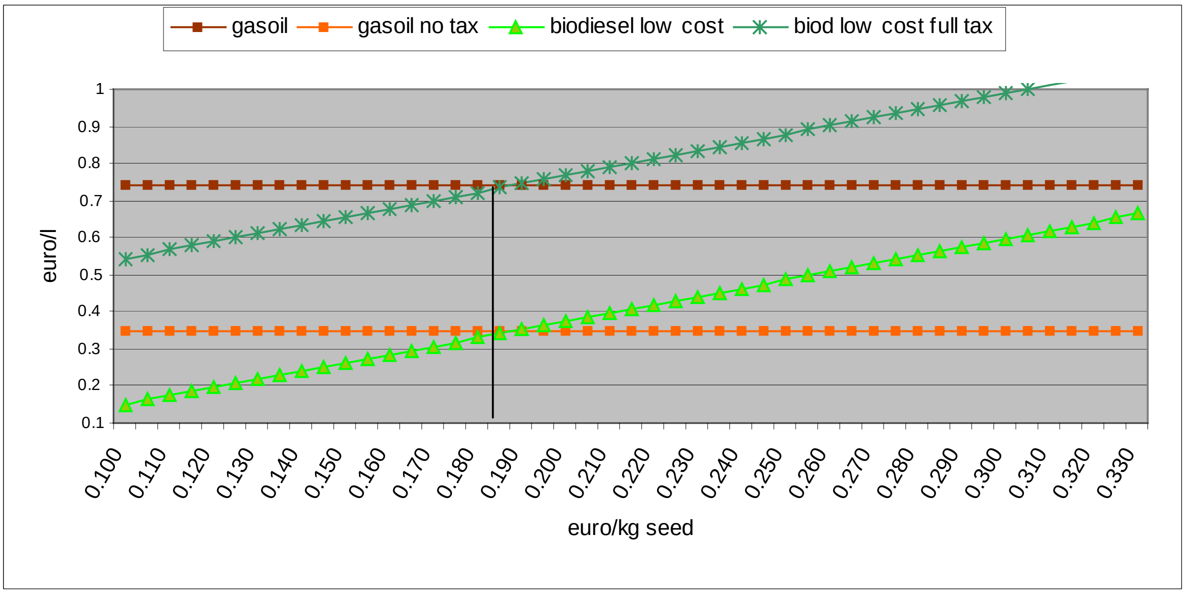


Figure 4 shows that the production of bio-diesel with competitive prices (no fiscal incentives foreseen) is only possible, even in an scenario of reduced costs by 0.152 Euro/l, only if stable supply of rape-seed at price not higher than 0.187 Euro/kg is guaranteed. This figure is to be compared with the 0.120 Euro/l threshold obtained in the full taxation case for the standard cost curve. However, if we combine the assumptions of low fixed costs (both due to cheaper technology and running costs and higher price paid for the by-products) and total tax exemption, the rape-seed price paid to farmers could go above 0.340 Euro/l preserving its competitiveness with respect to the full-taxed mineral gas-oil.

It can be concluded that partial or total exemptions on bio-fuels should be followed by an increase on the supply of raw material, and conditioned on a long term supplying commitment by farmers. Nevertheless, as the development of technologies using cheaper raw materials increases, the total exemption could be unnecessary and should be modulated, depending on the economic results obtained.

Bio-fuels are not likely to become competitive in absence or fiscal incentives and fully guaranteed supplies of raw materials and stable prices. No investment will be made without the certainty of gaining a long term fiscal advantage.

3.2.3. Tax linked to CO_2 emissions

Increasing fossil fuel consumption by transport is responsible for the large growth rate in greenhouse gas emissions, mostly CO_2 emissions in most advanced economies. According to Eurostat estimates, about 28% of the CO_2 emissions in the EU presently come from transport, with 84% of it from road transport alone. The former share is expected to increase in most baseline projections, whereas the latter is certainly not expected to decline.

A common pattern in the sectoral structure of carbon emissions in many advanced countries is that, while other sectors (industry, residential, tertiary and power generation) have reduced their emissions, greenhouse gas emissions from transport have been incresing with a relatively large, stable growth rate. CO_2 emissions from transport have increased by 18% from 1990 (Kyoto reference year) to 1998 in the EU. Over the whole period 1990-2010 a baseline projection indicates a possible growth of transport-generated CO_2 emissions to reach 40% of total carbon emissions. The transport sector therefore continues to face the well known conflict between consumption and environmental protection. On the one hand society is extremely fond of the personal mobility possibilities offered by technology, on the other hand society is less and less willing to accept the negative impacts on safety, health and environment induced by such a consumer behaviour.

