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# BIODIESEL - ENVIRONMENTAL IMPACT AND POTENTIAL FOR NICHE MARKETS

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# BIODIESEL - ENVIRONMENTAL IMPACT AND POTENTIAL FOR NICHE MARKETS

by

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**BIODIESEL - ENVIRONMENTAL IMPACT AND POTENTIAL FOR NICHE MARKETS**

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## EXECUTIVE SUMMARY

### 1 Introduction

Biodiesel is a diesel substitute that can be derived from many vegetable oils. The primary feedstock in the EU is oil seed rape. Interest in vegetable-based fuels and industrial products has risen for three main reasons: the introduction of the set-aside scheme; the quest for indigenous energy sources and the desire to substitute fossil fuels with vegetable fuels for environmental reasons.

Vegetable oil-based transport fuels have been used since the beginning of the century but their prices are currently higher than fossil fuel prices. In Europe (except the U.K.) and U.S.A., their use is subsidised or supported through the use of legislation.

There are only minor problems with the performance of Rape Methyl Ester (RME) in diesel engines. Major engine manufacturers have given engine clearance for the fuel but fuel consumption can be expected to increase by up to 6% compared with mineral diesel. RME can be used as a fuel additive to increase lubricity of the fuel. RME also has non-fuel uses such as for lubricants and solvents.

There are three constraints to industrial oilseed rape production:

- rotational - rape can only be grown on the same land every 3-5 years;
- the area of set-aside annually available - at present most double low rapeseed for non-food use is grown on set-aside land as rape for food use grown on main scheme land and has higher gross margins; the Blair House Agreement -

the Blair House Agreement limits EU non-food rape production to approximately 1 m hectares.

## 2 Economics of biodiesel production

The cost of biodiesel production ranges from 20p/l to 100p/l. The cost is most sensitive to the price of rapeseed and to a lesser degree, the value of the by-products glycerine and rapemeal. Lower cost alternative feedstocks such as *Camelina*, beef tallow and waste vegetable oil are being developed in Ireland, Austria and the UK. These may give producers the opportunity to produce biodiesel at lower cost.

Diesel is classified by Customs and Excise into Automotive Diesel (DERV) and Gas oil. DERV is taxed at 40.28p/l and gas oil at 2.58p/l. DERV is for road use and gas oil "off-road" use such as in agriculture and on waterways. The size of the market for these two fuels is approximately 13 Mt and 7.5 Mt per annum respectively. DERV consumption is predicted to increase to 20 Mt and Gas oil to decrease to 7 Mt by the year 2000. The size of the market for fossil oil-based lubricants and greases is approximately 0.8 Mt.

Rape methyl ester (RME) is unlikely to substitute for more than 1% of the UK diesel market. Constraints to market entry include price, poorly developed distribution networks, fuel performance, manufacturer's approval, maintenance availability and tightening EU vehicle emissions standards.

# 3 Environmental impact of biodiesel production and use

The environmental impact of biodiesel production and use has been compared to that of fossil diesel. Methods for assessment include energy ratios, carbon dioxide (and equivalent Greenhouse Gas) savings, emissions measurements and Life Cycle Analysis (LCA).

The cultivation of rapeseed has a range of environmental impacts commonly associated with agriculture. These include soil erosion, nitrate contamination of groundwater, eutrophication, pesticide problems, land demand, human allergies and altering of landscape appearance. Under intensive management systems it is difficult to say whether one crop has a greater impact than another, though UK authors suggest that rape cultivation loses more nitrogen through leaching than wheat and other crops.

Environmental constraints can be effectively reduced if low input farming methods or organic cultivation are adopted.

The fossil diesel system has a range of emissions to the environment. A full LCA will enable these emissions to be properly weighted against those of the biodiesel system.

For the *combustion of biodiesel*, there is a lack of corroborative data, but information available indicates that biodiesel has lower emissions than fossil diesel for Carbon Monoxide CO, Hydrocarbons HC and Particulate Matter PM, whilst emissions of Nitrogen oxides NO can increase (see Table). In most vehicular uses, *life-cycle emissions for biodiesel* are less than diesel for Carbon dioxide $CO_2$, CO and PM, whilst they are greater for HC, NO and in one study for Sulphur dioxide $SO_2$.

0.51 to 2.36 kg of $CO_2$ are estimated to be avoided if 1 litre of biodiesel is used in place of fossil diesel. This figure can be improved if straw and meal by-products are utilised with minimal transport and processing costs. Nearly all rape straw is presently incorporated back into the ground. As a strategy for reducing $CO_2$ emissions, biodiesel and miscanthus is less effective than short rotation coppice and miscanthus. However, it is unlikely that rape and woody biomass would be competing for the same land.

Biodiesel has advantage over fossil diesel as a boat fuel in terms of its biodegradability and lower toxicity in water.

## 4 Fuel markets for biodiesel

Potential niche fuel markets for biodiesel that have been identified include boats, timber, paper and pulp companies, construction and tunnelling, mining, golf clubs, airports, ski resorts, farms, fire brigades and the armed forces. Markets may also exist for biodiesel as a blend (20%) with fossil diesel (80%) amongst large volume users.

## 5 Survey of fuel markets

A total of 378 questionnaires were sent to potential consumers of biodiesel in industry and services. One hundred and four responded.

The order of importance in factors likely to influence a decision on the use of biodiesel was as follows: cost, engine compatability, environmental benefits, availability, health and safety issues, business advantage in using 'green fuel', anticipated changes in regulation.

A low level of particulates was considered to be the most important attribute followed by low sulphur content, non-toxicity, biodegradability, safety (high flash point), renewable and neutral carbon balance.

The sample were asked if they would be prepared to pay **45p/l** (excluding tax and VAT) for pure biodiesel and **21p/l** for biodiesel (20%) as a blend with fossil diesel (80%)

Thirty two (32.6%) respondents said they 'may' pay 45p/l for biodiesel. Two (2.1%) said 'yes' and 62 (63.3%) said 'no'. At a price of 45p/litre, the most promising sectors for the pure use of biodiesel are boats, forestry and construction. These three sectors represent a market of 1,666 Mt of diesel per annum, well in excess of UK biodiesel production capacity. There was minor interest from haulage and delivery and bus companies.

53.6% of respondents said they 'may' pay 21p/l for a blend. 36.1% said 'no' and 9.7% said 'yes' There may be large markets for biodiesel at this price from bus companies, haulage and delivery and electricity utilities. There is possible interest from local authorities, construction, mining, waste management and car manufacturers.

The survey sampled companies and local authorities and indicated that enough interest exists for preliminary research into the interest of oil companies, engine manufacturers and government in marketing biodiesel in this way.

## 6 Non-fuel markets for biodiesel

There are non-fuel applications for biodiesel where the substances advantages can be exploited. These properties include non-toxicity, biodegradability, low viscosity and non-evaporation. Potential uses for biodiesel include printing cleansers, drilling muds, lubricants and biosurfactants.

The development of RME-based printing cleansers is constrained by performance of RME against mineral based and other vegetable-based products and price. A maximum figure for the market is 30,000 t.

The market for ester-based drilling muds is estimated at 40-50,000 t. Without legislation or a reduction in price, it is unlikely they would be used by British oil companies.

RME performs better than other substances as a substrate in the production of biosurfactants. It is unknown what the demand implications are for RME or how RME biosurfactants will compare in price with petrochemical-based surfactants.

## 7 Conclusions

The lack of end-use fiscal and legislative support for biodiesel will make it very difficult to market biodiesel in the UK successfully.

In most smaller volume 'niche' markets, biodiesel must compete with gas oil which is subject to very little taxation.

## 8 Recommendations

### 8.1 Production

Studies have found that the cost of biodiesel production is most sensitive to the price of rapeseed. Double low rapeseed prices have been rising for the last three years. Biodiesel producers must therefore investigate alternative feedstocks such *Camelina,* beef tallow and waste vegetable oil. The viability in the UK of local waste oil collection schemes such as in County Cork and southern Austria needs research.

### 8.2 Niche fuel markets

Boat users, forestry and construction companies have been identified as the most likely consumers of biodiesel at 45p/l (excluding tax and VAT). Biodiesel producers should therefore continue negotiations with these groups to use the fuel. Engine manufacturers for these sectors need to give clearance for biodiesel use.

### 8.3 Large volume fuel markets

Substantial markets in excess of UK biodiesel capacity may exist for use of biodiesel as a blend (20%) with fossil diesel (80%) and sold at 21p/l. For this market to be developed, producers should have talks with oil companies, engine manufacturers and the UK Government. The project could not be feasible without all these parties' co-operation.

### 8.4 Niche non-fuel markets

Markets may exist for RME to used in industrial applications such as pesticide adjuvants, light lubricants, drilling muds, printing cleansers and biosurfactants. RME producers in the UK should therefore have exploratory talks with the companies involved in these sectors with regard to providing the feedstock RME.

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**ABBREVATIONS**

| | |
|---|---|
| CNG | Compressed Natural Gas |
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| DoE | Department of the Environment |
| DoH | Department of Health |
| DoT | Department of Transport |
| DTI | Department of Trade and Industry |
| EC | European Commission |
| ETSU | Energy Technology Support Unit |
| EU | European Union |
| GATT | General Agreement on Tariffs and Trade |
| GWP | Global Warming Potential |
| IEA | International Energy Agency |
| LAO | Linear Alpha Olefines |
| LCA | Life Cycle Analysis |
| LPG | Liquified Petroleum Gas |
| MAFF | Ministry of Agriculture, Food and Fisheries |
| NO | Nitric Oxide |
| $NO_2$ | Nitrogen Dioxide |
| NOX | Oxides of nitrogen (ie NO and NO2) |
| OECD | Organisation for Economic Co-operation and Development |
| OSR | Oil Seed Rape |
| PAH | Poly Aromatic Hydrocarbons |

| | |
|---|---|
| PAO | Poly Alpha Olophin |
| PM | Particulate Matter |
| RME | Rape Methyl Ester |
| SETAC | Society for Environmental Toxiology and Chemistry |
| SME | Soya Methyl Ester |
| $SO_2$ | Sulphur Dioxide |
| UBA | Umweltbundesamt (German Federal Environmental Agency) |
| US EPA | United States Environmental Protection Agency |

**UNITS**

| | |
|---|---|
| C | Degree Celsius |
| h | Hectare |
| GJ | Gigajoule (1,000 megajoules) |
| kg | Kilogramme |
| l | Litre |
| MJ | Megajoule (1,000 kilojoules) |
| Mt | Million tonnes |
| t | Tonne (1,000 litres) |

## BACKGROUND

Biodiesel is a diesel fuel substitute that can be derived from many vegetable oils including rapeseed, sunflower, corn, palm, cotton and soya, although the major feedstocks are rapeseed oil in Europe and soya in the USA.

Biodiesel is currently more expensive than mineral diesel, and has been supported by a number of mechanisms in the countries where it is produced. Within the EU, the introduction of the set-aside scheme has allowed the development of a two tier pricing system for oilseeds, effectively reducing the cost of the raw material for biodiesel production. Biodiesel production is also supported through tax exemptions in Italy, France, Austria and the Czech Republic. In Germany and the USA, it is supported through environmental legislation.

Within the UK there is interest in production of the fuel but no support exists in the form of tax exemptions or environmental legislation. Consequently, potential UK producers are looking for 'niche' markets where consumers will pay a premium for the environmental advantages of biodiesel. Niche markets for biodiesel may include not only fuel, but other industrial markets. Vegetable oils have a range of industrial uses in addition to fuel use, and the processing of vegetable oil to RME may alter the qualities of the oil (e.g. it lowers viscosity) to suit some industrial markets.

This study therefore aims to identify any industries and services that would be prepared to pay a premium for the environmental advantages of biodiesel for fuel or non-fuel use.

Chapter 1 gives background information on biodiesel and its properties, and considers some constraints to the production of the fuel. Chapters 2 and 3 review information on the costs of biodiesel production and the environmental impact of biodiesel production and use. Chapter 4 describes the current UK diesel market and quantifies diesel use by sectors which may be potential biodiesel users. Chapter 5 presents the results of a survey of almost 400 potential consumers of biodiesel as a fuel, potential non-fuel markets for biodiesel are identified in Chapter 6 and overall conclusions are drawn in Chapter 7 and recommendations made in Chapter 8.

# 1 INTRODUCTION

## 1.1 History of vegetable oil as a fuel

The use of vegetable oils for engine fuel dates back to the early development of the internal combustion engine. Rudolph Diesel, the inventor of the diesel engine, used peanut oil to run a small diesel engine in 1900 at the World Exhibition in Paris. During the 1930s and 1940s, work from China (Chang and Wang 1947, quoted in Commission of European Communities 1994a), Belgium, France, India and West Africa (Sadeghi-Jorabchi *et al.*, 1995) suggested that the use of vegetable oil as a diesel fuel was promising on a technical basis. However interest in this application declined as the cheaper mineral oil based fuels became widely available.

The energy crisis which followed quadrupling of world oil prices in 1973 renewed interest in biofuels, although for the UK, development of the North Sea oil industry increased energy security. During the 1980's environmental concerns relating to fossil fuel use became important in stimulating interest in biofuels, and the use of renewable resources as industrial feedstocks in general, and further impetus came from the revision of the EU common agricultural policy in 1992. Over-production of food in Europe and the excessive expenditure associated with disposal of food surpluses led to the introduction of the set-aside scheme. This scheme requires that larger growers set aside (at present) up to 5% of their arable acreage from food production. Non-food crops can, however, be grown on this set-aside land, and oilseed rape for biodiesel production, or for any other non-food use, qualifies as an industrial non-food crop.

## 1.2 Biodiesel as a diesel substitute

Use of pure rapeseed oil in direct injection diesel engines gives rise to the following problems, due to the viscosity and gumming properties of the oil.

- Coke deposition on the injector nozzles.

- By-passing of unburned fuel to the crankcase where dilution as well as polymerisation of the lubricating oil occurs (Sadeghi-Jorabchi *et al.*, 1995).

- High viscosity and low volatility lead to poor atomisation and inadequate mixing with air.

There are two approaches to overcoming these problems.

(i) Blending of the vegetable oil with mineral diesel. Engine trials by Robbe, a crushing and refining company in Picardy, France have shown that a blend of 20% rapeseed oil and 80% diesel can be used without engine modification. In excess of the 20% rapeseed oil component, it is necessary to adapt the fuel filter and injection pump mechanism, due to increased viscosity of the fuel. Using degummed rapeseed oil has the advantage of a higher calorific value (approximately 2%) than that of the ester (Non-Technical Barriers Network, 1995)

(ii) Transesterification of the oil to its methyl ester. Vegetable oil esters are referred to as biodiesel. The most common feedstocks for biodiesel are rapeseed oil in Europe, although some sunflower oil is also used, and soya oil in the U.S.A. Rapeseed oil methyl ester is often refered to as rape methyl ester (RME).

Transesterification is the most favoured method of lowering the viscosity of the oil so that it can be used in direct ignition engines (Commission of European Communities 1994a). Major engine manufacturers in Europe including VW, John Deere, Ford, Massey-Ferguson and Mercedes Benz have approved biodiesel for use in new and existing engines. Biodiesel has been used neat and in blends with mineral diesel in EU and USA.

## 1.3 Processing

The processes involved in RME production are described in detail by Walker (1996).

### 1.3.1 Oil Extraction

The oil content of oilseed rape is around 42 - 44%. Oil extraction can follow two routes. At low volumes (less than 150 t/day) mechanical oil extraction may be the most economical method. This involves high powered pressing of the seed through a fine gauge cage to leave only 10% oil in the resulting cake, perhaps followed by a second press to extract another 1 - 2%. The method used by high volume UK crushers (e.g 1, 000 t/day) involves pre-pressing to extract half of the oil, followed by solvent extraction of the remaining oil.

The rapemeal cake is currently sold as an animal feed for incorporation in cattle, pig and poultry rations. There does not appear to be a price advantage in selling cake with a high oil content (Sanders & Turner, 1995).

### 1.3.2 Refining

Refining rape oil for biodiesel production involves two processes: degumming and neutralisation. Degumming involves the recovery of natural phosphorus-based gums and dark coloured pigments. Neutralisation is the removal of free fatty acids (often caused by the breakdown of oil). These two processes can take place together. Neutraliser is added to remove fatty acids. These are spun off using centrifugal separators leaving a neutral oil and a separated soapstock (used in soap manufacture).

Phosphoric acid is added to chelate out iron and phosphatides. No fatty acid should be allowed to get through to an RME production process as it neutralises the alkaline catalyst used at that stage.

### 1.2.3 Transesterification

Rape methyl ester is produced from rape oil in a reaction called transesterification. Rape oil is modified to RME through the addition of an alcohol (usually methanol) in the presence of a catalyst (sodium hydroxide or potassium hydroxide) at atmospheric pressures and 60°C. During the reaction, the glycerol is separated and decanted into a distillation column where nearly all unreacted methanol is recovered and recycled through the process.

To clean the RME, traces of soap are removed by centrifugation. Excess methanol is removed by distillation and then recycled. The crude glycerol is evaporated and distilled to give 88% glycerol solution. This process is energy intensive and accounts for 50% of the total capital and operating costs of a RME plant (Sanders & Turner, 1995).

A second process uses non-alkaline catalysts, can process non-degummed, dried oils and is also capable of handling non-neutralised oils (Sanders & Turner, 1995). This process operates at 250°C and higher pressures. The biodiesel obtained is not suitable for use directly as a diesel fuel without distillation.

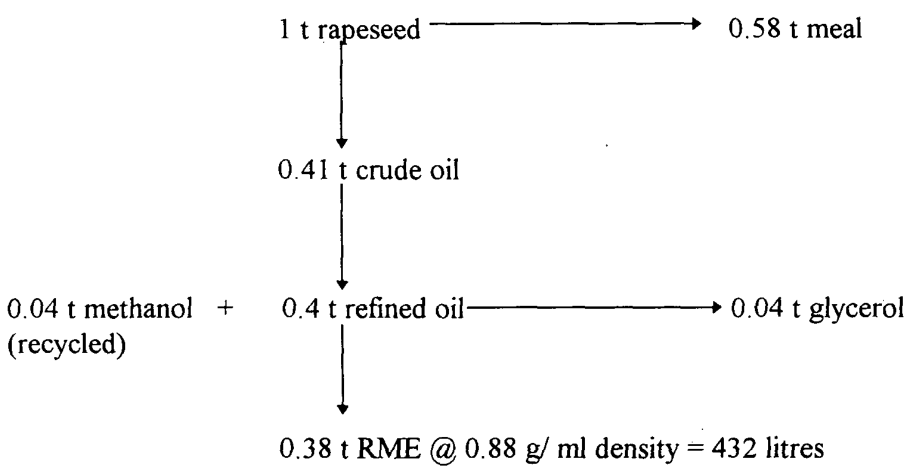
There are several options for the use of glycerol, the by-product of the esterification process. If the glycerol is purified, by distillation, there are pharmaceutical and cosmetic markets. Crude glycerol can be burnt, mixed as a fertiliser or sprayed onto rapemeal so as to increase its calorific value for feed.

A similar process using non-alkaline catalysts and operating at elevated temperature exists that claims to produce glycerol at 99.7% purity without distillation (Sanders & Turner, 1995).

The basic RME production process may operate as a batch or continuous process. Flexibility of the process is important in order to utilise cheaper raw materials such as used frying oils, low grade food oils, beef tallow and chicken fat.

Processing costs have been reduced in recent years as esterification technologies have allowed the use of crude oils obtained immediately after crushing, replacing the use of expensive top grade food quality oil. The potential yield from the vegetable oil's esterification has reached 99%. The purification of glycerine is an energy intensive process and can account for 50% of the total capital and operating costs of a biodiesel plant. The production of pharmaceutical grade glycerine requires high investment and production costs.

**Figure 1.1 Mass Balance for RME production**




**Source: Walker (1995)**

## 1.4 Physical characteristics

The viability of biodiesel as an alternative fuel depends on the technical limitations on its use in indirect combustion engines. There are no insurmountable technical barriers to the fuel's usage. The fuel's cold weather performance and stability have been studied and cost effective improvements made. Biodiesel can destroy rubber seals within some fuel systems, but alternative seals are available.

Oxygenates, simply because they contain oxygen, have a lower energy content than hydrocarbon fuels of similar boiling range. Each litre of fuel will therefore contain less energy when oxygenates are used, and fuel consumption can be expected to increase. This is illustrated by the relative heating values in Table 1.1, which shows the relative density and energy content of diesel and biodiesel (Hutcheson, 1995).

Tests by Prankl *et al.* (1992) on a indirect combustion passenger car engine found that specific fuel consumption (litre/kwh) of RME was increased (6%), but less than one would expect from the energy content of the fuels, implying some increase in thermal efficiency when using RME. The higher oxygen content of RME is likely to lead to more efficient combustion.

**Table 1.1 Energy content (MJ) of oxygenated fuels**

| | Gasoline | Ethanol | ETBE | MTBE | Diesel | RME |
|---|---|---|---|---|---|---|
| Lower heating value MJ/kg | 41.9-44.2<br>100% | 26.7<br>62% | 36.0<br>84% | 35.1<br>82% | 42.8<br>100% | 36.8<br>86% |
| Lower heating value MJ/l | 30.4<br>100% | 21.2<br>67% | 26.8<br>84% | 26.1<br>82% | 36.0<br>100% | 32.4<br>92% |

Source: Hutcheson (1995)

Table 1.2 gives a comparison of some important properties of biodiesel and diesel. The importance of these properties is described below.

Any vegetable oil can potentially be converted into biodiesel, but some have more desirable properties than others. Table 1.4 shows relative values for some properties of a selection of oils. It can be seen that rapeseed oil has a higher calorific value than the other oils listed. The lower melting points of sunflower and soya oils, however, may indicate that they are more suitable for fuel use in cold climates. In contrast, the very high melting point of palm oil indicates that it is likely to be unsuitable for use as a fuel in most environments. Stability, i.e. a low risk of oxidation and polymerisation is also a desirable quality of fuels. This property is expressed by the fuel's iodine number.

### 1.4.1 Iodine number

All vegetable oils contain a number of different fatty acids. The iodine number is a guide to the average content of unsaturated double bonds within those fatty acids. Fatty acids containing unsaturated double bonds such as linolenic acid are more unstable than those containing no unsaturated double bonds such as palmitic acid. A higher iodine number reflects an increased risk of rapid oxidation and lower stability in storage. It also indicates a higher risk of polymerisation.

Rape oil has a favourable fatty acid profile with respect to the iodine number (see Table 1.3). New varieties of rape such as Lubrizol 7633 have a higher oleic acid content and lower linolenic acid giving a very high degree of stability (See Table 1.3). This variety is not, however, grown widely.

### 1.4.2 Pour point and cold flow characteristics

Pour point is the lowest point at which the fuel will continue to pour. This affects the fuel flow in the system at low ambient temperatures. Biodiesel is more viscous than fossil diesel and so has a higher pour point. Cold-Filter Plugging Point (CFPP) is the temperature at which the fuel will block filters. RME has a CFPP of approximately -5° to -15° C. Diesel has a CFPP of -20°C.

To use biodiesel in winter conditions, specific additives known as pour point depressants can be used to reduce the temperature at which the fuel can be used. Research in the US suggests that these additives help lower the pour point of blended biodiesel, but do not affect the pour point of neat biodiesel (Booz-Allen & Hamilton Inc., 1994). The other possibility is physical separation. Research in Austria has reduced the CFPP to -40°C by fractionation, although the iodine number is pushed up to 125 (Rathbauer, 1994).

### 1.4.3 Cetane rating

The cetane number measures the fuel's ignition quality. High fuel cetane ratings reflect easy cold starting and low idle noise. RME has a higher cetane number than fossil diesel (see Table 1.2). Data from the South Western Research Institute in USA indicate that blends of biodiesel and fossil diesel may have cetane numbers that are higher than either of the original fuels, thus suggesting that methyl esters may have a blending cetane number that is greater than the value for the neat fuel (reported in National Soyabean Development Board, 1994).

### 1.4.4 Flash point

Flash point is the point at which the fuel will ignite. Therefore, a fuel with a high flash point may be desirable in terms of safety in handling. Diesel has a flashpoint of 55°C compared to 167°C for pure RME. However, at 0.5% residual methanol, the flashpoint falls to 35°C and at 1% of methanol to 25°C (Commission of European Communites, 1994a).

### 1.4.5 Fuel stability and microbial growth

Biodiesel is biodegradable and therefore microbial growth could present a concern under certain conditions. Anti-oxidant additive can delay the start of microbial growth (Du Plessis & De Villiers, 1983, quoted in National Soyabean Development Board, 1994).

**Table 1.2: Specification and standards for RME compared to fossil diesel. (Austrian specifications)**

| Property | Diesel ONORM C1104 | Biodiesel ONORM C1190 |
|---|---|---|
| Combustion energy (MJ/kg) | -43 | -37 |
| Viscosity at 20°C (mm/s) | 3-8 | 5.5-8.0 |
| Density at 15°C (ml) | 0.82-0.86 | 0.87-0.89 |
| Pour point (°C) | -9 to -18 | -6 to -12 |
| Cold filter plugging point (CFPP) (°C) | +5 max | -8 max |
| Cetane number | 45-55 | 48-58 |
| Neutralization (mg KOH/g) | - | 0.80 max |
| methanol (%) | - | 0.02 max |
| total glycerine (%) | - | 0.20 max |
| phosphorus (%) | - | 20 max |

**Source: Walker and Korbitz (1995)**

## 1.5 RME as a diesel additive

Recent regulations in EU and USA requiring lower levels of sulphur in diesel fuel have raised concerns about maintaining lubricity of low sulphur fuel. Trials have compared the performance of a low sulphur diesel with 20% biodiesel/diesel blend. It was observed that blending biodiesel with low sulphur diesel increases lubricity substantially (Howell, 1995).

## 1.6 Conclusion

Biodiesel can compete with fossil diesel on technical grounds as there are no major problems with its use. Major engine manufacturers have approved the fuel for use. Biodiesel has been successfully used as a fuel and industrial feedstock in Europe and the USA and has the potential to be used as an additive to increase lubricity.

**Table 1.3 : Reduction of CFPP and Iodine no.**

| | 00 - RAPESEED | | LZ 7633 RAPESEED | | LZ 7631 SUNFLOWER | |
|---|---|---|---|---|---|---|
| **Fatty acid** | **% fatty acid** | **Iodine number** | **% fatty acid** | **Iodine number** | **% fatty acid** | **Iodine number** |
| 14:0 | | | | | | |
| 16:0 palmitic | 4 | | | | | |
| 16:1 | | | | | | |
| 17:0 | | | | | | |
| 18:0 stearic | 2 | | | | | |
| 18:1 oleic | 60 | 51.60 | 72 | 61.92 | 80 | 68.8 |
| 18:2 linoleic | 21 | 36.37 | 15 | 25.98 | 10 | 17.32 |
| 18:3 linolenic | 11 | 28.78 | 2 | 5.23 | 0.3 | 0.78 |
| 20:0 | | | 1 | | | |
| 20:1 | | | | | | |
| 22:0 | | | | | | |
| 22:1 erucic | 2 | 1.45 | 1 | 0.723 | | |
| Total iodine no. | | 118.2 | | 93.85 | | 86.90 |

**Source: Austrian Biofuels Institute (1995)**

**Table 1.4 : Physical & chemical properties of oils and fats**

| Property | Unit | Rapeseed (low erucic) | Sunflower | Soyabean | Palmoil | Camelina s. | Tallow beef |
|---|---|---|---|---|---|---|---|
| Density 15°C | g/cm3 | 0.915 | 0.925 | 0.93 | 0.92 | | 0.937 |
| Flashpoint | C | 317 | 316 | 330 | 267 | | - |
| Cloud point | C | 0 | -16 | -8 | 31 | | - |
| Melting point | C | -5 | -15 | -22 | 30-40 | | 40-48 |
| Viscosity | mm2/s | 74 | 66 | 64 | 40 | | solid |
| Calorific Value | MJ/kg | 40.5 | 39.8 | 39.7 | 35.1 | | 39.1 |
| Cetane number | | 44 | 35.5 | 38.5 | 42 | | - |
| Fatty acid type in % | | | | | | | |
| Palmitic | C16:0 | 4 | 6 | 8 | 42 | 5 | 25 |
| Stearic | C18:0 | 1 | 4 | 4 | 5 | 2.1 | 19 |
| Oleic | C18:1 | 60 | 28 | 28 | 41 | 14.8 | 40 |
| Linoleic | C18:2 | 20 | 61 | 53 | 10 | 16.4 | 4 |
| Linolenic | C18:3 | 9 | - | 6 | - | 36.1 | 1 |
| Erucic | C22:1 | 2 | - | - | - | 3.7 | - |

**Source: Batel (1980), Schutt (1992) (both quoted in Walker & Korbitz 1994); Korbitz (1996)**

# 2 ECONOMIC AND MARKET FACTORS

## 2.1 Biodiesel Production

### 2.1.1 Rape Production

#### 2.1.1.1 Areas and grain yields

Oil seed rape is the most widely grown oilseed crop in the EU. It is successful as a break crop due to its high gross margins and improved yields of following cereal crops.

The production of oil seed rape increased rapidly in the UK during the 1980s. As a result of the introduction of 'double low' (low erucic acid/low glucosinolate varieties), production areas in the 1990s have exceeded 400,000 ha. During this period of expansion, average yields of winter and spring sown crops have remained fairly consistent at 3.0t and 2.1t/ha respectively (Scarisbrick & Ferguson, 1995). See Table 2.1 for UK areas and average yields. Winter rape accounts for the majority of rape grown in the UK (approximately 86% in 1995/96).

#### 2.1.1.2 Rapeseed Straw

Virtually all rape straw is currently incorporated back into the soil. However, the UK Government has a broad aim to install 1500MW of new renewable energy based generation by the year 2000. The Electricity Act of 1989 gave the Secretary of State powers to make Orders to oblige the regional electricity companies (RECs) to buy a certain amount of nuclear and renewable electricity at a premium price. Under the Non Fossil Fuel Obligation (NFFO), solid dry biomass sources from energy crops and agricultural wastes (e.g. straw) can be used to generate electrical power by incineration.

Under the third NFFO round, the European Development Corporation was awarded a contract for the first UK straw-fired power station, to be built in East Anglia. Demand

Table 2.1: UK Oilseed rape areas (h), yield (t/h) and production (t) 1984-1995

| United Kingdom | | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL LAND** | | | | | | | | | | | | | |
| | **Area (h)** | 269,000 | 296,000 | 299,000 | 388,000 | 347,000 | 321,000 | 390,000 | 440,000 | 421,000 | 417,658 | 469,033 | 438,805 |
| | **Yield (t/ha)** | 3.43 | 3.01 | 3.18 | 3.49 | 3.00 | 2.96 | 3.23 | 2.90 | 2.77 | 2.68 | 2.53 | 2.81 |
| | **Production (t)** | 923,000 | 891,000 | 951,000 | 1,353,000 | 1,040,000 | 950,000 | 1,258,000 | 1,278,000 | 1,166,000 | 1,099,869 | 1,253,361 | 1,234,822 |
| **NON-SET ASIDE LAND** | | | | | | | | | | | | | |
| | **Area (h)** | 269,000 | 296,000 | 299,000 | 388,000 | 347,000 | 321,000 | 390,000 | 440,000 | 421,000 | 377,000 | 404,311 | 353,952 |
| | **Yield (t/ha)** | 3.43 | 3.01 | 3.18 | 3.49 | 3.00 | 2.96 | 3.23 | 2.90 | 2.77 | 2.77 | 2.62 | 2.91 |
| | **Production (t)** | 923,000 | 891,000 | 951,000 | 1,353,00 | 1,040,000 | 950,000 | 1,258,000 | 1,278,000 | 1,166,000 | 1,044,000 | 1,057,854 | 1,030,670 |
| **SET-ASIDE LAND** | | | | | | | | | | | | | |
| | **Area (h)** | | | | | | | | | | 40,658 | 91,722 | 84,853 |
| | **Yield (t/ha)** | | | | | | | | | | 1.37 | 2.13 | 2.41 |
| | **Production (t)** | | | | | | | | | | 55,869 | 195,507 | 204,152 |

for the straw is limited to a 40-50 mile radius around the station. The DTI estimate that straw (does not specify whether the straw is rape or cereal) can be obtained for a price of about £22.50/tonne (DTI, 1995c).

Oilseed rape straw is suitable for burning as it is low in sulphur and the ash has a high content of calcium compounds, which react with and immobilise the sulphur compounds from other residues (Sanders, 1995).

### 2.1.2 Constraints to industrial rape production

#### 2.1.2.1 Rotational

Oil seed rape is a host plant for soil borne diseases which attack *Brassica* crops generally. A break is therefore recommended not only between successive OSR crops, but also between OSR and other *Brassica* crops of at least four years, and ideally six in the longer term (Ward *et al*, 1985).

#### 2.1.2.2 Set-aside

In 1995, 633000 ha of UK agricultural land were set-aside. If all of this area had been put under oilseed rape, 567,674 tonnes of RME could have been produced, replacing approx 2.65% of the UK total 1994 diesel market (Gas oil + DERV) which was 20,405 Mt in 1994 (see section 2.5) assuming biodiesel has 5% lower heating value than fossil diesel.

Set-aside land is a source of lower priced rapeseed for industrial uses. The average price for OSR grown on non set-aside land in the 1996/97 marketing year was £170/tonne (Nix 1996) and £120/tonne for OSR grown on set-aside (Martin Farrow, United Oilseeds pers comm. 1996).

The set-aside rate has fallen from 15% to 12% to 10% over the past 3 years. The future of set-aside cannot be predicted, although world grain stocks would suggest that the set-aside rates will continue to decline, and this may act as a major constraint to expansion of the area of OSR grown for industrial use. The European Commission accepted a 5% set-aside rate for 1996/97 which was adopted in July 1996 (Agra Europe, 1996).

#### 2.1.2.3 1992 GATT Oilseed Panel US-EC Agreement (Blair House Agreement)

Under the 1992 GATT oilseed panel US-EC agreement, known as the Blair House agreement, the EU is limited to a maximum production of 1,000,000 t of soya meal equivalent as a by-product of rapeseed, sunflower seed and soya beans grown on set-aside. Officially, the 1 million tonne equivalent is absolute and cannot be increased regardless of future enlargement of the EU. The method of calculating what constitutes 1 tonne of soya bean meal equivalent is under discussion, but the total area of oilseeds which can be grown on set-aside is likely to be approximately 1 million ha. Assuming one tonne of rapeseed can be converted to 0.38 t of RME (Walker, 1995), the total EU capacity for RME (from oilseed rape grown on set-aside) under the Blair House agreement is likely to be approximately 920,000 tonnes. However, the US-EC limit refers only to meal for human or feed use, so this area could be increased if non-food/feed uses could be developed for the meal or if the meal was discarded.

## 2.2 Costs of biodiesel production

A number of studies have been carried out in different countries to determine the cost of biodiesel production (see Table 2.2). Table 2.3 shows the extent of production in Europe. In general the production cost of biodiesel in the EU and USA is 3-5 times that of fossil diesel.

Although there is no large scale production in the UK, biodiesel is available in small quantities. United Oilseeds import biodiesel from Italy and sell it for 49p/litre excluding excise duty and VAT. A consortium called British Biodiesel based in Darlington can currently produce biodiesel for 45p/litre (Hamilton, pers. comm 1996). However, lower estimates of potential production costs have been made based on greater economies of scale.

The British Association for Biofuels and Oils (BABFO) estimated the net cost of RME production in the UK to be 32.9 p/l, assuming a 150,000 t seed crushing plant with esterification facilities producing 50,000 t of RME (BABFO, 1995). A price of £130/t was assumed for rapeseed and it was noted that the cost of biodiesel production was most sensitive to the price of rapeseed. The net cost of RME was considered to be less sensitive to the price fluctuation of the by-products which were given a price of £100/t for high oil content meal and £450/t for glycerol (80%).

It may be argued that an increase in biodiesel production could result in a fall in the market value of glycerine. However the price of glycerine is difficult to predict due to the complexity of the oleochemical industry and interchangeability of its products. Studies of the market (quoted in Walker & Korbitz 1996, BABFO, 1994) do not anticipate a UK biodiesel industry flooding the glycerol markets. It is interesting to note that glycerine can be the primary objective of an esterification plant if the glycerine price is high: in the USA, Proctor and Gamble originally produced biodiesel as a by-product of glycerine production (Watson, NSDB, pers. comm. 1996).

**Table 2.2 : Comparative costings (£/l) of biodiesel production in EU**

| Study/Company | Rapeseed (£/t) | Rapeseed cake (£/t) | Glycerine (£/l) | Plant capacity (t) | RME price (£/l) |
|---|---|---|---|---|---|
| United Oilseeds (imported) | | | | | 0.49 |
| British Biodiesel | | | | 10,000 | 0.45 |
| Walker (1995) | 120 | 95 | 700 | 19,200 | 0.23.8 |
| Sanders & Turner (1995) | 110 | 90 | 800 | 50,000-100,000 | 0.31-0.25 |
| Sanders & Turner (1995) | 110 | 90 | 1,200 | 50,000-100,000 | 0.27-0.21 |
| BABFO (1995) | 130 | 100 | 450 | 50,000 | 0.32.9 |
| Culshaw & Butler (1993) | 110 | 80 | 600 | | 0.26 |
| TEASAC (1995) | | | | | 0.26-0.37 |
| Mauguin et al. (1995) | | | | 120,000 | 0.26 |
| Levy (1994) | 111 | | 266 | | 0.42.2 |
| Scharmer et al. (1993) | | 110 | 440 | | 0.46-0.63 |
| Friedrich et al. (1993) | | | | | 0.82-1.00 |

**Table 2.3 : Present and expected European biodiesel production and capacity ('000 t) 1995-1997**

| Country | Capacity | Actual production | Projects in development | Potential production 1997 |
|---|---|---|---|---|
| Austria | 28 | 21 | 30 | 51 |
| Belgium | 240 | 40 | - | 40 |
| Denmark | - | - | 32 | 32 |
| France | 260 | 140 | 120 | 380 |
| Germany | 125 | 83 | 162 | 287 |
| Ireland | - | - | 5 | 5 |
| Italy | 451 | 240 | 250 | 521 |
| Spain | 1 | 1 | 50 | 51 |
| Sweden | 16 | 16 | 30 | 46 |
| UK | 2 | 2 | 30 | 32 |
| EU 15 TOTAL | 1,123 | 543 | 736 | 1445 |
| Czech Republic | 58 | 40 | 1 | 59 |
| Slovakia | 8 | 5 | 1 | 59 |
| Switzerland | 2 | - | - | 2 |
| Yugoslavia | 9 | 5 | - | 9 |

**Source: Austrian Biofuels Institute 1996**

Walker (1995) argues that due to excess oil crushing and refining capacity in Europe, the true cost of biodiesel production may be approximately 20p/litre, depending on how existing capital facilities were being written off. In this case, a rapeseed price of £120/t was assumed with a by-product income of £95/t for meal and £700/t for glycerine to give a net cost of RME of 23.8p/litre for a plant producing 19,200 t per year.

Sanders & Turner (1995) underline the sensitivity of price of biodiesel to glycerol price. Using typical prices of £110/t for rapeseed, £90/t for meal and £800/t for glycerol production costs of 31p/l and 25p/l were reached for 50,000 t p.a and 100,000 t p.a. capacity plants respectively. With a glycerol price at £1,200/t, the production costs were calculated as 27p/l and 21p/l respectively. They note that production costs could be reduced if a new oil crushing facility was built adjacent to an existing and modified chemical plant.

A study for the Department of Trade and Industry by the Energy Technology Support Unit (ETSU) (Culshaw and Butler, 1992) reaches a price of 26p/l assuming a rapeseed price of £110/t; a rapeseed meal price of £80/t and a glycerine price of £600/t. The study analysed the sensitivity of the price of RME to changes in price of rapeseed and the by-products glycerol and rapeseed cake. The price was most sensitive to rapeseed price, slightly less sensitive to processing costs and least sensitive to meal and glycerine prices. A complete loss of credits from the by-products had a strong effect on RME price.

A study by the French environment and energy agency ADEME established the refinery cost of RME as 39.3p/litre. It assumes a plant with a capacity of 120,000 t such as at Rouen. It foresees that costs could be reduced by 10-16p/litre depending on genetic improvement of rapeseed giving 20% improvements in yield, advanced processing and up-grading of quality of the by-products glycerol and rape cake (Mauguin *et al.*, 1995). Figures from Austria (Korbitz, Pers. Comm., 1995) show a price of 41p/l. Rice (1995) estimates that RME would cost between 26p and 37p/litre. If Camelina was used as an alternative feedstock the cost of biodiesel could be cut by up to 12p/litre. A similar cost is arrived at using waste frying oil as a feedstock assuming a cleaning cost of £220/t.

Scharmer (1993) calculates a price for RME under 'good' and 'marginal' conditions - the prices reached are 46p/l and 63p/l. Gains of by-products are estimated at 44p/kg for glycerine and 11p/kg for rapeseed meal.

## 2.3 Excise duty

### 2.3.1 Automotive diesel (DERV)

DERV carries a duty rate of 40.28 pence per litre (ppl) effective from 2 July 1997. The market price known as the 'Rotterdam Spot Price' was approximately 8ppl throughout 1995. Realistic transport, wholesale and retail margins add another 7-8ppl, giving a total of approximately 56ppl, plus VAT at 17.5%, equals 65.8ppl. The market is very competitive, which means that suppliers and retailers discounted their margins, reducing prices at garages to 52.3ppl prior to the 1995 Budget (Palmer-Lewis, pers. comm., 1995). See Table 2.4 for a breakdown of biodiesel production cost including excise duty and VAT.

### 2.3.2 Gas oil ('red diesel')

Gas oil is taxed at a rate of 2.58ppl. This is a dramatically lower rate of tax than for automotive diesel. The advantageous tax status of gas oil originates from the withdrawal of the duty rebate for diesel in road vehicles in 1935. The rebate applicable to "off-road" use remained, 'partly because such use was not regarded as a significant source of revenue but also in line with the protection traditionally afforded to industry and agriculture by the UK excise duty structure' (Todd, HMCE, pers. comm., 1995). Red diesel has a cost price of approximately 15p/litre, so the total price excluding VAT is 17.58p/litre.

### 2.3.3 Biodiesel

The existing tax treatment of biofuels is governed by EC Council Directive 92/81 on the harmonisation of the structures of excise duties on mineral oils. Article 2 (3) requires Member States to tax any product sold as a motor fuel at the rate applicable to the equivalent mineral oil (either diesel or petrol).

**Table 2.4 Comparison of cost of production of and taxation of fossil diesel and RME (pence/litre)**

| | **Automotive Diesel [1]** | **Gas Oil [1]** | **RME @ 45p/litre[2]** | **RME @ 45p/litre (with 10% excise tax)** | **RME @ 32.9/litre[3]** | **RME @ 32.9/litre (with 10% excise tax)** |
|---|---|---|---|---|---|---|
| Production | 7.50 | 7.50 | 45.00 | 45.00 | 32.90 | 32.90 |
| Distribution, wholesale & retail margin | 7.50 | 7.50 | 7.50 | 7.50 | 10.77 | 10.77 |
| **Sub-total** | **15.00** | **15.00** | **52.50** | **52.50** | **43.67** | **43.67** |
| Excise tax (On road/Off road) | 34.30 | 2.77 | 34.30/2.77 | 3.40/0.30 | 34.30/2.77 | 3.40/0.30 |
| **Sub-Total** | **49.30** | **17.70** | **86.80/55.20** | **55.9/52.80** | **77.97/46.44** | **47.07/43.97** |
| VAT | 8.60 | 3.10 | 15.10/9.70 | 9.80/ 9.20 | 13.64/8.13 | 8.24/7.69 |
| **Total** | **57.90** | **20.83** | **101.40/64.90** | **65.7/62.0** | **91.61/54.57** | **55.31/51.66** |

1 Palmer-Lewis, DTI, pers. comm. (1996)

2. David Hamilton, British Biodiesel, pers. comm. (1996)

3. BABFO (1994)

In the UK RME is therefore subject to the same "off-road" or the higher "on-road" rate as fossil diesel according to its use. This makes biodiesel uncompetitive with fossil diesel in terms of final cost, as the cost of biodiesel production is 2-5 times higher than the cost of fossil diesel. Table 2.4 shows the price of automotive diesel, gas oil and biodiesel with their respective duties. Two prices for biodiesel are shown. Forty-five pence/litre is the current cost of production in the UK and near to the imported price (49p/litre). However, this may not be representative of the price at which biodiesel would be available if there was larger scale production in the UK. The lower price of 32.9p/litre, is quoted by BABFO for when there are significant economies of scale of production although Walker (1995) argues that an even lower production cost of 21p/litre is achievable. (See Section 2.2).

Article 8 (2) of the same Directive empowers Member States to apply reduced rates for fuels used in the context of "pilot projects". A Pilot project in this case refers to the four categories of actions on renewable energy sources that are financed under the EC's ALTENER Programme (Commission of European Communities, 1993). The UK government has not taken up this opportunity and so is not encouraging the establishment of a trial biodiesel plant in the UK.

Once production moves beyond the stage of a "pilot project" to the stage of industrial production, there is currently no provision in Community legislation for Member States to apply either a reduced rate or an exemption from tax (Bill, 1994). However, tax exemptions for biodiesel presently exist in France, Germany, Austria, Czech Republic and Italy.

The Commission has put forward a proposal (COM (94)147) (Commission of European Communities, 1994b), modifying an earlier draft Directive (COM(9)36) known as the 'Scrivener Directive' to regulate the tax regime for biofuels during the stage in which they begin to be exploited industrially. Its basic aim is to require Member States to apply a rate of excise duty to biofuels of no more than 10% of the rate levied on the equivalent fuels that the biofuels are to replace (petrol or diesel as the case may be). After 10 years the duty would be increased by 10% to 20% and then by another 10% every five years up to a maxiumum of 50%.

Any Directive needs unanimous approval by Member States. The revised Scrivener Directive is currently opposed by the UK and Denmark.

## 2.4 Feedstocks

Some of the studies quoted in section 3.4 indicate that the cost of biodiesel production is most sensitive to the price of rapeseed and to a lesser extent to the cost of processing and value of the by-products glycerol and rapeseed cake (Culshaw & Butler 1993; Sanders & Turner, 1995; BABFO, 1994)

Industrial rapeseed prices rose between 1993 and 1995, from £85 to £100 to £120/t (United Oilseeds, pers. comm., 1996). It is uncertain what future prices will be: Meikle (1995) note that vegetable oil production in the Far East and oilmeal production in the Americas can have a greater influence on price than EU production, consumption or agricultural policy.

To reduce the price of biodiesel, lower cost and alternative feedstocks are being developed in Europe, U.S.A and Japan (Tapp, pers. comm., 1996).

### 2.4.1 Lower cost alternative feedstocks

Several options potentially exist to reduce the feedstock cost of biodiesel. Different feedstocks have different properties (for example see Table 2.5) and these have to be considered when producing a biodiesel to EU draft specifications.

**Table 2.5 : Low-temperature properties and iodine values of alternative raw materials**

| Oil | Iodine Value | CFFP (°C) |
|---|---|---|
| Rape | 115 | -4 |
| Waste Cooking | 100 | -3 |
| Camelina | 160 | -2 |
| Tallow | 50 | 18 |

**Adapted from TEAGASC (1996)**

#### 2.4.1.1 Waste frying oil

Waste frying oil collected from local households and restaurants is used as a feedstock for biodiesel in a co-operative plant in Mureck, Austria and is being evaluated in trials in Ireland by The Agriculture and Food Development Authority (TEAGASC) at Oak Park Research Centre, Co. Carlow. The biodiesel produced with this feedstock meets Austrian and draft EU specifications respectively and no technical problems have been encountered (Frohlich, TEAGASC, pers. comm., 1996).

#### 2.4.1.2 Camelina

*Camelina sativa* is currently being examined in several European countries, including Ireland and the UK, as an alternative oil-seed crop. Its oil yield is similar to that of rape, but it requires lower fertiliser and pesticide inputs, which leads to a lower cost and a more favourable energy ratio. For bio-diesel production, *Camelina* has two problems. The first is the low temperature properties of the ester which are slightly inferior to those of rape. Additives could overcome this problem which would not be serious, for example in the Irish climate with an average monthly temperature in the coldest month of 4°C. The second problem with *Camelina* biodiesel is its high iodine value. The draft EU maximum iodine number has been set at 115. With an iodine number of 160, *Camelina* can not be used as a feedstock for biodiesel on its own. However, in blends it would have some desirable properties, such as a low viscosity. TEAGASC state that use of *Camelina* in this way could reduce the cost of biodiesel by up to 12p/litre (Agence de l'Environement et de la Maitrise de l'Energie, 1996).

#### 2.4.1.3 Beef tallow

The inclusion of beef tallow as a feedstock could also reduce costs. It has an iodine value of approximately 50 and so would be a useful in blends. Researchers in the US have blended tallow with Camelina and waste oil to give biodiesel with an iodine value of 115. Researchers have found that tallow will not respond to additives to reduce the Cold Filter Plugging Point (CFPP) (the temperature at which a liquid starts to solidify) and so conclude that a satisfactory biodiesel can not be produced with more than 5% tallow (Agence de l'Environement et de la Maitrise de l'Energie, 1996). Table 2.6 shows how the above materials could be blended to give an iodine value close to 115 with reasonable low-temperature properties.

**Table 2.6 : Alternative feedstock blends for biodiesel with iodine values close to 115**

| | | |
|---|---|---|
| Waste oil 75% | Camelina 25% | |
| Waste oil 65% | Camelina 30% | Tallow 5% |
| Waste oil 55% | Camelina 35% | Tallow 10% |
| Waste oil 40% | Camelina 40% | Tallow 20% |

**Source: Agence de l'Environement et de la Maitrise de l'Energie, (1996)**

#### 2.4.1.4 Used hydraulic oils

Used hydraulic oils derived from rape seed have also been suggested (Korbitz, pers. comm. 1996) as a potential feedstock for biodiesel. Esterification is made more difficult by the presence of additives, incorporated to provide the hydraulic oil property. In this case, it is recommended to distill the final methyl ester.

#### 2.4.1.5 Conclusion

A number of options appear to be available for reducing the cost of biodiesel through the use of cheaper feedstocks.

The challenge for the biodiesel manufacturer is to have both the access to various low cost feedstocks and the expertise to find the lowest cost blend that still meets EU specifications such as an iodine value of 115.

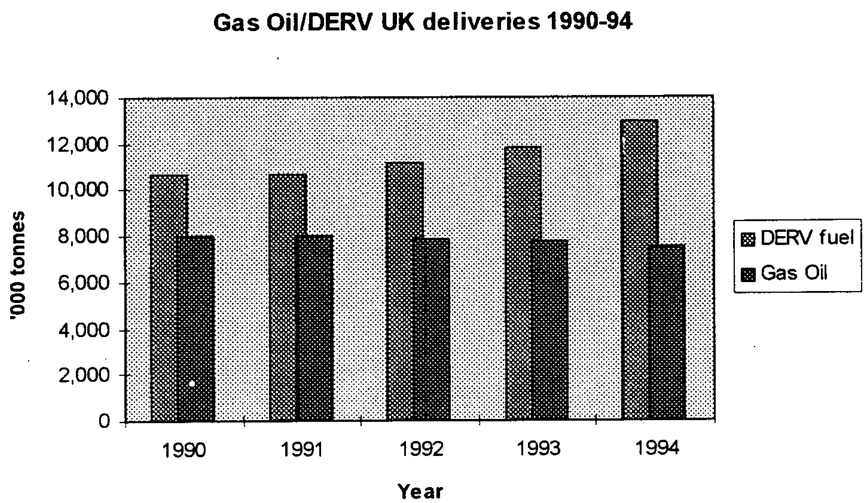
## 2.5 Macroeconomic benefits

The macroeconomic benefits of a biodiesel industry have been argued by agricultural interest groups across Europe. In the UK, BABFO (British Association for Biofuels and Oils, 1994) calculated that the 'net job saving' for a 50,000 t biodiesel production capacity to be 966 jobs and that the Treasury would benefit from between £2.5m and £10m. In France, Vermeersch (1995) argued that 11 jobs are created for every 1,000 t of ester produced. Kinsella (1994) estimated that a biodiesel industry in Ireland would create 350 jobs. The study assumed that the 30,000 hectares of set-aside in Ireland was utilised for biodiesel feedstock with a processing capacity of 30,000 t per year.

## 2.6 Market size

DERV deliveries increased by 21.2% between 1990 and 1994 from 10,652 Mt to 12,914 Mt, whereas gas oil deliveries decreased by 6.9% from 8,047 Mt to 7,491 Mt during the same period (Figure 2.1). Cambridge Econometrics predict that DERV consumption will rise to 19.79 Mt and gas oil will drop to 7.1 Mt by the year 2000 (Hargreaves, Cambridge Econometrics, pers. comm., 1996).

**Figure 2.1 Gas oil/DERV UK inland deliveries 1990-94**




Source: Institute of Petroleum (1995)

## 2.7 Market breakdown

### 2.7.1 DERV markets

The Department of Transport have made the following estimate of sectoral consumption of automotive diesel fuel between 1988 and 1994: the percentage of DERV consumed by goods vehicles (light vans and HGVs) fell from 80% to 69%, consumption by buses and coaches remained fairly constant decreasing only 2% from 11% to 9%, and consumption by cars and taxis increased from 9% to 23%.

### 2.7.2 Gas oil markets

Gas oil end users are spread among a variety of sectors. These have been identified in table 2.7. These estimates are intended by the DTI and Institute of Petroleum for general guidance only.

Table 2.7 **Gas oil/DERV UK inland deliveries 1990-94 ('000 tonnes)**

| | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|
| **GAS OIL** (by sector) | | | | | |
| Agriculture & Forestry | 662 | 672 | 664 | 657 | 640 |
| Marine | 1,181 | 1,202 | 1,145 | 1,098 | 971 |
| Food | 169 | 162 | 150 | 148 | 150 |
| Mines & Quarries | 259 | 277 | 318 | 303 | 302 |
| Chemicals | 172 | 153 | 143 | 147 | 150 |
| Metals | 172 | 162 | 152 | 162 | 159 |
| Engineering | 360 | 340 | 334 | 316 | 312 |
| Textile & Leather | 46 | 51 | 44 | 45 | 44 |
| Bricks & Ceramics | 166 | 163 | 153 | 158 | 154 |
| Timber, Rubber & Paper | 54 | 56 | 54 | 57 | 55 |
| Other Man. Industries | 321 | 284 | 256 | 287 | 294 |
| Building & Contracting | 641 | 650 | 648 | 602 | 596 |
| Utilities | 686 | 710 | 707 | 687 | 680 |
| Laundries | 15 | 11 | 10 | 10 | 10 |
| Central Heating - Non industrial | 2,586 | 2,588 | 2,531 | 2,446 | 2,302 |
| Misc. Non-manufacturing | 490 | 486 | 498 | 593 | 603 |
| Petroleum Industry | 68 | 65 | 64 | 67 | 69 |
| **GAS OIL TOTAL** | **8,047** | **8,032** | **7,871** | **7,782** | **7,491** |
| **DERV TOTAL** | **10,652** | **10,694** | **11,132** | **11,806** | **12,914** |

Source: Institute of Petroleum (1995) & Department of Trade and Industry (1995)

The size of the lubricant oil and grease market in the UK in 1994 was 794,542 tonnes (Institute of Petroleum 1995). The demand has remained constant over the last five years.

## 2.8 Conditions for uptake of biodiesel in the UK

The conditions for biodiesel to achieve substantial uptake in the UK diesel market are demanding and constitute significant barriers to entry. Issues include:

- economic competitiveness - biodiesel has a major cost disadvantage against fossil diesel (see 1.4.4.2)
- problems of distribution - biodiesel is a small volume product and very limited infrastructure (production and distribution capacity) is in place to meet large demand from around the UK
- availability of vehicle technology - biodiesel is almost a direct substitute for mineral diesel but consumers have to be convinced of its performance
- acceptance of biodiesel by engine manufacturers - any fuel must have a warranty from engine manufacturers
- availability of maintenance services - consumers know little about biodiesel and so need to be reassured that a responsive and well-trained vehicle service industry is in place.
- vehicle emissions standards - the tightening of EU standards will help to improve the market potential of alternative fuels offering low emissions of regulated pollutants (Gover *et al.*, 1996). It needs to be assessed whether new regulations will offer biodiesel new commercial advantages, for example, in terms of its low sulphur content.

# 3 ENVIRONMENTAL IMPACT OF BIODIESEL PRODUCTION AND USE

## 3.1 Introduction

This chapter will outline the environmental impact of the production and use of biodiesel.

In order to justify the substitution of fossil diesel with biodiesel, the environmental impact of production and use of biodiesel can be compared to that of fossil diesel. Figure 3.1 shows a schematic life-cycle comparison of biodiesel and fossil fuel.

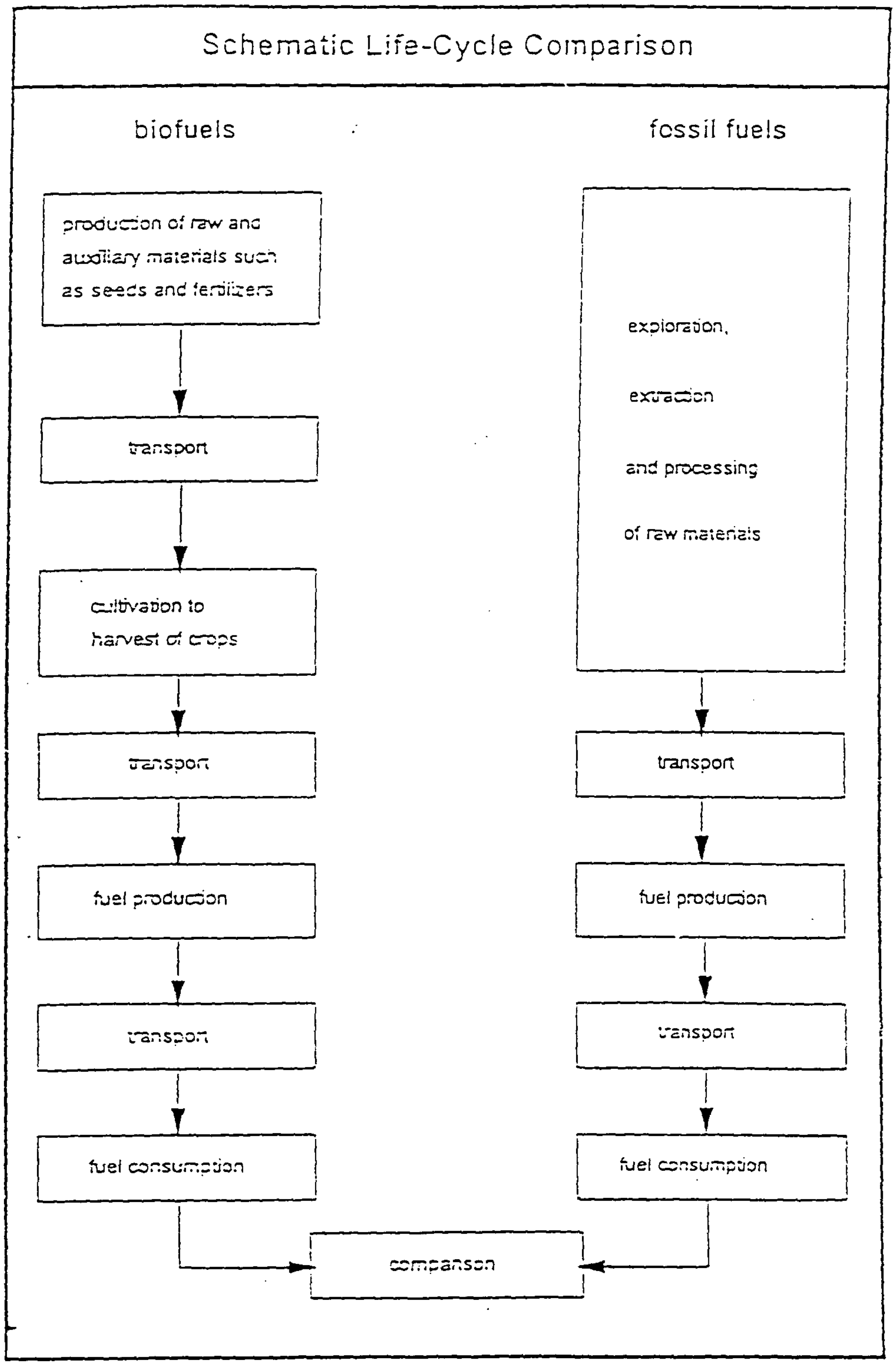
Biodiesel production and use consists of the following stages

- Cultivation of rapeseed
- Harvesting, drying and storage of rapeseed
- Crushing and esterification of rapeseed
- Distribution
- Use of the biodiesel in combustion engines

Fossil fuel production and use consists of the following stages

- Exploration
- Extraction
- Refining
- Use of the fossil diesel in combustion engines

Figure 3.1 : Schematic Life-Cycle Comparison




Source : Reinhart *et al.* (1994)

## 3.2 Methods for assessing environmental impact of biodiesel production

Methods for assessing environmental impact of biodiesel production and use include the following:

### 3.2.1 Energy ratio

The energy ratio of biodiesel determines its viability as a renewable energy source. The energy ratio of a fuel can be defined as the ratio of the energy used in its production to the energy value of the fuel and any utilised by-products. If the energy ratio of rape is 1:>1, then the energy supplied by the vegetable oil is higher than the sum of the energy used for its production, from cultivation through processing stages to its combustion. The ratio can be affected by how co-products are used. For example, biodiesel will have an improved energy ratio if the energy value of co-products such as gylcerine, rapeseed meal and straw are included as an energy output.

### 3.2.2 Carbon dioxide (and equivalent Greenhouse Gas) savings

Plants absorb $CO_2$ from the atmosphere during photosynthesis. When this carbon is converted to a biofuel and released through combustion, the $CO_2$ is simply being returned to the atmosphere. The combustion of fossil fuels releases carbon that has been stored for millions of years. This increases the atmospheric concentration of $CO_2$, a 'greenhouse gas' i.e. a gas that contributes to the warming of the Earth's atmosphere.

The balance of energy inputs and outputs for biodiesel and fossil diesel production and use can be used to calculate the difference between the $CO_2$ emitted from the fossil diesel's life cycle and the $CO_2$ released in the life-cycle of biodiesel. One can calculate the amount of $CO_2$ emitted in the life-cycle of a fuel on the assumption that each unit of energy (gigajoule) (GJ) emits a certain amount of $CO_2$. For example, ETSU assume that all energy inputs in the production of biodiesel use fossil oil as a fuel source which emits approximately 69.3kg $CO_2$/GJ. However, the use of oil could be substituted by straw in the grain drying and processing heat stage, in which case the $CO_2$ savings would be greater as straw is 'carbon neutral' (Culshaw & Butler, 1992).

Since other 'greenhouse gases' like nitrous oxides are emitted in the production of biofuels, the 'greenhouse balance' will be greater than the 'carbon balance'. These other gases can be weighted in terms of the degree to which they contribute to global warming. The International Panel for Climate Change (IPCC) has calculated the weighting (or 'equivalence' factors) for each gas (Houghton, 1992). For example, $CO_2$ has a base factor of 1 for a time period of 20 years, $CH_4$ is 35 and $N_2O$ is 260. This means one unit of $N_2O$ has the potential to contribute to global warming, 260 times more than one unit of $CO_2$.

### 3.2.3 Emissions measurements

The production and use of biodiesel and fossil diesel produces measurable emissions to the air and water over their life cycles that have environmental and health impacts.

### 3.2.4 Life Cycle Analysis (LCA)

LCA is an analytical tool used to *quantify* all the environmental impacts that arise from all the stages related to a process or product from raw material extraction to disposal. Although the methodology is still developing, The Society for Environmental Toxicology and Chemistry (SETAC) has outlined a standardised LCA structure. This consists of the following stages (SustainAbility, 1993):

*Goal definition and scoping* - definition of the purpose of the analysis, system boundaries, data requirements, assumptions and limitations. A process tree is constructed to show the materials identified in this stage.

*Inventory analysis* - the data collection stage: quantitative description of all flows of materials, energy, emissions across the system boundary either into or out of the 'system'.

*Impact Assessment* - The data gathered from the inventory stage is translated into corresponding environmental categories (classification and characterisation). These categories are weighted to facilitate comparison under a single figure (valuation).

*Improvement Assessment* - options for reducing aggregate loadings are identified and evaluated

With the environmental agenda rising in importance during the 1980s, LCAs have been adopted by private companies to provide 'green' audits for their products and processes. The endorsement of LCA by various seal-of-approval schemes, including the European Commission's Eco-labelling scheme has increased LCA's current prominence. The production of an LCA by a private company for public consumption might be used as a strategic marketing tool. LCA is also being applied by public authorities and pressure groups.

## 3.3 Sources of the environmental impact of biodiesel production and consumption

Figure 3.2 shows the process tree for the agricultural part of the life-cycle of biodiesel production. The inputs and process listed apply to any conventionally grown rape crop and most arable crops.

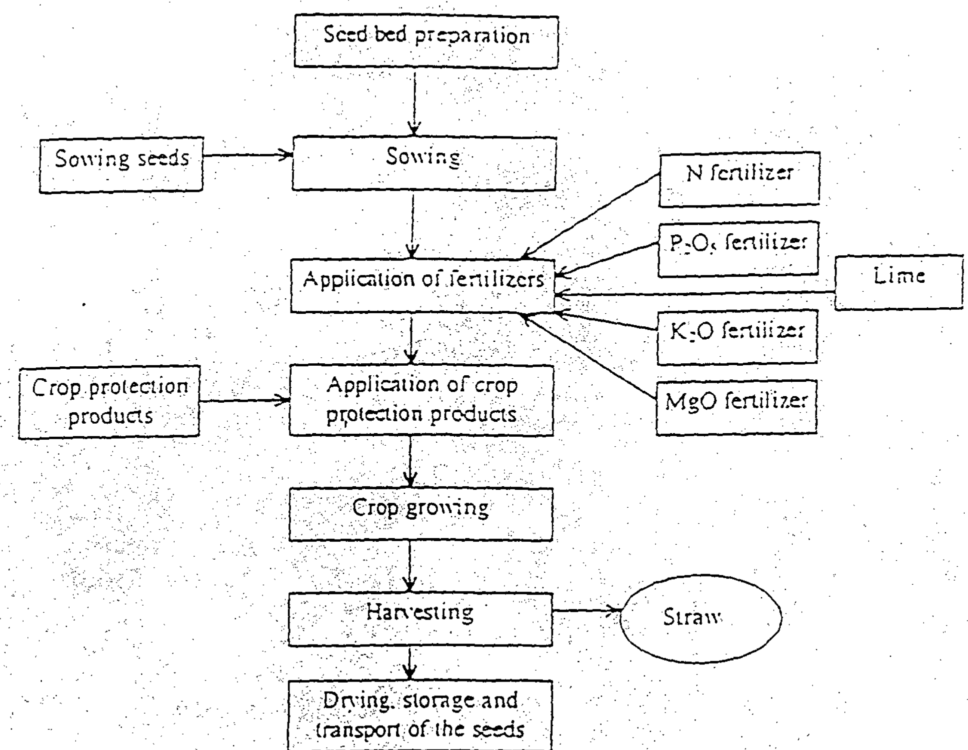
### 3.3.1 Seed bed preparation and Sowing

A number of operations are involved in seed bed preparation and sowing of crops. The tractor makes a number of passes for ploughing, harrowing, drilling and rolling. Reduced cultivation and direct drillling methods have been developed which may reduce the environmental impact of these stages, but they are not suitable for all conditions. Environmental impacts result from fuel use, manufacture and maintenance of machinery and soil cultivation.

### 3.3.2 Production and application of fertilisers

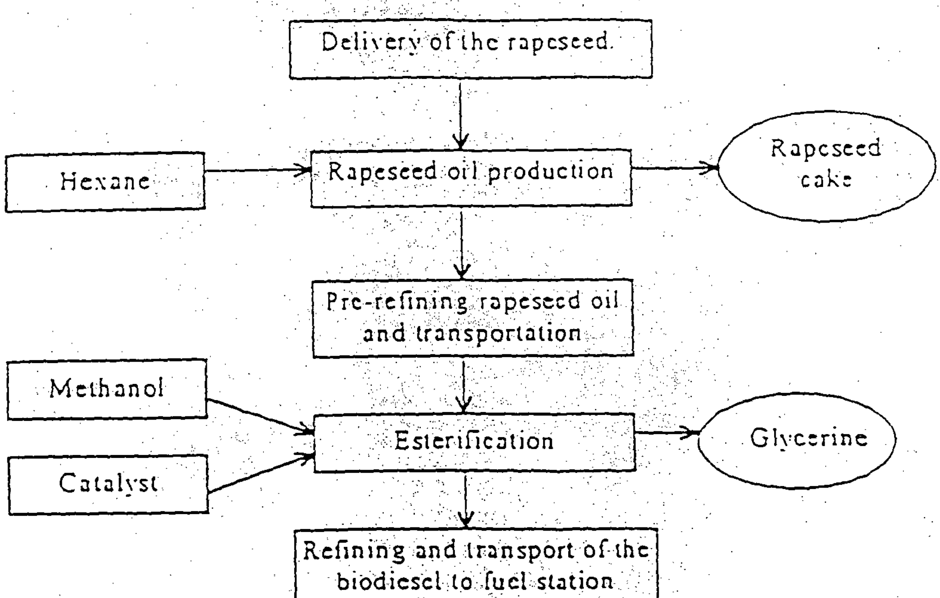
Fertiliser use consumes energy and emissions are produced during the manufacturing process and fertiliser application.

Figure 3.2 : Process tree for agricultural part of biodiesel life-cycle




Source : VITO (1996)

Figure 3.3 : Process tree for industrial part of biodiesel life-cycle




Source : VITO (1995)

#### 3.3.2.1 Fertiliser production

Nitrogen fertilisers are produced from ammonia, which is produced by steam reforming of natural gas or by partial oxidation of heavy fuel oil. It can also be produced from urea, the production of which generally requires more energy than nitrogen from ammonia.

#### 3.3.2.2 Phosphate (P) and Potash (K)

Phosphate rock is the raw material for the production of phosphorous fertilizers. During the mining of phosphate rock, fluorine is emitted to the air; phosphate and fluorine to water and gypsum as solid waste. Potash fertilisers are produced from potash ores. The potash ore that is often used is sylvinite, which is composed of sylvite and halite in various proportions depending on the potash seam. Sylvinite can be used directly as a fertiliser (Spirinckx & Ceuterick, 1996). There are a range of impacts on the environment associated with mining and quarrying operations. They include the following (Wye College External Programme, 1995)

- blasting
- machinery & processing plant noise
- dust
- visual intrusion
- hydrological and hydrogeological impact
- contaminated drainage waters
- possible effects on surrounding flora and fauna from dust and desiccation
- traffic generation
- safety matters e.g. unstable faces, deep water, tip heaps.

In the longer term, the main environmental concern about mining and quarrying is the potential scar left on the landscape. This can to some extent be mitigated by restoration.

Energy requirements for phosphate and potash production are less than for nitrogen and a very small proportion of total energy use in biodiesel production.

The rate of application for phosphate and potash fertilisers are dependent on soil status, expected yield and whether straw is ploughed into the soil or removed.

**3.3.2.3 Nitrate pollution from agriculture**

Nitrate levels in unconfined acquifers and surface waters have been rising during the last thirty years (National Rivers Authority, 1995), giving rise to environmental and health concerns (OECD, 1986; Harrison, 1992).

The main source of these nitrates is agriculture (MAFF, 1994), though agricultural activities are not the only potential source of the problem (Pan, 1994). Losses of nitrate from agriculture are dependent on the type of farming system being operated. The ploughing of permanent pasture is recognised as a prime source (MAFF, 1994). Addiscott *et al.* (1991), argue that the nitrate problem is caused by leaching losses from soil organic matter rather than from direct losses from fertilisers. Less nitrate is generally leached under permanent grassland than under either arable land or ploughed grassland (DoE, 1986).

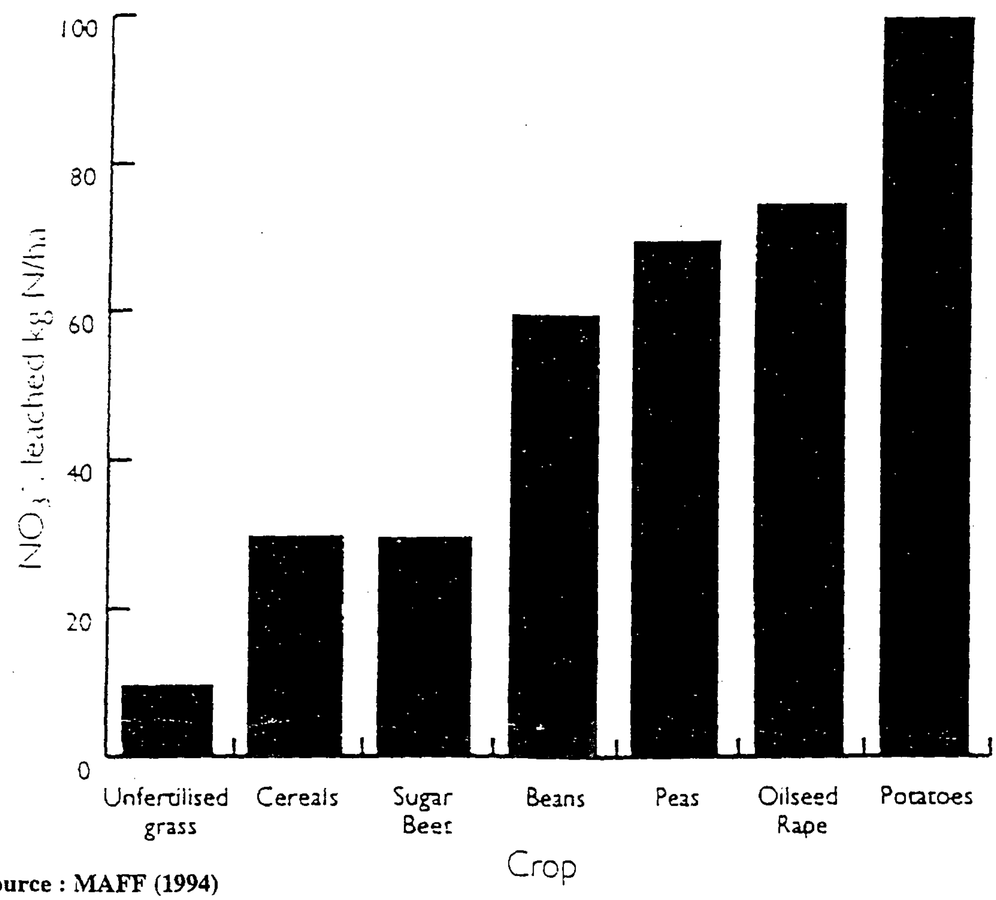
The environmental impact of individual crops may be difficult to differentiate from one another in a rotation when under intensive management practices (Marquard & Walker, 1995). Nitrate leaching losses to water are determined by a variety of agricultural factors, notably soil cultivation and cropping practice, rate and timing of nitrogen fertiliser and rate of crop uptake. Economic factors such as whether the value of the seed justifies high nitrogen usage are also important (DoE 1986). MAFF estimates show oilseed rape to leach more nitrogen than any other crops except potatoes (see Figure 3.4 ) (MAFF, 1994).

Problems of nitrate leaching may occur when growers, striving for maximum yield apply nitrogen fertilisers at rates which the crop cannot fully utilize. During the 1980s, incomes from oilseed rape were high enough to allow farmers to avoid serious scrutiny of the cost-benefit relationships of input usage. However, as EC policy has changed and the price of rapeseed has fallen, nitrogen applications have also been reduced (Meikle, 1995; MAFF, 1994). Consequently, the likelihood of excessive nitrate leaching from rapeseed crops has also declined. There are no data on application responses to the rise in price of double low OSR prices over the last three years.

#### 3.3.2.4 N emission rates from oilseed rape

Nitrogen compounds in the soil are partly denitrified into nitrous oxide, an important greenhouse gas and destroyer of the stratospheric ozone layer. Its residence time in the atmosphere is about 160 years and its Global Warming Potential (GWP) is 260 times higher than that of $CO_2$ (Houghton, 1992). The Intergovernmental Panel on Climate Change (Houghton *et al.*, 1990) gives the emission rate of nitrous oxide from

**Figure 3.4 : Nitrate leaching loss from different crops without use of manures**




**Source : MAFF (1994)**

nitrogen fertiliser as 0.4 to 3.2% although this depends on application levels or the crop being fertilized. Scharmer *et al.*, (1995) calculated that when 100kg/ha Nitrogen is applied to rapeseed crops, 30% is utilised, 15% is denitrified and 3-10% nitrous oxide (0.31 to 1.05 kg N/ha) escapes into the atmosphere. Recent trials on sites in Germany found that 0.32 kg/ha of nitrous oxide were emitted during the 300 days measurement period (Kohrs *et al.*, 1995). These figures contrast with the high estimation by UBA in which between 3.8 and 5.7kg/ha/year are emitted (UBA 1993). German commentators have criticised the UBA report, which was influential in shaping German biofuels policy, for overestimating nitrogen inputs and the resulting nitrous oxide emissions. Scharmer *et al.*, (1993) calculate that 0.4% of nitrogen applied was emitted compared to 2.5% estimate by UBA. The International Energy Authority estimates a rate of 1% nitrogen fertiliser applied to the field that is converted into $N_2O$.

Ecobilan (1993) in France use measurements from CETIOM (Centre Technique Interprofessionnel des Oleagineux Metropolitains) to conclude that it is probable that emissions of $N_2O$ from the cultivation of rape are equivalent to those from wheat. Marquard & Walker (1995) report on an experiment carried out by Scheffer (1993) over several years involving rotation of winter wheat and winter rape on heavy soil that showed an increased concentration of soil nitrogen in the drainage water of the wheat crop following rapeseed.

### 3.3.3 Pesticide Application

Table 3.1 shows typical applications of pesticides for winter and spring grown double low rape on rotational and set-aside land.

The British Agrochemical Association (1996) report that in 1995/6, pesticide usage increased due to the increased area of winter sown varieties and climatic conditions. Herbicides were up by 4%, insecticides up by 17% and fungicides up by 45%.

#### 3.3.3.1 Pesticides and water

As pesticides are designed to control living organisms, they can be expected to have an environmental impact, in particular in the aquatic environment. The general problem areas of pesticide use identified by the OECD include the use of persistent and toxic pesticides, risk of ecotoxicological effects, soil and groundwater contamination, impurities in commercial preparation, migration to acquifers and the misuse and mismanagement of pesticides (OECD, 1986).

Harrison (1992) notes that most effects have been due to accidents or deliberate misuse and there is little evidence to suggest that when used properly, and thereby acting as a diffuse source, pesticides cause any adverse enviromental effects.

**Table 3.1 : Typical applications of pesticides (litres/ha) for winter and spring grown double low rape on rotational and set-aside land.**

| Control | Winter (rotational) | Winter (set-aside) | Spring (rotational) | Spring (set-aside) |
|---|---|---|---|---|
| Weed | Metazachlor - 1.5 (pre-emergence), then fluazifop-P-butyl - 0.5 for volunteer cereals | Metazachlor - 1.5 (pre-emergence) | Often none required | Often none required |
| Disease | | | Iprodione - 2.0 | Tebuconazole 0.5 |
| Light leaf spot | Tebuconazole - 2x 0.5 | Tebuconazole - 2x 0.25 | | |
| Sclerotinia stem rot | Vinclozolin - 1.0 | | | |
| Pest | Cypermethrin 0.25 | | | Cypermethrin 0.25 |
| Pollen beetle | | | Cypermethrin - 2x0.25 | |

**Source: Walker, SAC, pers. comm. (1996)**

Harrison concludes that there is very limited evidence that chemical constituents of drinking water are involved in health problems and that water components represent only a very small proportion of the dietary intake of chemicals. Any health effects of chemicals in drinking water are likely to result from long-term exposure and some effects will be difficult to detect.

### 3.3.3.2 Pesticide poisoning

Data concerning pesticide incidents investigated by the Health and Safety Executive (HSE) in UK have been collated for 1989-92. During this period, HSE investigated 613 incidents concerning pesticides: 338 related to general or environmental complaints not involving human poisoning and 275 were suspected poisoning incidents. Of the 275 poisoning incidents, 129 (48%) were assessed as 'confirmed' or 'likely'. Thirty-six per cent of these resulted from working with, or in close proximity to a pesticide, 41% occurred on private property adjacent to a field being sprayed and a further 23% involved those walking, cycling or jogging past a sprayed field. The study does not specify which crops were being sprayed when the incidents occurred (Thompson *et al.*, 1995).

#### 3.3.3.3 Harvesting

Air quality deteriorates due to crop dust thrown up by combine harvesters. Chemicals are sometimes used to desiccate the crop before harvest.

#### 3.3.3.4 Drying, storage and transport of the seeds

Drying, storage and transport of seeds requires energy, and also results in emissions and other environmental impacts resulting from the use and production of machinery.

## 3.4 Energy ratio

When energy outputs attributable to glycerol and meal are included in the calculation, RME has an energy ratio of around 3:1 (Batchelor *et al.,* 1994). In terms of total renewable energy gains, other energy crops have been shown to provide higher energy ratios than RME. ETSU quote short rotation coppice (SRC) and *Miscanthus spp.* as having ratios of 30:1 and 5.9-14.3 respectively (ETSU, 1994) but this is for solid biofuel. Table 3.2 shows that energy ratios for biodiesel are higher than other liquid biofuels such as ethanol and methanol. The energy ratio of fossil diesel is approximately 5:1 (Boustead & Hancock, quoted in Culshaw & Butler (1992)).

### 3.4.1 The sensitivity of biodiesel energy ratios to energy usage in farming

Table 3.3 shows that in the life cycle of biodiesel the agricultural system accounts for the majority of the energy used. In particular, the sensitivity of the energy ratio to nitrogen inputs has been identified by several authors (Batchelor *et al.*, 1995; Gover *et al.*, 1996) as being significant. Energy associated with nitrogen fertiliser accounts for approximately 60% of agricultural activites which in turn account for approximately 60% of the total energy input to RME production although inventory analyses in the literature reveal a wide range of energy values assigned to fertiliser, especially inorganic nitrogen. The range of energy values for nitrogen inputs are a reflection of improvements in efficiency of manufacture of both ammonia production and subsequent processing steps. Winter oilseed rape and winter wheat receive the highest nitrogen applications in UK agriculture after potatoes (MAFF, 1994). The average field application rate of nitrogen for oilseed rape in 1994 was 182 kg/ha. A lower input or organic system using organic fertilisers could improve the energy ratio of biodiesel. Furthermore in France, Ecobilan (1993) and Maugin *et al.* (1995) see realistic gains of 15-20% in efficiency to be made in increased yields from new hybrid varieties.

**Table 3.2 : Energy ratio of biofuels**

| Source | Crop | Fuel | Energy ratio |
|---|---|---|---|
| Poitrat (1994) | Wheat | Ethanol | 3.7 |
| Poitrat (1994) | Sugar beet | Ethanol | 1.7 |
| Batchelor *et al.* (1994) | Oil seed rape | Biodiesel | 0.91-3.95 |
| Batchelor *et al.* (1994) | Wheat | Ethanol | 0.47-1.79 |

**Table 3.3 : Energy value of inputs for industrial rape production (MJ/ha)**

| Inputs | Reinhart *et al.* (1991) | Ecobilan (1993) | Scharmer *et al.* (1993) | Culshaw & Butler (1992) [2] | Batchelor *et al.* (1995) [3] |
|---|---|---|---|---|---|
| Seed | 35 | - | 30 | 93/93 | - |
| Fertiliser N | 10,680 | 10,241 | 6,435 | 15,522/8,955 | 2,843-24,072 |
| $P_2O_5$ | 1,260 | 750 | 1,075 | 715/715 | 732-1,900 |
| $K_2O$ | 760 | 2,100 | 760 | 332/332 | 0-765 |
| CaO | 530 | - | 90 | - | - |
| Total | 13,230 | 13,091 | 8,390 | - | 3,575-26,137 |
| Pesticides | 520 | 306 | 670 | 144/144 | 316-1,002 |
| Machinery | 6,970 | 2,887 | 4,430 | 2,030/2,030 | 3,103-6,700 |
| Fuel | | | | 2,331/2331 | 2,555-3,278 |
| Agricultural Input Total | 20,755 | 16,284 | 13,490 | 21,167/14,599 | 9,549-37,117 |
| Processing Total [1] | 14,750 | 13,872 | 9,005 | 113,366/7,811 | 18,763-16,791 |
| **INPUT TOTAL** | **35,505** | **30,156** | **22,495** | **32,532/22,411** | **28,312-53,908** |

*Notes*

1. Processing includes crushing, refining, transesterification and transport.

2. Culshaw & Butler (1992) calculate energy inputs for winter and spring rape respectively.

3. Batchelor *et al.* (1995) have calculated a range of values from 'best case scenario' to 'worst-case scenarios'.

**Table 3.4 :Energy value for system outputs (MJ/ha)**

| System Output | Reinhardt *et al.* (1991) | Ecobilan (1993) | Scharmer *et al.* (1993) | Culshaw & Butler (1992) | Batchelor *et al.* (1995) |
|---|---|---|---|---|---|
| RME | 42,408 | 42,978 | 55,700 | 43,926/30,199 | 63,037-36,302 |
| Rapemeal | 10,600 | | | 39,060/26,880 | 45,507-11,044 |
| Glycerine | 11,200 | | | 2,352/1,512 | 3,361-1,679 |
| Straw | 59,400 | | | 37,500/25,800 | 151,200-71,098 |
| TOTAL (with straw) | 137,408 | | 101,700 | 122,838/84,391 | 263,105-120,123 |
| TOTAL (without straw) | 74,251 | | | 85,338/58,591 | 111,905-49,025 |
| RATIO (with straw) | 3.87 | | | 3.77/3.77 | 2.22-9.18 |
| RATIO (without straw) | 2.09 | 3.15-3.61 | | 2.62/2.61 | 0.91-3.95 |

## 3.5 Carbon dioxide (and equivalent Greenhouse Gas) savings

$CO_2$ balances can be estimated from energy balances, since most energy consumption results in emission of greenhouse gases. Highly active greenhouse gases such as methane and nitrous oxide are emitted in the fuel's production and their omission or overestimate (as in the case of UBA [1993]) can result in variability in $CO_2$ balance figures.

As is the case with its energy ratio, the $CO_2$ balance for RME can be improved if straw and meal by-products are utilised with minimal transport and processing costs (Culshaw & Butler, 1992).

The amount of $CO_2$ emitted through replacement of diesel fuel can be calculated with reference to the fossil diesel carbon content and all previous emissions. Table 3.5 shows quantities of fossil $CO_2$ emission estimated to be avoided, if 1 litre of fossil diesel fuel is replaced by biodiesel. If investment in biodiesel is to be justified purely in terms of its carbon dioxide balance, its costs and benefits must be considered within the context of other $CO_2$ abatement strategies such as energy conservation measures, investment in public transport and other biofuel options such as short rotation coppice and miscanthus. Energy ratios for biodiesel are lower than those published for woody biomass crops and higher than those published for other biofuels such as bioethanol. It has therefore been argued that biodiesel has a lower greenhouse gas saving than woody biomass crops. However, biodiesel and woody biomass options are not strictly comparable for two reasons. Firstly, it is unlikely that woody biomass would be grown in the same way that oilseed rape is, i.e. a break crop within the arable rotation and secondly, the end-use is different. Biodiesel is a transport fuel or industrial feedstock. Woody biomass is grown for electricity generation, but energy ratios for this fuel are often calculated on the basis of total energy content of the biomass, ie they do not take into account the efficiency of electricity production.

**Table 3.5 :Quantity of fossil $CO_2$ emission (kg) which is estimated to be avoided, if 1 litre of fossil diesel fuel is replaced by biodiesel.**

| | **Reinhart *et al.* (1991)** | **Culshaw & Butler (1992)** [1] | **UBA (1993)** | **Ecobilan (1993)** | **Scharmer (1993)** |
|---|---|---|---|---|---|
| $CO_2$ avoided (kg/litre diesel fuel) | 2.28 | 1.46/1.58 | 1.34-0.51 | 2.35 | 2.36 |

*Notes*

1. The higher figure (1.58) is for when straw is used for grain drying and processing heat.

## 3.6 Further impacts of the biodiesel system

### 3.6.1 Soil erosion

The activites of intensive agriculture tend to leave the soil exposed, reduce the structured stability of the soil and so accelerate soil erosion. This has been exacerbated by the conversion of permanent pasture to arable (such as on the Downs), the increasing areas of maize production (in Europe) and the removal of field boundaries. These however are general impacts of intensive agriculture and not oilseed rape in particular.

Organic practices including rotation with grass leys, green manuring and undersowing of crops such as maize can make significant contribution to reducing the rate of erosion.

### 3.6.2 Land use

The Federal Environment Agency in Germany (UBA, 1993) concluded that rape production has a greater environmental impact compared to permanantly abandoned land, extensification or afforestation. The Commission of European Communities (1994a) point out that in the EU energy crops are only considered economically viable when grown on set-aside, which is land previously used for cultivation, and that extensification is only contemplated in areas where soil resources are already highly depleted or recording high levels of pesticides.

More land is required to produce biodiesel than fossil diesel. No figures exist on the land requirement for oil refineries. However, the approximate area of land necessary to produce rapeseed to substitute 1994 diesel consumption levels can be calculated.

The UK consumption of diesel in 1994 was 20,404 Mt, equivalent to 21,425 Mt of biodiesel which has a 5% lower calorific value. To subsitute total UK diesel consumption with UK produced biodiesel would require approximately 23,890 million hectares of land, ie almost 10% of the UK land mass which amounts to 244,020 sq km.

### 3.6.3 Biodiversity

Intensive farming is linked to a decline in biological diversity (for example, see Green 1985; Adams, 1989). If biomass is cultivated on areas of natural fallow land, renaissance of ousted species through natural regeneration may be barred. Further decline in biodiversity is probable through cultivation on permanent fallow land.

### 3.6.4 Aesthetics of rape cultivation

The expansion in areas growing oilseed rape has changed the appearance of the countryside. No literature has been found on public perception of yellow rape fields, which may or may not be unpopular aesthetically.

### 3.6.5 Bees

The intensification of cultivation of cereal crops has reduced the availability of flowering plants to bees and reduced the population of some species such as bumblebees (*Bombus* sp.). The increase in acreage of oilseed rape has reversed this trend to some extent as bees are attracted to oilseed rape due to the large quantities of nectar and pollen it produces. However, the applications of pesticides are potentially detrimental, especially as effective spraying times coincide with peak foraging times.

### 3.6.6 Deer and hares

In the 1980s, wild deer were reported to behave abnormally in rapeseed growing areas. The problem appears to have been associated with the S-methylcysteix sulphoxide content - a danger associated with most Brassica crops, not just oilseed rape. A condition known as the European Brown Hare Syndrome (EBHS), where hares died of acute liver dystrophy, was at first associated with oilseed rape. However, it is now attributed to a virus rather than the rapeseed crop (Marquard & Walker, 1995).

### 3.6.7 Human Allergy

The cultivation of oilseed rape is associated with complaints of allergic reactions such as headaches, respiratory problems and eye irritation. Soutar *et al.* (1994), quoted in Marquard & Walker (1995), found that there were small numbers of allergic symptoms attributable to oilseed rape locally and that compounds released by oilseed rape would contribute to the overall irritancy of air in country districts, but not necessarily disproportionately, in comparison to other known allergies, such as grass or tree pollen.

## 3.7 The sources of the environmental impact of fossil diesel production and consumption

### 3.7.1 Exploration and extraction

Non-gaseous emissions to the environment during the exploration and extraction of oil include the following (Gover *et al.*, 1996):

- Heavy metals, toxic compounds & oil in produced water - produced water being defined as all water separated at the platform by primary processing from well fluids.
- Chlorine in cooling water
- Contaminated ballast water
- Emulsified oil in deck drainage water
- Linear alpha olophins (LAOs), Poly alpha olophins (PAOs) in drilling fluids & cuttings
- Discharge of chemicals in well completion & workover fluids
- Oil spills at offshore platforms
- Oil spills from tankers

Gaseous emissions to the environment include methane, unburnt hydrocarbons, carbon dioxide, other combustion products, and fire fighting chemicals.

### 3.7.2 Refining

Refinery operations emit $CO_2$, CO, NOx, HC, $SO_2$. The major sources are:

- boilers and process heaters
- fluid catalytic crackers
- vacuum distillation units
- blowdown systems
- sulphur recovery
- fugitive/evaporative losses

(US Environmental Protection Agency 1985, quoted in Gover *et al.,* 1996)

Section 4.9 explains the environmental and health impacts of these different gases. Table 3.6 compares the quantities of these gases emitted when biodiesel and fossil diesel are burnt.

## 3.8 Comparison in biodegrability and toxicity of biodiesel and diesel

### 3.8.1 Biodegradability

Biodiesel is biodegradable. This means that the substance is broken down by micro-organisms. Being biodegradable, does not however make a substance completely harmless. High concentrations of nutrients in water raises the biological oxygen demand, thus depleting the water and its fauna of oxygen, so a very large scale spill may still cause problems.

However a recent study for MAFF by the Centre for Aquatic Plant Management (Birchall *et al.*, 1996) found that biodiesel enters the water body faster than mineral diesel. Biodiesel was found to degrade faster than mineral diesel as it forms lower levels of intermediate compounds in its degradation to $CO_2$. This, along with the globular distribution of the biodiesel on the water surface results in less interference with oxygen diffusion into the water and with surface breathing or moving invertebrates, as compared with uniform 'slicks' produced by fossil diesel.

### 3.8.2 Toxicity

Tests by Procter and Gamble (quoted in National Soyabean Development Board, 1994) on rats show biodiesel to be 'practically non-toxic' and the Centre for Aquatic Plant Management found that biodiesel has a 'significantly' lower degree of toxicity towards most of the algae, macrophytes and animals tested, than fossil diesel. However it was found that some toxic effect exists and that this may be enough to allow shifts in balance and diversity of aquatic species, especially where contamination is severe. The report concludes that overall biodiesel does appear to offer considerable environmental advantage over fossil diesel as a boat fuel (Birchall *et al.*, 1996).

## 3.9 Comparison of air emissions through the combustion of biodiesel and fossil diesel

Fuel emissions from vehicles have health and environmental impacts. The changes in emissions resulting from use of biodiesel in place of fossil diesel are shown in Table 3.6. The figures show a wide range of estimates from trials in Germany, France and the UK. The variations in results could be attributed to whether or not a catalyic converter was used and the load, speed and condition of the engines involved. The large variability in test results suggests the need for a large scale (i.e. statistically valid) study to systematically examine the emissions from the use of biodiesel and to understand why some vehicles give such different results than others (Holman, 1994). In the UK, an 18 month series of alternative fuels trials sponsored by the DoE, MAFF, DTI and DoT and managed by ETSU will have been completed by the end of 1996.

It is worth considering that if biodiesel can find non-fuel industrial markets and so is not combusted, its performance over its life-cycle may improve.

### 3.9.1 Carbon monoxide

Carbon monoxide is a toxic gas that combines with haemaglobin in the blood more readily than oxygen and thus reduces the blood's capacity to transport oxygen. Table 3.6 shows that there is a substantial reduction in carbon monoxide emissions when using biodiesel in place of fossil diesel.

### 3.9.2 Nitrogen oxides

The oxides of nitrogen are implicated in a number of health and environmental problems, including global warming (Houghton, 1992), photochemical smog, acid deposition and damage to vegetation (Quality of Urban Air Review Group, 1993). Trial data from Germany shows increases of 25% and 10% in NOx emission with the use of biodiesel (Krahl *et al.*, 1994). Conversely, Walker & Korbitz (1996) report that two trials in Switzerland and Canada showed a decrease of more than 25% in NOx emissions when timing of fuel injection was delayed. However, these gains are accompanied with slight increases in levels of particulates.

### 3.9.3 Sulphur oxides

Sulphur oxides are important air pollutants due to their impact upon human health, especially in asthmatics (O'Neill, 1993), as well as making a contribution to acid deposition and decay of building materials. However, agriculture has previously received a fertility benefit from anthropogenic sulphur emissions. Their decline in recent years means farmers will have to replace this with fertilisers.

Crude oil naturally contains a proportion of sulphur compounds. They are concentrated in the heavier parts of crude oil, so there are more in the diesel than in the petrol fraction. Vegetable matter has an extremely low sulphur content, so there is nearly a 100% reduction in sulphur oxide emissions compared to fossil diesel (Culshaw & Butler, 1992).

Diesel emissions only account for 1% of national sulphur emissions so substituting biodiesel for fossil would have a negligible impact on a national level. Its use would have a greater impact at an urban level where as according to Quality of Urban Air Review Group (1993) diesel contributes to 14% of sulphur dioxide emissions in London.

European legislation on sulphur emissions (EC Directive 93/12/EEC) is narrowing the gap between biodiesel and fossil diesel as the maximum amount of sulphur permitted in diesel is to be reduced from the current 0.2% to 0.05% by 1 October 1996. This will reduce the environmental advantage that biodiesel has over fossil diesel. However, there may be increased energy consumption and carbon dioxide emissions involved in reducing sulphur levels in fossil diesel. Reformulated 'City Diesel' has a very low sulphur content and costs 4p more than conventional diesel.

**Table 3.6 : Percentage Change in Emissions with the use of RME in relation to fossil diesel**

| NOx | CO | HC | PM | PAH | $CO_2$ | Smoke | Ref |
|---|---|---|---|---|---|---|---|
| -2 | +1 | -13 | -40 | | | | 1 |
| -15 | -10 | -40 | - | | - | | 2 |
| +1 to -16 | -10 to -65 | -12 to +50 | | | | -50 to -57 | 3 |
| -10 | +10 | -10 | +80 | | +5 | -45 | 4 |
| | | | <-67 | | | | 5 |

- Biodiesel emissions reduced relative to fossil diesel emissions

\+ Biodiesel emissions increased relative to fossil diesel emissions

References


1. Ecobilan (1993)
2. Krahl *et al.* (1994)
3. Culshaw & Butler (1992) quote: Long (1991), Austrian Institute of Agricultural Engineering (1991), Federation Francaise de Producteurs d'Oleagineux et Proteagineux (1990), Kock (1992), Wade & Irving (1991), Pachter Hohl (1992)
4. Reading Buses (1993)
5. Morton (1995)


### 3.9.4 Hydrocarbons and other organic compounds (including aldehydes)

Organic compounds are of concern due to their direct toxicity to some species, their role in atmospheric photochemistry and impact upon global warming (Quality of Urban Air Review Group, 1993). Results of trials show a general reduction in hydrocarbons (see Table 3.6) and possibly aldehydes (Levy, 1993, quoted in Holman, 1994) when biodiesel is used in the place of diesel.

### 3.9.5 Smoke and particulates

Diesel engines emit larger quantities of particulate matter than petrol engines. These are of concern due to their possible carcinogenicity and probable impact upon global warming. Concentrations of fine particulate matter (PM10), to which vehicle-emitted particles contribute substantially, correlate with human mortality and respiratory morbidity (Quality of Urban Air Review Group, 1993). Smoke is a visual nuisance. Table 3.6 suggests a reduction in particulates and smoke through use of RME.

## 3.10 Life Cycle Analysis (LCA)

A full Life Cycle Analysis (LCA) is beyond the scope of this study. LCAs have recently been carried out by ETSU for the UK government (Gover *et al.*, 1996) and VITO in Belgium, supported by the European Commission DGXII (Spirinckx & Ceuterick, 1996). An LCA of soya methyl ester (SME) is currently being carried out in the USA by the US Department of Agriculture. With regard to air emissions, it is important to emphasise that a LCA considers emissions over the life-cycle. Therefore, whilst biodiesel may have improved emissions over fossil diesel from combustion, the emissions of that particular gas over the whole life-cycle may be worse. This may be the case with $SO_2$ (ETSU, 1994). Policymakers seeking to reduce sulphur levels in urban areas, may consider a strategy that utilises a low-sulphur fuel like biodiesel (or City Diesel) even if that means using a fuel with higher life-cycle emissions than the fuel being substituted.

### 3.10.1 ETSU study

Gover *et al.* (1996) compare fossil and alternative fuels including biodiesel on a life-cycle basis, taking into consideration the energy use and emissions associated with their production, distribution and end-use in vehicles. Table 3.7 shows a comparison of life-cycle energy use and emissions for fossil diesel and biodiesel.

**Table 3.7: Life-cycle energy use and emissions for fossil diesel and biodiesel**

| | | Energy MJ/km | $CO_2$ g/km | CO g/km | HC g/km | NOx g/km | $SO_2$ g/km | PM g/km |
|---|---|---|---|---|---|---|---|---|
| RME | Car | 1.6 | 59 | 0.5 | 0.4 | 1.1 | 0.2 | 0.2 |
| Diesel | Car | 2.3 | 154 | 0.4 | 0.3 | 0.7 | 0.1 | 0.2 |
| RME | LGV | 3.1 | 114 | 1.4 | 0.8 | 2.3 | 0.4 | 0.3 |
| Diesel | LGV | 4.5 | 295 | 1.4 | 0.7 | 1.5 | 0.3 | 0.2 |
| RME | HGV | 10.0 | 363 | 3.3 | 2.2 | 17.0 | 1.3 | 1.0 |
| Diesel | HGV | 14.3 | 942 | 4.0 | 1.8 | 13.5 | 0.9 | 1.1 |
| RME | Old bus | 13.5 | 489 | 11.6 | 6.5 | 21.0 | 1.7 | 1.4 |
| Diesel | Old bus | 19.3 | 1238 | 16.1 | 6.9 | 16.5 | 1.2 | 1.6 |
| RME | New bus | 10.0 | 376 | 3.5 | 2.2 | 18.3 | 1.3 | 1.0 |
| Diesel | New bus | 14.8 | 977 | 4.3 | 1.8 | 14.5 | 0.9 | 1.1 |

**Source: Gover *et al.*, 1996**

*Notes:*

- HC emissions include methane.
- $SO_2$ emissions assume complete oxidation of fuel sulphur.
- Life cycle energy use per vehicle kilometre assumes an energy balance for biodiesel production of 0.88 GJ/GJ RME (produced from spring rape using natural gas as the process fuel and allowing an energy credit for cattle cake).

The life-cycle energy (MJ) needed per vehicle kilometre for all vehicle categories is lower for RME than for diesel i.e. biodiesel is more efficient.

Life-cycle emissions for biodiesel are lower than diesel for $CO_2$, CO (except in a car) and PM (except LGV).

Life-cycle emissions for biodiesel are higher than fossil diesel for HC (except in old buses and cars), NOx and $SO_2$.

Life-cycle emissions are the same for both fuels for CO (LGV) and PM (Car).

### 3.10.2 VITO study

Spirinckx & Ceuterick (1996) make a comparative LCA of biodiesel and fossil diesel and conclude the following:

- that in the biodiesel life-cycle, the use of fertilisers has an important contribution to the impact categories: inorganic raw material use, landfilled waste production and fossil fuel consumption

- biodiesel's combustion results in important impacts towards the categories: greenhouse effect, acidification, eutrophication and the formation of photochemical oxidants.

- that replacing fossil diesel by an equivalent amount of biodiesel would increase significantly the contribution to the impact categories 'eutrophication and photochemical oxidant formation.

## 3.11 Conclusion

There are a diverse range of environmental impacts for both biodiesel and diesel production and use (see Table 3.11). This study has sought only to highlight impacts associated with the different systems. A full LCA would be needed to quantify these impacts and compare systems.

Whilst there is a lack of corrobarative data, information available indicates that biodiesel has lower emissions than fossil diesel for CO, HC and PM, whilst emissions of NOx can increase (see Table 3.9). In most vehicular uses, life-cycle emissions for biodiesel are lower than those for diesel for $CO_2$, CO and PM, whilst they are greater for HC, NOx and $SO_2$

There are $CO_2$ emissions savings when substituting fossil diesel for biodiesel. Higher $CO_2$ emissions savings are made with woody biomass, although the two crops are not strictly comparable as they would not be competing for the same land or markets.

The clearest environmental advantage that biodiesel has over fossil diesel is in terms of its biodegradability and toxicity characteristics.

**Table 3.11: Environmental impact of biodiesel in comparison to fossil fuels**

| Biodiesel | Fossil diesel |
|---|---|
| **Cultivation** | **Exploration, extraction** |
| *Non-gaseous emissions*<br>Eutrophication of surface waters<br>Water pollution by pesticides<br>Ground water pollution with nitrates<br><br>*Gaseous emissions*<br>Negative $N_20$ balance<br><br>*Mining impacts in production of fertilisers*<br>*Possible allergies* | *Non-gaseous emissions*<br>Heavy metals, toxic compounds & oil in produced water<br>Chlorine in cooling water<br>Contaminated ballast water<br>Emulsified oil in deck drainage water<br>LEOs, PEOs in drilling fluids & cuttings<br>Discharge of chemicals in well completion & workover fluids<br>Oil spills at offshore platforms<br>Oil spills from tankers<br>*Gaseous emissions*<br>Methane, unburnt hydrocarbons, carbon dioxide, other combustion products, and fire fighting chemicals during exploration<br>Emissions $CO_2$, CO, NOx, HC, $SO_2$, $CH_4$ in refining |
| **Combustion** | **Combustion** |
| Lower particulates, $SO_2$<br>Downward trend with CO, HC<br>Higher NOx<br>Better biodegrability<br>Lower toxicity | |
| **Life cycle** | |
| Lower emissions for $CO_2$, CO, PM<br>Greater emissions for HC, NOx, $SO_2$<br>Increase significantly the contribution to the impact categories 'euthrophication and photochemical oxidant formation'. | |

# 4 FUEL MARKETS FOR BIODIESEL

This chapter considers the potential fuel markets for biodiesel. Consultations were made amongst trade and industry associations, private companies, government agencies and regulatory bodies in order to identify as many niche fuel markets for biodiesel as possible. Large volume markets are also considered.

## 4.1 Niche markets

### 4.1.1 Boats

#### 4.1.1.1 Consultations

A range of organisations were consulted. They are listed below.

**The Royal Yacht Association (RYA)** - The UK national authority for recreational boating. The organisation has 1,500 affiliated clubs with a membership of about 400,000 and 80,000 personal members.

**The Yacht Charter Association (YCA)** - This association campaigns for safety in recreational boating in the UK. It has a membership of 85 charter companies throughout the world.

**The National Association of Boat Owners (NABO)** - This is a lobbying organisation representing the interests of 2,500 boat owners on UK inland waterways.

**The British Marine Industry Federation (BMIF)** - This is the trade association for the UK boating industry. Its members are involved in boat building, marine equipment manufacture, yacht brokerage, marine operation and holiday hire fleets.

**Holiday boat companies**

**London Port Authority**

**British Waterways (BW)** - This organisation manages over 3000 km of navigable waterways and is the owner of the majority of UK's canals.

**The National Rivers Authority (NRA)** - This is the UK regulatory authority for rivers. Since 1 March 1996 the NRA's operations have been incorporated into the newly established Environment Agency.

#### 4.1.1.2 Total Market Size

Coastal (excluding fishing and oil exploration) and inland boat consumption of diesel amounted to 348,883 t in 1994. This was a reduction in comparison to the 1990 figure of 434,592 t (Institute of Petroleum, 1995).

In terms of number of craft, the RYA estimate that 200,000 recreational boats have a diesel engine in UK inland and coastal waters (Robin Sjoberg, RYA, pers comm., 1996). British Waterways estimate that in 1994/95 there were almost 21,000 powered private pleasure boats licensed and over 1,500 powered hire craft on canals and rivers in the UK. The proportion that could use gas oil is not known (Paul Beckwith, British Waterways, pers. comm., 1996), although all weekly hire boats on the broads run on diesel. The Yacht Charter Association estimate that there are 4,600 charter boats in the UK, probably running for 8 weeks per year, consuming 68.19 litres of diesel per week. This gives an approximate figure for total annual diesel consumption of 25,116 t. Yachts chartered for holiday makers are used for sailing and therefore fuel represents a small proportion of the overall cost of hire.

#### 4.1.1.3 Regulations and Guidelines

There is no specific environmental regulation to promote biodiesel usage on UK waterways. Some general regulations and guidelines are however in place and may be of relevance.

These are listed below.

- It is an offence under the Water Resources Act 1991 to cause or knowingly permit any poisonous, noxious or polluting matter (such as diesel) or any solid matter to enter any controlled waters.

- The British Waterways Code for Boaters (1995) relates to best refuelling practice.

- The British Waterways/NRA Boat Safety Scheme (1995) sets standards for safe practice, including the use of inboard and outboard and portable engines. The standards are legally enforceable by the navigation authorities through local Acts, or bylaws. Examples are the British Waterways Act 1995 and the Thames Navigation Licensing and General Bylaws 1993.

- National Rivers Authority Pollution Prevention Guidelines: Inland Waterways Marinas and Craft (1995).

- British Waterways Bylaws (1991) may apply to the use of fuel (section 39, Nuisance; section 40, thowing of rubbish into a canal; section 8, storage of inflammable spirit intended for use of vessel).

#### 4.1.1.4 Potential for biodiesel as a boat fuel

Diesel oil is used to power boats and their heating systems. Boat users are eligible to purchase diesel/gas oil in the low tax bracket as they are 'non-road' users. This fact may suggest that the prospect for biodiesel as a fuel for boats is poor as it is unlikely to be priced competitively with red diesel. Indeed, the National Association of Boat-Owners expressed the fear that the promotion of biodiesel may indirectly affect the present arrangement whereby boat users are allowed to consume diesel at the lower "off road" tax rate. Boat users may therefore be reluctant to support the use of biodiesel. However, environmental legislation has promoted biodiesel use in inland waterways in the Netherlands (Agence de l'Environnement et de la Maitrise de l'Energie, 1996) and the national biodiesel marketing organisation in the United States foresees substantial uptake of biodiesel by recreational boat owners on inland and coastal waters (National Soyabean Development Board, 1994). Biodiesel is sold to boat users in these countries because of its biodegradability and non-toxicity. In the UK, the Yacht Charter Association consider that biodiesel's odourless nature and high flash point would be an advantage in its use on yachts, and would welcome information of biodiesel for inclusion in its newsletter.

Within the UK, the NRA regard oil pollution from boats on a national scale as 'commonplace', mostly associated with careless refuelling and pumping out of oily bilges (National Rivers Authority 1995). Twenty-one Category 1 ('serious') and 2 ('significant') incidents were recorded in 1993 and 1994. These incidents do not appear to be uniform in their distribution. For example, pollution is not identified as a significant problem in the Lake District, and more specifically it has been noted that there are 'surprisingly few incidents involving diesel' in this area. In addition the Port of London Authority does not perceive diesel pollution as a serious problem. The body perceives that spills forming a thin layer on the water's surface look worse than they are. Diesel is used by water companies for stand-by generators, for example when major installations have power failure. However, Southern Water do not perceive a problem with water pollution and so are unlikely to consider the use of biodiesel, especially if the price is higher. Despite this, any alternative that poses a lower threat to the environment is to be 'welcomed'. (Wiggins, NRA, pers comm., 1996), and British Waterways stated that they would be prepared to encourage the use of biodiesel in accordance with their policy on the environment, although any increase in use would have to be achieved through consensus with boat owners, and not by enforcement.

#### 4.1.1.5 Conclusions

Boat-users are entitled to purchase diesel in the lower tax bracket, and therefore it is unlikely that, even if biodiesel is taxed at a lower rate than fossil diesel, it will be attractive to boat users, unless it is perceived to have some additional benefit, or its use is encouraged via legislation. There does not seem to be a strong environmental push for use of biodiesel, although the NRA are considering using it. Use of biodiesel in yachts appears to be an attractive option, as the odourless nature and high flash point would be advantageous, and as yachts are chartered primarily for sailing, fuel represents a small proportion of the overall cost of hire.

### 4.1.2 Timber, paper and pulp

The timber, paper and pulp industries consume approximately 55 Mt of gas oil annually. No figures exist for DERV consumption. Diesel is used in this sector to fuel timber harvesters and forwarders as well as forklift trucks in warehouses.

The largest forestry operators in the UK are Forest Enterprise, the managers of the Forestry Commission forests. The organisation does not have an all embracing policy statement on working in an environmentally friendly manner during timber harvesting operations. Its policy is to observe best industry practice as promulgated in Forestry Authority management guidelines, for example by refuelling and maintaining machinery well away from watercourses and guarding against spillage. Consequently, there is no existing demand for biodiesel in this sector.

Private contractors, however, may feel that the use of a biodegradable fuel such as biodiesel would act as a further insurance against environmental damage.

### 4.1.3 Construction and tunnelling

#### 4.1.3.1 Background

Construction companies use diesel fuel for a range of 'indoor' operations including tunnelling and excavation. Gas oil fuels mobile and static plant on construction sites. The main equipment consists of excavators, forklift trucks, telescopic handles (cranes), crawler cranes, generators (up to 170 kilo volt amps) and compressors. Plant is used in confined spaces in the following applications: small forklifts and excavators inside buildings and car parks; access platforms (including scissor lift devices); heaters used to dry out buildings during construction (e.g. layers of plaster).

The products from quarries are transported in HGV vehicles fuelled by DERV. DERV is also used to fuel vehicles delivering plant and materials, and removing waste. Normally quarry products have a market within 30-50 miles, with longer journeys being made by rail and sea.

#### 4.1.3.2 Environmental factors

Demolition and construction sites were involved in 16% of all pollution incidents in the Anglian, South Western and Thames Regions of the NRA in 1993/94. Causes included unbunded and leaking tanks, movement of tanks still containing oil, use of poorly situated and/or overfilled bowsers and careless refuelling (NRA, 1995). Water courses can also be contaminated through release of oil during refilling and delivery and leakage of oil from container tanks. