

European Environmental Bureau (EEB) background paper 18-03-2002
On the use of biofuels for transport
By Gerie Jonk

1. Introduction

The European Commission has recently put forward a Communication on alternative fuels for road transportation accompanied by a proposal for a directive on the promotion of biofuels for transport and one that allows tax breaks for these fuels. This document deals with the environmental consequences of these proposals and presents the EEB's view on the Commission's action and ways to improve it. The Commission's proposals have led to concern within the environmental movement, since they seem to favour environmentally harmful biofuel production on agricultural land that has been set-aside.

The first section of the position paper gives an overview of the scope and contents of the Commission's proposals. The next section deals with the different sources for biofuels and presents alternative ways to reduce greenhouse gas emissions from the transport sector. Section 4 focuses on the environmental impact of biofuels and deals with fossil energy use and greenhouse gas emissions, emissions of regulated pollutants, and effects on biodiversity respectively. The paper ends with a conclusion and a proposal for stimulating a more environmentally friendly production of biofuels.

2. Commission Proposals

The increasing dependence of the European Union (EU) on oil imports and the commitments to reduce the emissions of greenhouse gases following the Kyoto protocol, are urging the European Commission to explore the possibility of alternative fuels for road transport.

At the moment, the transport sector is virtually 100 % dependent on mineral oil products, mainly gasoline and diesel. In the coming years, gross domestic oil consumption in the EU is expected to increase considerably, notably because of the growth of the transport sector. The EU's dependency on oil imports is already particularly high at 75 % of total oil supplies in 2000, but is likely to increase even further. (DG Energy and Transport, 2000) Since most of the oil imports come from only a limited number of countries, the EU is trying to diversify its sources away from these countries. One way of improving the diversity and security of energy supply is to increase the contribution of renewable energy sources to energy consumption. The substitution of oil derived transport fuels by biofuels is advocated for this reason.

Another reason for the Commission to advocate the use of biofuels is that they regard them in principle as CO₂ neutral, because the amount of CO₂ that is released during their combustion is equal to the amount that was assimilated from the atmosphere for the growth of the biomass. However, the production of biofuels requires an input of fossil fuel, which gives rise to CO₂ emissions. The Commission admits that this has to be taken into account. (COM (2001) 547, page 22)

Finally, with the Common Agriculture Policy (CAP) being refocused towards more emphasis on rural economy, the production of raw materials for biofuels is seen as a means to create new

sources of income and to maintain employment in rural areas. The accession of the Central and Eastern European countries makes this need even more pressing, since they have a large agricultural sector that will have to be restructured. The Commission sees potential for sustainable farming of biofuels in these countries. (COM (2001) 547, page 29)

The EU set an objective in its Green Paper on the security of energy supply to reach a substitution of mineral oil fuels by alternative fuels of 20% in the year 2020. (COM (2000) 769) On the 7th of November 2001, the Commission put forward a Communication on this issue. (COM (2001) 547) This paper on alternative fuels for road transportation investigates various alternative fuels, such as: biofuels, natural gas, gasoline and diesel substitutes derived from natural gas (methanol, dimethylether, Fischer Tropsch fuel), hydrogen, Liquefied Petroleum Gas (LPG), and alternative fuel converters, such as: electric cars, hybrid cars and fuel cells. The Commission points out three main alternative fuels, which in its view have the biggest potential to be developed until 2020:

- biofuels (short term)
- natural gas (medium term)
- hydrogen (long term)

Attached to the Communication are two proposals for directives. One proposal concerns a directive on the promotion of the use of biofuels for transport and sets compulsory substitution targets; the other allows Member States to grant reduced excise duty for biofuels as an incentive. As mentioned above, the first directive sets a minimum percentage of biofuels to replace diesel or gasoline for transport purposes in each Member State. Biofuels may be made available as pure fuel, biofuel blended into gasoline and diesel, or additives derived from biofuels, such as ETBE (ethyl-tertio-butyl-ether). The minimum proportion of biofuels sold on the Member States' markets must be 2 percent by the end of 2005, calculated on the basis of energy content of the fuel. After 2005, the share of biofuels should increase according to a yearly schedule up to 5.75 percent in 2010. The Commission eventually wants to reach a substitution of 8 percent towards 2020. (COM (2001) 547, page 13) According to the Commission, it is unlikely that a percentage of biofuels above 4 to 5 percent can be reached by using only biofuels in pure form. Therefore, a minimum share of blending of 1 percent must be achieved from 2009, increasing up to 1.75 percent by 2010.

Before 2008, the Commission will have to report to the Parliament and the Council on the progress made in the use of biofuels in the Member States. On the basis of this report, the Commission may propose adaptations to the system of targets.

The second proposal concerns an amendment of the directive on excise duties on mineral oils (92/81/EEC). It allows Member States to reduce excise duties on pure biofuels or biofuels blended into other fuels, when they are used for heating or transport purposes. A reduction of 50 percent of the rate for normal fuels is allowed. When fuels are used in local public passenger transport, including taxis, an additional tax exemption, up to a 100 percent, is allowed. The tax exemptions are allowed for the period from January 2002 until December 2010. The tax reductions must be evaluated every year against changes in raw material prices to avoid the over-compensation of biofuels in the event of a rise in the price of crude oil.

3. Biofuels and other options

3.1 Biofuels

Biofuels are liquid or gaseous transport fuels produced from biomass. In the EU definition, biomass comprises the biodegradable fraction of products, waste and residues from agriculture, forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste. (2001/77/EC) Biomass such as wood or straw can be used to generate heat as well as electricity. The term biofuels is used to describe biomass derivatives that are used for transport purposes.

Different biomass sources can be used for the production of biofuels, such as:

- plant oils (rapeseed, soybean, sunflower and others)
- starch or sugar containing crops (sugar beets, wheat, maize and others)
- ligno-cellulosic material (wood, straw)
- organic waste material (waste oil, animal manure, biodegradable fraction of municipal waste)

Different conversion processes are available to produce fuels from these sources, which are not all equally well developed or cost efficient. Basically three different conversion processes are used: physical-chemical, thermo-chemical and bio-chemical conversion.

In thermo-chemical conversion, biomass feedstock is dried and gasified and yields a gas from which motor fuel can be synthesised. Physical and chemical processes such as extraction and esterification are used to produce fuels from raw material or synthesis gas produced after thermal treatment. Bio-chemical conversion processes, such as fermentation or anaerobic digestion, yield liquid or gaseous fuels.

With these different sources and processes a range of fuels can be produced, which are either used for transport purposes in pure form or blended with conventional fuels.

Biodiesel is the most frequently used biofuel and is produced from plant and waste oils in a physical-chemical conversion process. In this way, biodiesel can be produced from sunflower, soy oil, rapeseed and other oils. Usually the fats and oils are chemically reacted with an alcohol to produce fatty acid methyl esters. Biodiesel produced this way from rapeseed (colza) is called Rapeseed Methyl Ester (RME). Biodiesel can be blended into conventional diesel or used in a pure form in adapted vehicles.

Bioethanol is produced from starch and sugar holding crops in a bio-chemical process, but ligno-cellulosic material also forms an interesting potential source of bioethanol. Bioethanol can be used as an automotive fuel by itself or can be mixed with conventional fuels. **ETBE** (ethyl-tertio-butyl-ether) is produced from bioethanol after etherisation and is blended into gasoline as substitute for lead as anti-knock agent and octane booster.

Biogas (methane) is a gaseous biofuel that is produced through anaerobic digestion of biomass. It can be used as a transport fuel in gas engines.

Other types of biofuels can be produced after thermo-chemical conversion of organic material. Examples are **biomethanol**, **biodimethylether (bioDME)**, and **biooils (pyrolysis oil)**. These

fuels are not yet produced on a large scale, but pilot projects are coming up that boost the development of the technology.

Biofuels are already used for transport purposes in the United States, where they made up about 0.5 % of total transport fuel consumption in the year 2000. In Europe, only a few countries make any real contribution to the total European biofuel production. In France, the front runner, total biofuels contribution in the transport sector in 1999, amounted to 0.7 % of total oil products consumption, with approximately one third bioethanol and two thirds biodiesel. Other European countries that are active in the promotion of biofuels for transport are Austria, Germany, Sweden, Italy and Spain. This mostly concerns biodiesel, but also bioethanol and ETBE are produced. Bioethanol is usually produced from conventional agricultural crops, such as wheat and sugar beets. Sweden is most active in the development of ethanol production from woody biomass.

3.2 Other options to reduce greenhouse gas emissions from transport

While the EEB welcomes the Commission's ambition to tackle greenhouse gas emissions from transport, it does not consider the proposed support for biofuels as the right way to bring this about. There are various alternatives to the use of biofuels that offer more advantages to the environment, as well as being more attractive from an economic perspective. The Commission's proposal seems to favour biofuels produced from agricultural crops on set-aside land. The production and use of biofuels from conventional agricultural crops offers only slight environmental advantages compared to conventional fuels, and involves high costs. The next section will go into detail concerning the environmental impacts of biofuels produced from energy crops. In this section the EEB would first of all like to point out some alternative ways of reducing the climate impact from the transport sector.

First of all, there seems to be little use in accommodating the ever-growing transport sector by providing a biological fuel that is easily fitted into the current transport fuelling system. The Commission reports in its, "Green Paper on Security of Supply" that the transport sector is likely to grow some 2 percent per year over the coming decade (COM (2000) 769). The potential of biofuels is small since the area of agricultural land is limited. In the Communication, the Commission estimates that the maximum transport fuel substitution through biomass is around 8 percent of present gasoline and diesel consumption. (COM (2001) 547, page 5) This 8 percent is reached when 10 percent of agricultural land in the EU is used for the cultivation of biomass for fuels, which corresponds to almost 14 million hectare. (DG Agriculture, 2001) When only set-aside land is used the possible substitution is less; around 5 to 6 percent. One hectare of rapeseed yields 1 toe (ton of oil equivalent) of biodiesel (COM (2001) 547, page 19). This is only enough to supply one car with fuel for one year¹.

With an annual growth of the transport sector of 2 percent this maximum 8 percent substitution by biofuels is offset by the growth in the use of fossil fuels in less than four years! This hardly justifies the utilisation of 10 percent of the agricultural land of the Union.

¹ A passenger car 's annual distance run is on average 15,000 km, average consumption is 7.2 litre per 100 km, thus annual average consumption is about 1,000 litre per year.

Secondly, other biomass use of agricultural land is much more promising, for instance the growth of short rotation coppice. Short rotation forestry could be used as an energy source for the generation of heat and electricity, for instance in a combined heat and power generation plant. The energy balance of short rotation coppice is high (1:10 to 1:30). This means that with one unit of fossil fuel 10 to 30 units of renewable fuel can be produced. This is a much higher gain than for biofuels that are produced from annual crops, as will be shown in the next section.

Thirdly, the Commission should look also into the opportunities to reduce the volume of the transport sector. This could be done by supporting public transport, carpooling, biking, using rail road or waterways for freight transport, and stimulating people to use their cars less often.

Fourthly, the Commission rightly says in its Communication that any cost-effective strategy to reduce oil dependency and CO₂ emissions from the transport sector must have fuel efficiency as its top priority (COM (2001) 547, page 4). In 1996, the Commission adopted a CO₂ emission target of 120 g CO₂/km for new cars by 2010 at the latest. The car industry committed itself to a target of 140 g CO₂/km by 2008. However, to secure security of supply and climate protection much more has to be asked from the car and oil industry than up to now, as the Commission admits. Applying and further developing existing technology will allow higher fuel efficiency than has been agreed upon thus far. (COM (2001) 547, page 4) However, the Communication only states that support for the accelerated introduction of advanced, high efficiency cars should be considered. The EEB thinks this should be a top priority since it offers more CO₂ savings and at lower costs than the biofuels scheme. High efficiency fuel converters that could be considered are for instance, advanced hybrid cars, which combine combustion and electric drives.

Fifthly, besides the lack of attention by the Commission for the measures to reduce the climate impact of transport that were named above, something can also be said about the type of biofuels that the Commission is emphasising. The Commission Proposals consider mainly biodiesel, bioethanol, and ETBE produced from bioethanol. These fuels are usually produced from intensively farmed annual crops. However, organic waste material could also be considered as a raw material for biofuels. Waste streams that are suitable for conversion into biofuels are for instance waste products from agriculture and forestry, waste oil (slaughter house refuse, cooking oil, etc.), animal manure and organic household waste. The Commission acknowledges these possibilities but states that the amount of organic waste material that can be used for the production of biofuels is limited (COM (2001) 547, page 20). This statement can be questioned as it is not the amount of waste that is limiting the production of biofuels, but rather the infrastructure that has to be set up for waste collection and processing.

The Commission also acknowledges that there is reason to believe that future developments will also make it possible to produce economically competitive bioethanol from cellulose (wood or straw), and to produce other liquid and gaseous fuels produced by thermo-chemical processing of biomass, such as bioDME, biomethanol or biooils (COM (2001) 547, page 5). However, the Commission considers these processes to be feasible in the medium term only. Nevertheless, methanol and ethanol are already produced from agricultural and forestry residues in Sweden and Germany.

The Commission admits that there is little scope for large-scale biofuel production under the existing system of set-aside land (COM (2001) 547, page 6). However, it is clear from the language of the Commission that it wishes to attain the goal of 5.75 percent of biofuels in 2010, mainly by using biofuels from conventional agricultural crops, such as wheat, rapeseed, and sugar beet. The Communication argues that the amount of available agricultural land is limiting the substitution possible by biofuels, and that it would be difficult to justify large-scale Community support for biomethanol and bioDME (COM (2001) 547, page 6).

However, research indicates that the more energy efficient fuel chains include ethanol from cellulose and biogas from waste, but also large-scale production of methanol or DME from biomass. It is difficult to get impressive results from biofuels produced from intensively farmed annual crops. (Ecotrafic, 2001)

The Commission wants to promote biofuels in the short term, because they can be fuelled into the existing vehicles and distribution system and thus do not require expensive investments in fuelling infrastructure and engine technologies. It acknowledges that biofuels will hardly be seen as a long-term high volume substitute for motor fuels because of the limitation of available land. **It seems more rational then to promote promising and innovative technologies to convert organic waste fractions from industry, agriculture and forestry into biofuels than to rely on biofuels from intensively farmed annual crops that only have a small potential and dubious environmental benefits (see the next section). When bioenergy use has come so far as to motivate energy plantations, the things that have to be considered are multifunctional plantations and energy wood-plantations such as willows or poplars (salix, populus), and not plantations of annual food crops.**

The other alternative fuel options the Commission is considering until 2020, are natural gas and hydrogen. Natural gas can shift energy supply away from oil and offer potential reductions of CO₂ emissions in the order of 15 to 20 percent compared to gasoline. This advantage disappears when more efficient engines are used, already with the diesel engine. Natural gas is a fossil fuel, so in the end it will offer neither substantial reductions of CO₂ emissions nor security of energy supply.

Hydrogen is usually associated with fuel cells, but its use is not restricted to these fuel converters only. It must be stressed that hydrogen is not an energy source but an energy carrier. It only offers an environmental advantage over fossil fuels when it is based on renewable energy sources and it will take a lot of time until hydrogen will be available at reasonable costs. There are still more problems than solutions in the use of hydrogen for transport.

The EEB welcomes the Commission's intention to develop the use of alternative fuels such as natural gas for transport purposes. It would like to stress that it is important to develop promising technologies, but that environmental objectives should form the basis of this promotion. Only those technologies that have the potential to provide significant environmental benefits deserve to be promoted.

4. Environmental impacts of biofuels

The Commission states in its Communication that “any long-term solution (concerning alternative fuels for transport) will, as a minimum, have to offer a reduction in oil dependency and a reduction in greenhouse gas emissions, compared to the most fuel-efficient vehicles running on conventional fuel. In addition, it must be required that such alternatives permit a continued reduction in emission of “conventional” air pollutants from the vehicles.” (COM (2001) 547, page 3) This section explores the environmental impacts of biofuels in view of these requirements. There are several studies in which the environmental performance of biofuels is assessed, usually in comparison to other fuels. However, it is difficult to compare these studies, since they differ in methods and assumptions. Moreover, large differences between the different types of biofuels are possible. Finally, some studies are biased towards biofuels, while others seek to point out that biofuels are undesirable, making the interpretation of the data highly questionable. Still, in this section it is attempted to come to some conclusions on the performance of biofuels with regard to fossil energy use and greenhouse gas emissions, emissions of regulated air pollutants, and effects on biodiversity.

4.1 Fossil energy use and greenhouse gas emissions

Since the Commission argues that the use of biofuels could bring about a reduction in greenhouse gas emissions from transport, this claim will be investigated first. This can be done by comparing greenhouse gas emissions during the biofuel lifecycle with those during the lifecycle of the conventional fuels they replace.

In order to come to comparable lifecycle data, they have to be standardised. Several methods have been developed:

1. The output-input ratio is used to express the fossil energy input in the lifecycle of the biofuel. This reflects the energy content of a certain amount of biofuel (e.g. 1 litre) divided by the fossil energy used in the production of this amount.
2. CO₂ savings are expressed in absolute numbers referred to a parameter like a hectare of agricultural land, or a passenger kilometre with a certain car.
3. Relative figures are given on the share of CO₂ or total greenhouse gas emissions (as a percentage) that are avoided when biofuel is used instead of conventional fossil fuel for the same type of transport.

Fossil energy use

Energy efficiency of biofuels relates to the amount of energy that is needed in the biofuel lifecycle to accomplish a certain task, for example; one passenger kilometre with a certain car. Of course the efficiency of the whole fuel chain depends on the fuel used, the production method, the engine technology, and many other factors. The lifecycle efficiency of biofuels is usually lower than of fossil fuels, since more energy is needed for the production of the fuel, for instance in the cultivation of the raw material and in the conversion of biological material into fuels. In the context of this paper it is important to know how much fossil energy is used in the lifecycle of the biofuel, i.e. from “well to wheel”, from oil production to consumption in the vehicle, because this gives rise to CO₂ emissions.

The best-studied biofuel so far is Rapeseed Methyl Ester (RME), the most common type of biodiesel. For RME, different studies come up with output-input values of 1.9 to 3.0, but most

studies confirm a value of 2.5 to 3.0. This means that with the use of one unit of fossil fuel, two and a half to three units of RME can be produced.

Some studies also calculate the total amount of fossil energy that is saved using RME. If 1 litre diesel is replaced by RME, fossil energy saving is between 42.8 to 45.9 MJ. Due to the differences in energy content 1 litre diesel is replaced by 1.1 litre RME. With these numbers it is possible to calculate fossil energy savings from 1 hectare of rape. Estimations of the yield of 1 hectare of rape field vary between 1,000 to 1,500 litre biodiesel. Fossil energy savings per hectare of rapeseed are then between 40 and 60 GJ.

For fuels other than RME, less studies are available, which means that results should be treated with more caution. For rapeseed oil, which is not converted to RME, estimations in literature of the output-input ratio range from 1.8 to 4.1. Biodiesel from other oily plants, such as sunflower and soy oil, has a slightly higher output-input ratio than RME (2.8 to 3.2). Energy savings per hectare are higher, since the biodiesel yield from one hectare is higher. The output-input ratio is much higher when secondary products such as straw are used as energy input in the production of the fuel.

Bioethanol typically results in lower energy output-input ratios. For ethanol from sugar beets the ratio is lowest, studies resulting in values from 1.1 to 2.3. However, these studies are somewhat outdated and the present ratio is estimated at about 2.4. Fossil energy savings per hectare are however considerably higher than in the case of RME, i.e. at least 100 GJ per ha, due to the higher agricultural yields of sugar beet.

For ethanol from maize, the output-input ratio is estimated in a somewhat older study to be about 3.0 with energy savings per hectare of over 150 GJ (BLT, 1999). Another study comes up with an output-input ration of 1.9 (CLM, 1994).

Estimations in literature for the output-input ratio for ethanol from wheat are in the range of 1.0 to 2.8. One study shows good projections for the ratio after 2000 (BLT, 1999). When straw is produced as a by-product and utilised in the process the ratio goes up to 4.8 to 5.6.

Ethanol and methanol from tree residues or dedicate energy forests lead to a much higher output-input ratio. It can get as high as 17 for ethanol from tree residues.

Greenhouse gas emissions

The use of fossil fuel in the production of biofuels gives rise to CO₂ emissions. Another greenhouse gas that is emitted during the lifecycle of biofuels is N₂O. This is a particularly powerful greenhouse gas, because it is very persistent in the atmosphere. N₂O is emitted in the cultivation of the biomass feedstock due to the application of nitrogen fertiliser. N₂O emissions relate to the nitrogen surplus in the soil and are dependent on the soil type. The total emission of greenhouse gases is expressed in CO₂ equivalents, where 1 unit of N₂O is equal to 270 to 290 CO₂ equivalents.

Again, most data are available for RME. Estimations of CO₂ savings are within the wide range of 25 to 80 percent, which means that 25 to 80 percent less CO₂ is emitted in the RME lifecycle, compared to the use of fossil diesel. When N₂O emissions are also considered the greenhouse gas emissions savings are lower, but estimations of the impact of N₂O vary widely also. Most

studies however attribute a loss of about 10 to 15 percent of the CO₂ equivalent savings to the emissions of N₂O.

CO₂ equivalent savings can also be expressed in an absolute number. If 1 litre diesel is replaced by RME, CO₂ savings are in the range of 3.2 to 3.3 kg CO₂ equivalents. When N₂O emissions are taken into account the savings are reduced to about 2.8 to 2.9 kg CO₂ equivalents. If the rapeseed yields of the previous paragraph are used, greenhouse gas savings per hectare of rape field can be calculated. These are between 2.9 and 4.5 ton CO₂ equivalents per hectare. This is more or less in line with estimations that exist in literature of 2.1 to 3.0 ton per hectare. (GET, 2001)

All in all, the studies investigated come up with a positive climate effect for RME.

For fuels other than RME, the relative CO₂ savings are usually lower, but the savings per hectare are higher. Ethanol from wheat has lower CO₂ emissions in the range of 20 to 60 percent compared to the use of gasoline, and savings of 2.5 to 3.1 ton CO₂ equivalents per hectare. Ethanol from sugar beets gives a much better result of 5.4 to 6.9 ton CO₂ equivalents avoided per hectare due to higher yields.

Fuels from ligno-cellulosic sources, such as methanol and ethanol from energy forests or tree residues, result in CO₂ emissions that are about 70 to 80 percent lower than from conventional fossil fuels. The same holds for biogas fuel.

N₂O emissions are not a big issue for the other fuels. N₂O emissions from rape cultivation are much higher than for other agricultural crops, because of the larger use of nitrogen fertiliser.

The Commission uses an estimate of 3.2 tons CO₂ emissions per 1000 litre fossil diesel, and 2 to 2.5 tons CO₂ savings per 1000 litre biodiesel. This corresponds to 70 percent CO₂ savings for biodiesel, which is rather optimistic considering the range of CO₂ savings from biodiesel found in literature of 25 to 80 percent. Since 1 hectare rape field yields 1,000 to 1,500 litres of biodiesel, CO₂ savings per hectare are around 3 tons, which is within the range found in literature.

For bioethanol CO₂ savings are estimated at 2 tons per 1000 litre. (COM (2001) 547, page 22)

Costs of CO₂ reductions from biofuels

The analysis above shows that biofuels indeed lead to lower CO₂ emissions compared to their fossil fuel substitutes. In this section, the significance of these emission reductions is assessed by comparing the costs of CO₂ emission reduction by the use of biofuels with other options to reduce CO₂ emissions. These can be options within the field of transport, but also measures to reduce CO₂ emissions from households or industry, or other economic sectors.

The CO₂ reductions achieved using RME instead of fossil diesel were estimated in the range of 3.2 to 3.3 kg per litre, corresponding to 2.1 to 4.5 ton CO₂ per hectare. N₂O emissions are not considered in these numbers, since most of the data on costs of emission reductions deal with CO₂ only. CO₂ savings from bioethanol are in the range of 2.5 to 3.1 ton per hectare for ethanol from wheat, and 5.4 to 6.9 ton per hectare for ethanol produced from sugar beets.

Below are some data on the costs of CO₂ emission reductions from biofuels. The costs refer to the extra costs of the production and use of biofuels compared to conventional fuels, which have to be provided for in the form of state aid.

In France, tax exemptions for biofuels are 0.35 EUR per litre for biodiesel, and 0.50 EUR per litre for bioethanol (EEA, 2001). Combining these data with the numbers on CO₂ savings from biofuels lead to emission reduction costs of about 110 EUR per ton CO₂ for biodiesel, 180 EUR per ton CO₂ for ethanol from wheat, and 80 EUR per ton CO₂ for ethanol from sugar beets.

Other studies come up with numbers that are not very well in line with this. Estimations of emission reduction costs when using RME or another biodiesel range from 37 to 235 EUR per ton CO₂. Estimations for CO₂ reduction costs from bioethanol are scarce, but are usually a bit higher than the numbers for RME. The highest estimation found was over 400 EUR per ton CO₂ for ethanol from sugar beets. When indirect subsidies, such as subsidies for set-aside land, are also taken into account, the costs of CO₂ emission reduction are even higher; for RME they can be as high as 430 EUR per ton CO₂. (UBA, 1999)

The Commission seems to be on the optimistic side of the cost range with their estimate of reduction costs for biofuels of 100 to 150 EUR per ton CO₂. The Commission does not really explore other options to reduce CO₂ emissions and their costs. Alternative ways to reduce CO₂ emissions from the transport sector are various and range from the promotion of public transport and carpooling to technical adaptations in vehicles, for instance in the engine, but also in the resistance or weight of the car, to the use of alternative fuels from fossil origin. The costs of these measures are difficult to assess, as there are for instance, different ways to bring changes in car use about. One study estimates the costs of bringing about less car use on 165 EUR per ton CO₂ (GET, 2001). Another study (UBA, 1999) estimates the costs of adaptations in engines. These are in the broad range of 100 to 360 EUR per ton CO₂, depending on the type of engine. These numbers are all within the range of emission reduction costs for biofuels. However, it is difficult to compare CO₂ reduction costs of the biofuels scheme with improvements of engine technology. The latter have the potential to lead to much higher reductions in CO₂ emissions, and costs might be brought down by economies of scale. Biofuels from agricultural crops can never have a big impact due to the limited amount of land that is available.

Comparisons of the costs of CO₂ reduction from biofuels with CO₂ reduction schemes in other economic sectors, provide a clearer image. Measures such as energy saving, insulation of homes or other buildings, wind and hydro- energy, cleaner fossil fuels, and the use of biomass for heating and electricity purposes, yield CO₂ emission reductions against much lower costs than biofuels. Insulation schemes could even have negative costs, meaning they provide financial benefits by savings on heating bills. The costs of renewable forms of energy such as wind and water power for the generation of electricity are in the range of 0 to 130 EUR per ton CO₂. Also, biomass used for the generation of heat and power presents CO₂ reductions against much lower costs than biofuels for transport (21 to 31 EUR per ton CO₂, CE, 1993).

It is clear there are various options to achieve CO₂ emission reduction with relatively low costs. The measures taken in the traffic sector, and especially the use of biofuels, are among those with the highest costs. On top of this, there is only a small market potential for biofuels. Even if all the available agricultural land would be used to produce biofuels,

only a small effect on total CO₂ emissions would result. Biofuels from annual food crops like wheat, sugar beet, rape etc. are therefore hardly an attractive option to reduce greenhouse gas emissions, looking from an economic perspective.

The data on energy use, CO₂ emissions and reduction costs can be found in the Appendix.

4.2 Emissions of regulated air pollutants

The group of regulated air pollutants comprises the substances causing acidification, eutrophication, photochemical smog formation, or substances that are detrimental to human health. These substances are regulated by means of emission limits. Also, reduction percentages have been established, at least in the EU. The group of regulated air pollutants includes mainly sulphurdioxide (SO₂), nitrogenoxides (NO_x), ammonia (NH₃), volatile organic compounds (VOC), particulate matter (PM), and carbonmonoxide (CO).

As in the case of energy use and greenhouse gas emissions, it is difficult to compare studies that estimate emissions of regulated air pollutants from the production and use of biofuels. Sometimes only direct emissions of air pollutants in the exhaust of the car are considered, when otherwise also indirect emissions from the production process of the fuel are included. This paper therefore refrains from quantitative estimations of emissions, but focuses on qualitative statements.

As concerns acidification, most studies confirm higher emissions of acidifying substances from biofuels. This is mainly caused by the high emission of NH₃ from agriculture and fertiliser production². Of course, emissions from agriculture depend on the energy crop that is used. In the case of rape, fertiliser use is high and yields per hectare are low, which means that NH₃ emissions per litre of fuel are high. Diesel from soy oil has a more positive balance, because less nitrogen fertiliser is used.

Emissions of the strongest acidifying component, SO₂, are lower from biofuels than from conventional fuels. This is due to the very low sulphur content of biofuels. However, in more recent studies the positive balance as regards SO₂ from biofuels has changed, because of the decreasing sulphur content of conventional fuels due to desulphurisation techniques. NO_x emissions from vehicles are usually higher in the case of biofuels. This is especially true for RME, due to the high oxygen content of this fuel. NO_x is not only an important acidifying substance, but also a precursor in the formation of ground-level ozone, and contributes to eutrophication of the environment.

In general, NO_x emissions from bioethanol are lower than from biodiesel due to the fact that petrol engines can be equipped with a three-way catalyst. NO_x emissions from diesel engines are therefore always higher. However, SO₂ emissions from bioethanol are somewhat higher than from biodiesel.

Concerning the precursors of tropospheric ozone, such as VOC, hydrocarbons and aldehydes, differences between biofuels and fossil fuels are usually small. For VOCs as a whole, emissions

² NH₃ is oxidised in the end to NO_x which gives rise to acidification, eutrophication and ozone formation.

during the biofuel lifecycle are usually not very different than from fossil fuels, although for bioethanol, the emissions are somewhat lower. For specific organic components, such as benzol, emissions from biofuels are higher than from fossil fuels. Emissions of aldehydes are especially high when alcohols, such as bioethanol and biomethanol, are involved.

As regards CO emissions, usually lower values for biofuels are found, but again the differences are small.

Emissions of substances that can be detrimental to human health, such as particulates and dust, are difficult to evaluate, because numbers in studies are rare. The numbers that are available do not show much difference between biofuels and conventional fuels as regards these compounds.

From the above, it is clear that differences in emissions of regulated air pollutants between biofuels and fossil fuels are small. However, it must be kept in mind that the differences are not insignificant, due to the lack of and the uncertainties in data. The Commission acknowledges in the Explanatory Memorandum to the biofuels directive that biofuels will offer in theory little, if any, emission advantage over gasoline and diesel in the future (COM (2001) 547, page 24). It is important to stress that emissions of regulated pollutants from biofuels should meet the pollution control standards of EURO 3 and 4 as defined in EU legislation (98/69/EC). The compliance with these emission limit values depends highly on the fuel quality. It must be ascertained that biofuel use does not give rise to higher emissions.

4.3 Effects on biodiversity

Effects of biofuel production and use on biodiversity are even more difficult to quantify. Therefore, this section focuses only on biodiversity effects of agricultural production of energy crops. A distinction has to be made between biomass crops for the generation of heat and electricity, such as short rotation coppice, and crops for biofuels. This section focuses on the effects of biofuel crops; annual food crops such as rapeseed, sugar beet and wheat.

Since effects of the cultivation of biofuel crops on biodiversity are difficult to quantify, this section is mainly concerned with the use of fertiliser and pesticides for the production of biofuels, as this has effects on water and soil quality and because of that also on biodiversity. Also, some comments will be made on the effects of energy crop monocultures and the loss of habitats and landscape variation.

When evaluating effects of biofuels on emissions of greenhouse gases and regulated air pollutants, the use of biofuels was compared to the use of conventional fossil fuels. However, when evaluating the effects on biodiversity, biofuel crop plantations are compared to alternative uses of agricultural land, such as for the cultivation of other agricultural crops or set-aside.

When they replace intensively cultivated food crops, the cultivation of biofuel crops can bring ecological advantages, such as less use of pesticides and fertilisers. However, the ecological advantages disappear with intensification of feedstock production. Moreover, biofuel plantations usually do not replace existing food crop plantations, because the most attractive options for farmers are to replace set-aside land or grains (CLM, 1994). On set-aside land, which is not used

for food production, the cultivation of energy crops will generate a higher environmental impact on soil and groundwater than leaving it fallow. When land is set aside it at least recovers part of its soil life (invertebrates), but this will be reversed if the land is used again for intensive production of agricultural crops.

The cultivation of biofuel crops, such as rapeseed, sugar beet and wheat, requires a rather intensive use of fertilisers and pesticides. Nutrient losses from plantations of these crops expressed in losses per litre of biofuel produced are highest for rape, and lowest for sugar beets. Nutrient losses of nitrogen per hectare are highest for rape and lowest for wheat, with sugar beet very close to rape. Wheat plants have a very fine root network, which allows them to take up most of the nutrients that are applied. The difference between the ranking of the crops per hectare and per litre of biofuel is mainly accounted for by the lower yields of rape and wheat per hectare compared to sugar beets.

Pesticides use per litre of biofuel is also highest in the case of rape. Per hectare, the use of pesticides is highest for wheat and lowest for rape.

Nutrients, such as nitrogen and phosphorous, and pesticides, can end up in soil, groundwater or surface waters. Here they can cause eutrophication or toxification of ecosystems, which has impacts for ecosystem health and biodiversity. Pesticides, for instance, kill invertebrates in the soil, thereby taking away the food source for birds such as grey partridge, corn bunting and skylark. (PAN UK, 1999)

Crops used for biofuels such as rape, sugar beet and wheat, are among the most common crops used for food production. What is needed to increase biodiversity in agriculture is a larger variety in crops and longer rotation cycles. Biofuel crop plantations on set-aside land will only create more monocultures with all its effects on biodiversity.

The cultivation of energy crops also has impacts on the landscape. Here, the variation in the landscape is important. Rape and wheat are the most appreciated crops; rape is known for its colour. Plantations of sugar beet do not contribute to the variation of the landscape, because beets are already cultivated on a large scale. When compared to set-aside land, plantations of all these crops will most likely decrease the variation of the landscape.

The Commission argues in its Communication that increased production of raw materials for biofuels will contribute to the multi-functionality of agriculture. The agri-food and forestry industry biofuels could also turn problematic waste production into a sustainable product. (COM (2001) 547, page 23) This is, however, only the case when residues from agriculture, forestry or industry, or perennial woody energy crops are used. Unfortunately, most likely only conventional annual crops will be used for the production of biofuels.

The Communication also states that agricultural policy should encourage sustainable farming and afforestation and the avoidance of negative environmental impact (COM (2001) 547, page 23).

The Commission is not in line with this if it promotes cultivation of biofuel crops on set-aside land.

When biofuel crops are intensively cultivated on set-aside land they will have detrimental effects on biodiversity. Not only because they provide less habitats for animals, push

aside other plants when cultivated in monocultures, and decrease the variation in the landscape, but also because the intensive farming of biofuel crops is accompanied by a high use of fertiliser and pesticides deteriorating ecosystem health and thereby biodiversity.

5. Conclusion

The Commission has signed the Biodiversity Convention and Agenda 21 of the United Nations Conference on Environment and Development, which aim at having less chemically-intensive agriculture. Following this, the Commission has issued a Communication on Indicators for the Integration of Environmental Concerns into the Common Agricultural Policy in the year 2000. (COM (2000) 20) This document provides a first step in the completion of a set of integration indicators for agriculture, particularly where indicators are poorly defined or where full data sets are missing. A Biodiversity Action Plan for Agriculture has also been published. With these documents, the EU has declared its intention in moving towards an environmentally sound agriculture.

With the proposed biofuel directive the Commission is not in line with this intention. While biofuel production results in more intensive, high chemical-input agriculture, it also would require large areas of agricultural land. It has detrimental effects for biodiversity, both by polluting soil and water and by creating crop monocultures

The United Nations Framework Convention on Climate Change, the Union's Sustainable Development Strategy, the 6th Environmental Action Programme, and many other documents emphasise the need to reduce emissions of greenhouse gases. In the Action Plan for renewable energy as well as in the Green Paper on Security of Energy supply the need to find alternative fuels for transportation purposes in order to decrease greenhouse gas emissions from transport is stressed.

The proposed directive sees the use of biofuels as an important way to reduce greenhouse gas emissions from transport, but:

- biofuel production requires a considerable amount of fossil energy
- greenhouse gas emissions savings from biofuels are by no means certain and likely to be very different according to the crop, soil and climate conditions, ranging from very small gains to 80 percent gains at maximum.
- CO₂ abatement costs of biofuels are very high

To sum up, the scheme proposed by the Commission could lead to intensive biofuel production on set-aside land, and intensive food production on the rest. There are questions about the energy balances of biofuels, as well as concerns over chemical inputs and narrowing biodiversity. The Commission says in the Communication accompanying the proposed directive that the directive will give a clear signal that the Community is serious about developing alternatives to petroleum products in transportation (COM (2001) 547, page 13). If this is the aim of the directive it is no use risking all the possible undesirable environmental impacts that could result from intensive biofuel production on agricultural land in the EU. **A less energy intensive agriculture**

would in the end save more energy than promoting intensive agriculture for marginal CO₂ gains through production of biofuels.

5. Proposal for biofuel production in harmony with environmental requirements

The EEB would like to stress again the urgency to develop measures that significantly reduce energy consumption in the transport sector such as reducing the volume of transport and improving engine efficiency.

Also, it would like to point again to the fact that there various possible biomass sources for biofuels. The biofuels that deserve to be promoted are the ones that offer significant environmental benefits, such as the use of residues from agriculture and industry, and other organic waste fractions.

When it comes to agricultural solutions, the EEB advocates two main principles for a good agricultural system:

1. The support for everything that maintains or increases the mixture of productions; species diversity, long rotation, multifunctional production, etc.
2. At least maintaining but preferably increasing biodiversity (soil flora and fauna, natural elements such as hedges), contributing to a better functioning of natural cycles by using good management in the use of pesticides and fertilisers.
(France Nature Environnement, 2001)

In the light of these principles the EEB rejects the promotion of biofuels coming from conventional agricultural crops. The Union's agricultural land could be better used for organic farming, extensification of agriculture, fodder production, afforestation or even short rotation coppice.

References

92/81/EEC. Council Directive of 19 October 1992 on the harmonization of the structures of excise duties on mineral oils. Official Journal L 316, 31/10/1992 P. 0012-0015

98/69/EC. Directive of the European Parliament and of the Council of 13 October 1998 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Council Directive 70/220/EEC. Official Journal L 350, 28/12/1998 P. 0001–0057

2001/77/EC. Directive of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market. Official Journal L 283, 27/10/2001 P. 0033-0040

COM (2000) 20. Communication from the Commission to the Council and the European Parliament; Indicators for the Integration of Environmental Concerns into the Common Agricultural Policy. 26 January 2000

COM (2000) 769. Green Paper; Towards a European Strategy for Energy Supply. 29 November 2000

COM (2001) 547. Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions on alternative fuels for road transportation and on a set of measures to promote the use of biofuels.
Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of biofuels for transport.
Proposal for a Council Directive amending Directive 92/81/EEC with regard to the possibility of applying a reduced rate of excise duty on certain mineral oils containing biofuels and on biofuels. 7 November 2001

Biocosts Research group (Almeida *et al.*). 1998. Total Costs and Benefits of Biomass in Selected Regions of the European Union. Research funded in part by the European Commission in the framework of the Non-Nuclear Energy Programme JOULE III, Contract JOR3-CT95-0006

Bayerisches Staastministerium für Landwirtschaft und Forsten. 2001. Ganzheitliche Systemanalyse für die Erzeugung und Anwendung von Biodiesel und Naturdiesel im Verkehrssektor. München

BLT (Bundesanstalt für Landtechnik). 1999. Ökobilanz biodiesel; Eine Studie im Auftrag des Bundesministeriums für Land- und Forstwirtschaft. Wieselburg

CE (Centrum voor Energiebesparing). 1993. Environmental and Energy Aspects of Liquid Biofuels. Delft

CLM (Centrum voor Landbouw en Milieu). 1994. Kan de landbouw schone energie leveren?; Onderzoek naar duurzaamheid van energie gewassen. Utrecht

DG Agriculture. 2001. Agricultural in the European Union; Statistical and economic information 2000. http://europa.eu.int/comm/agriculture/agrista/2000/table_en/index.htm, 21/01/2002

DG Energy and Transport. 2000. The European Union's oil supply. Brussels

EEA (European Environment Agency). 2001. Renewable energy; Success stories. Copenhagen, Environmental issue report No 27/2001

Ecotrafic. 1992. The life of fuels; Motorfuels from source to end use; An energy and emissions systems study of conventional and future options. Stockholm

Ecotrafic. 2001. Well-to-wheel efficiency; For alternative fuels from natural gas or biomass; A report for the Swedish National Road Administration. Stockholm

France Nature Environnement. 2001. Expertise associative sur les bonnes pratiques agricoles. Orléans

GET (Gesellschaft für Entwicklungstechnologie). 2001. Biodiesel; Energie- und Umweltbilanz Rapsölmethylester; Im Auftrag der Union zur Förderung van Oel- und Proteinpflanzen. Aldenhoven

IFEU-Institut. 1999. Ressourcen- und Emissionsbilanzen; Rapsöl und RME im Vergleich zu Dieselmotortreibstoff, Heidelberg

PAN Europe (Pesticides Action Network). 2000. Position on Good Agricultural Practice; October 2000. Hamburg

PAN UK. 1999. Pesticides News 46. December 1999

UBA (Umwelt Bundes Amt). 1999. Aktuelle Bewertung des Einsatzes von Rapsöl/RME im Vergleich zu Dieselmotortreibstoff. Berlin

US Department of Energy. 2001. Transportation Energy Data Book; Edition 21. Washington

Appendix

Fossil energy savings, CO₂ savings, and costs of avoided emissions from literature

Biofuel (crop)	Energy savings (usually output-input ratio)	Relative CO ₂ savings	Absolute CO ₂ savings	Costs per ton CO ₂ avoided	Costs of other options	Reference
Rapeseed	1.8		2.1-3.0 ton CO ₂ per ha ³			CLM, 1994
Biodiesel (rapeseed)	3.4	32-55 % ⁴	58-100 g CO ₂ eq. per km	10-30 DPF/l = 0.05-0.15 EUR per l		Bayerisches Staastministerium für Landwirtschaft und Forsten. 2001
Biodiesel (rapeseed)	2.7 38 GJ per ha					BLT, 1999
Biodiesel (rapeseed with utilisation of straw)	4.1 94 GJ per ha					BLT, 1999
Biopdiesel (rapeseed) and RME				280-600 DM per ton CO ₂ = 143-307 EUR per ton CO ₂ Including set-aside subsidies: 336-848 DM per ton CO ₂ = 172-434 EUR per ton CO ₂	Diesel engine improvements: 190-545 DM per ton CO ₂ = 97-279 EUR per ton CO ₂ Gasoline engine improvements: 320-505 DM per ton CO ₂ = 164-258 EUR per ton CO ₂	UBA, 1999

³ Depending on the soil type.

⁴ The number depends on the use of by-products of rapeseed cultivation as energy input in the process.

Biodiesel (RME)	2.6	17-45 %	30-82 g CO ₂ eq. per km	10-30 DPf/l = 0.05-0.15 EUR per l		Bayerisches Staastministerium für Landwirtschaft und Forsten. 2001
Biodiesel (RME)	2.28 to 2.96 Fossil energy saving: 42.8 MJ per l		3.24 kg CO ₂ per l 2.82 kg CO ₂ eq. per l 4.2 ton CO ₂ eq. per ha	141 DM per ton CO ₂ eq. = 72 EUR per ton CO ₂ eq.	Less car use: 325 DM per ton CO ₂ eq. = 166 EUR per ton CO ₂ eq.	GET, 2001
Biodiesel (RME)	1.9 3 42.8 MJ per l	> 25 % CO ₂ eq. 32 % CO ₂ eq. 40-80 % CO ₂ eq. 70 % CO ₂ eq. 75 % CO ₂ eq.	3.3 kg CO ₂ eq. per l			BLT, 1999 ⁵
Biodiesel (RME)	3.4	66 % CO ₂ eq.				Ecotraffic, 1992
Biodiesel (RME)	2.5 2.9 ⁶	52 % CO ₂ eq.	121 g CO ₂ eq. per km	994 EUR per ton CO ₂ 235 EUR per ton CO ₂ ⁷		CE, 1993
Biodiesel (RME)		78 % CO ₂ eq.		106 EUR per ton CO ₂ eq.		Biocosts Research group (Almeida <i>et al.</i>), 1998
Biodiesel (sunflower, with utilisation of straw)	6.2 144 GJ per ha					BLT, 1999

⁵ This study makes a comparison of several other studies, mostly concerning RME.

⁶ This is a projection for after the year 2000.

⁷ Idem.

Biodiesel (sunflower)	2.8 43 GJ per ha					BLT, 1999
Biodiesel (soybean)	3.2	78 % CO ₂				BLT, 1999
Sugar beet	2.2		5.4-6.9 ton CO ₂ per ha			CLM, 1994
Ethanol (sugar beets)	1.7 104 GJ per ha					BLT, 1999
Ethanol (sugar beet)	1.3 1.1 1.8 2.3 2.4 ⁸	41 % CO ₂ eq.	116 g CO ₂ eq. per km	786 EUR per ton CO ₂ 434 EUR per ton CO ₂ ⁹	CHP ¹⁰ : 29 EUR per ton CO ₂ Insulation: 59 EUR per ton CO ₂ Wind energy 82 EUR per ton CO ₂	CE, 1993
Maize	1.9					CLM, 1994
Ethanol (maize)	3.0 153 GJ per ha					BLT, 1999
Wheat	2.8		2.5-3.1 ton CO ₂ per ha			CLM, 1994
Ethanol (wheat with utilisation of straw)	4.8-5.6	57 % CO ₂ eq.				Ecotraffic, 1992
Ethanol (wheat)	1.1-1.2					Ecotraffic, 1992
Ethanol (wheat)	1.0 1.2 2.0 4.3 ¹¹	19 % CO ₂ eq.	54 g CO ₂ eq. per km	1754 EUR per ton CO ₂ 193 EUR per ton CO ₂ ¹²		CE, 1993
Ethanol (tree residues)	14-17	78 % CO ₂ eq.				Ecotraffic, 1992

⁸ This is a projection for after the year 2000.

⁹ Idem.

¹⁰ Combined Heat and Power.

¹¹ This is a projection for after the year 2000.

¹² Idem.

Ethanol (energy forest)	5.2-6.1	69 % CO ₂ eq.				Ecotraffic, 1992
Methanol (tree residues)	10-12					Ecotraffic, 1992
Methanol (energy forest)	6.3-7.5	80 % CO ₂ eq.				Ecotraffic, 1992
Biogas		69-75 % CO ₂ eq.				Ecotraffic, 1992
17 % ETBE ¹³ (sugar beet)	Energy saving: 13 %	0 % CO ₂				Biocosts Research group (Almeida <i>et al.</i>). 1998
17 % ETBE (sweet sorghum)	Energy saving: 5 %	18 % CO ₂		14 EUR per ton CO ₂ eq.		Biocosts Research group (Almeida <i>et al.</i>). 1998
Electricity from straw					31 EUR per ton CO ₂	
Electricity from poplar					21 EUR per ton CO ₂	

¹³ In this study gasoline made up of 17 % ETBE additive is compared to pure gasoline.