Therefore, the fulfillment of the Kyoto commitments and control of CO_2 emissions are essentially a matter of energy and transport policy. Without measures in both these sectors, any climate change policy is very likely to fail. Climate protection measures can only be effectively met if the European Union makes a firm commitment to undertake concrete measures (notably fiscal and regulatory) geared to energy-saving and the promotion of renewable energy sources. Despite major disparities between Member States, taxation can be an effective tool in energy policy. The internalisation of costs linked to degradation of the environment and/or the application of the polluter pays principle, can be effective attained by tax incentives.

In this section will be discussed the possible tax linked to CO_2 emissions applied to fossil diesel fuel (gas-oil) as well as the cost of the avoided emissions due to fossil diesel replacement by bio-diesel.

Tax linked to CO_2 emissions applied to gas-oil

Assuming that carbon dioxide released from burning bio-diesel will be entirely recaptured and absorbed through the carbon cycle, net bio-diesel carbon dioxide emissions are zero. Given the carbon content of mineral fossil gas-oil, the replacement of one liter of fossil diesel by one liter bio-diesel will avoid the emission of 2.81 kg of CO_2**.**

The equivalent carbon tax linked to CO_2 emissions, according to different analysts (Green Paper on the Establishing of a EU Market for CO_2 Emissions Rights, EU 2000 and references therein) would range from 30 to 80 Euro per CO_2 ton emitted. The corresponding **equivalent tax calculated for gas-oil would have a value between 0.084 and 0.224 Euro/l gas-oil**. These figures are obtained, depending on a number of assumptions and hypothesis, either by assuming an equivalent carbon tax or as the equilibrium price that the carbon emission permit would reach in a perfect market for emissions rights. If this amount is added to the average price of gas-oil (0.739 Euro/l), the final price will be between 0.823 and 0.963 Euro/gas-oil. These prices is are considerably much closer to the bio-diesel price calculated on a full tax scenario (0.950 Euro/liter), and definitely above the bio-diesel price in the case of full exemption from hydrocarbon tax (amounting 0.557 Euro/l). Under this respect, putting a price to carbon emissions either by (further) taxing fossil carbon or by establishing a emission allowance market would lead to a better competitiveness of the bio-diesel *filière*.

Cost of the avoided emissions due to fossil diesel replacement by bio-diesel

Considering the prices for gas-oil and bio-diesel calculated on the precedent section, under the scenario of full gas-oil taxation and a rape-seed price of 0.214 Euro/kg (0.739 Euro/l for gas-oil and 0.950 Euro/l for bio-diesel), the difference between bio-diesel and gas-oil price is about 0.211 Euro/l. In **terms of CO_2 emissions, this difference in emissions avoided would imply an implicit cost of about 75 Euro/ton CO_2 emitted**.

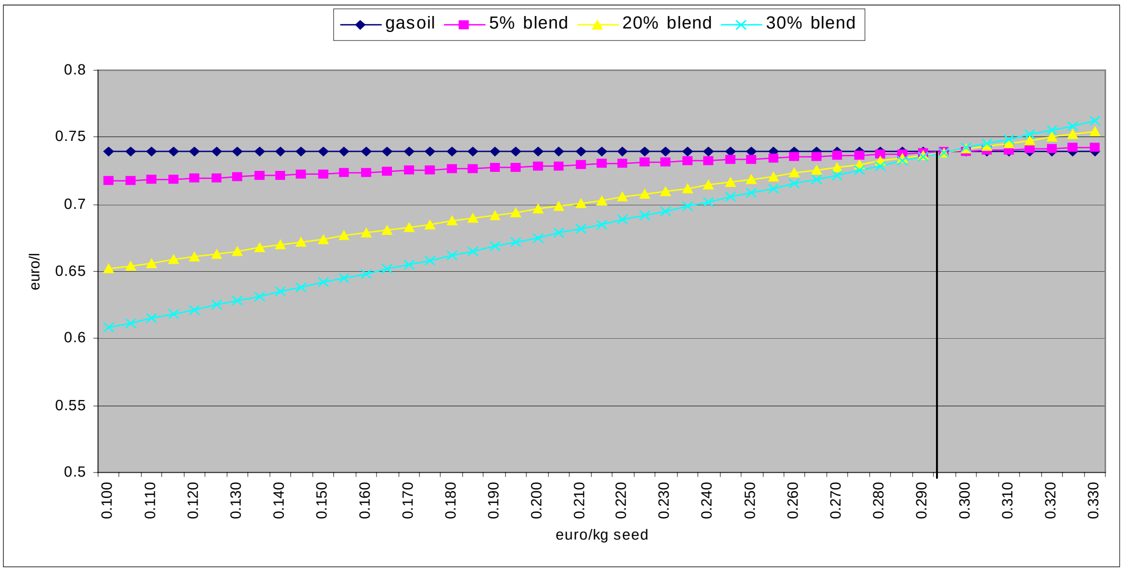
3.3. BIO-DIESEL AND GASOIL BLENDS

As explained previously, it has been proved that at current production costs bio-diesel is not competitive against gas-oil. Up to present the high cost of production has prevented bio-diesel from becoming a more widely used alternative fuel. But an economic balance of different blends level show that they could represent a more likely scenario.

Currently, 50% of French diesel cars consume up to five percent diester incorporated into diesel, and 4000 vehicles (mainly city buses) use diester with a 30 percent incorporation rate into diesel. The mix of diester into diesel was favored by the 1997 EU regulation requiring reductions in the sulfur content in gasoline. Since diester does not contain sulfur, it has been largely used as a sulfur-free lubricant by petroleum companies since the implementation of the 1997 regulation.

In the following graph the possible costs of 5, 20 and 30% blends are observed for different prices of rape-seed. Bio-diesel costs do not include hydrocarbon taxes.

Figure 5 *Prices for B5, B20 and B30 blends depending on rape-seed prices*



Below a price of 0.295 Euro/kg rape-seed all blends have a lower price than full-taxed gas-oil. This threshold price is much higher than the one expected for the year 2007 (the binding condition again being the total exemption from fuel taxation), so farmers could cultivate rape-seed for blends getting the same income as the received cultivating with food/feed purposes.

Besides, an important reduction of blend prices in relation to gas-oil is observed. Assuming tax exemption for bio-diesel, gasoil price of 0.739 Euro/l and three possible hypothesis for rape-seed prices (minimum, medium and maximum), the corresponding reductions in the final blend price are shown in the following table.

Table 5 *Costs reduction in relation to gasoil (0.739 Euro/l)*

Euro/l	**rape-seed price 0.200 Euro/kg**	**rape-seed price 0.214 Euro/kg**	**rape-seed price 0.242 Euro/kg**
5% blend	0.011	0.009	0.006
20% blend	0.043	0.036	0.024
30% blend	0.064	0.055	0.036

Blends are a real opportunity for bio-diesel development, giving an appropriate income for farmers, competitive prices for final consumers and even providing a less polluting image to major oil companies (which to date have not been implemented).

3.4. BIO-DIESEL POTENTIAL IN EUROPEAN UNION

In EU it vegetables oils can be considered as the most suitable basis for a bio-diesel industry. Especially seeds in France, Spain, the United Kingdom and Germany and all Eastern European countries have a considerable area potential.

The large scale production of bio-fuel started after the implementation of the reformed Common Agricultural Policy. Set-aside, which was previously nonexistent, was made compulsory with the possibility to grow non-food crops. For this reason almost all oilseed production for non-food destination is grown in set-aside land.

According to the latest information available[4], land set aside in the European Union and used for the production of non-food crops totalled 474 000 hectares in 1998/99, compared with 451 000 hectares in 1997/98. For 1999/2000 figures suggest that the area used for non-food production will more than double.

Of the 474 000 hectares used for non-food purposes in 1998/99, some 408 000 hectares were under oilseed crops, i.e. rape-seed (354 000 hectatares) and sunflower (61 000 hectares), with about 60% of this production being used for manufacturing bio-diesel and 40% for lubricants and chemicals.

Table 6 *Non-food production area on set-aside in EU (1000 ha)*

	EU-12		EU-15			
1000 ha	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Rape seed	172	479	825	571	311	354
Sunflower seed	32	138	144	89	82	61
Linseed	22	59	28	0	0	0
Cereals	9	16	18	18(e)	18(e)	18(e)
Sugar beet	1	6	6	12(e)	12(e)	12(e)
Short rotation	0	0	14	18	18	19
Medicine plants	4	6	6	6(e)	6(e)	6(e)
Others	2	3	4	4(e)	4(e)	4(e)
TOTAL	**242**	**707**	**1045**	**718**	**451**	**474**
Set-aside area	15%	12%	10%	5%	5%	10%
% oilseeds	**94%**	**96%**	**95%**	**92%**	**87%**	**88%**

(e) estimation
Source DG VI

According to "Prospects for Agricultural Markets 2000-2007", non-food oilseed area is estimated to adapt to the level of the set-aside rate and to stabilize at around 0.8 million hectares over the 2000/01-2007/08 period. Oilseed yields are expected to increase in the

[4] COM(2000) 485 final. The Agricultural situation in the European Union. 1999 Report

medium term and reach 2.7 t/ha on average in 2007/08. Therefore non-food production will evolve until 2.3 million t over the medium term.

Considering that diesel consumption of road transport in EU is 120 million ton, and one hectare gives 1070 liter bio-diesel, the replacement rate by bio-diesel depending on the oilseed surface is presented in table 7.

Table 7 *Oilseed surface and potential bio-diesel production*

Oilseed Surface 1000 ha	**production bio-diesel** 1000 t	**replacement rate** %
400	428	0.4
800	856	0.7
1 500	1 605	1.3
5 500	5 885	4.9
10 000	10 700	8.9
22 430	24 000	20.0

Figures in preceding table show that:

- With the current surface dedicated to grow non-food oilseeds the replacement rate reaches only the 0.4% of total diesel consumption.
- Dedicating the whole set-aside surface of the EU (5,5 mio hectares), the replacement rate would be of 4,9%.
- In order to reach a 20% rate of replacement, 22,4 Million hectares should be cultivated. Taking into account that the current surface of oilseeds (rape-seed, sunflower and soya-beans with food/feed destination) is 6 Million hectares, even cultivating the whole set-aside and oilseed area, only half of the 20% objective could be reached using bio-diesel.

4. CONCLUSIONS

It is well known that transportation is almost totally dependent on fossil fuel. This critical situation requires sustainable alternatives to fossil fuel: bio-fuels, and specially bio-diesel, from agriculture is one of these alternatives.

The production of crops for non-food purposes has a long tradition in the 15 EC Member States. Their importance has increased due, among other factors, to the need to develop renewable energy in order to meet environmental objectives such as climate change. In this context, agriculture might become in the future a very large provider of energy.

Considering the different policies related with the bio-diesel development (energy, agriculture and RTD), from the analysis made in this paper, some conclusions can be pointed out:

- Bio-fuels provide an alternative to fossil fuels, but nowadays bio-diesel price is 1.5 to 3 times higher than diesel price.

- Bio-diesel presents clear environmental advantages reducing emissions in front of the gasoil (especially CO_2 and sulfur oxides). Bio-diesel is not toxic and rapidly degradable. The risks of handling, transporting and storing bio-diesel are reduced.

- The competitiveness of bio-diesel crucially relies on the price of bio-mass feedstock and the price of the by-products obtained from the chemical conversion process (basically glycerol and meal). The costs linked to the conversion technology are of relatively minor importance.

- The competitiveness of bio-diesel is heavily dependent on the level of duty levied on them by Governments.

- The possibility of growing non-food crops under the compulsory set-aside scheme was an opportunity for the non-food sector, but it seems not to be an appropriate instrument to promote non-food production It has to be recall that compulsory set-aside is a supply-management instrument conceived to deal with cereal surplus situations. The uncertain future of this policy precludes long-term investment.

- The main barrier to the development of bio-diesel across Europe is uncertainty surrounding the long-term supply of feedstock.

- The sustainable development of bio-fuels cannot be ensured solely by instruments on the agricultural supply side. The possibility of growing non-food crops under compulsory set-aside scheme is an opportunity for bio-diesel development, but is not an appropriate instrument to promote non-food production.

- Fiscal incentives are an instrument to develop bio-diesel industry, and tax exemption has proven to be an effective approach. Other actions could be considered on the demand side, such as specifications for the quality of fuels.

- The advantages offered by bio-fuels have to be considered at levels beyond the agricultural sector, it is a matter of public interest, for which global economic policy instruments are to be applied.

- Blends are a real opportunity for bio-diesel development, giving an appropriate income for farmers, competitive prices for final consumers and even providing a less polluting image to major oil companies (which to date have been lacking).

- Dedicating the whole set-aside surface of the EU 15 (5,5 mio hectares) to cultivate non-food crops, the replacement rate would be of 4.9%, which coincides with the needs for a 5% blend in all diesel consumption of the EU. A higher area dedicated to non-food crops is difficult to reach.

- Taxation and legal obligations linked to international commitments of the Member States and the European Union are key issues.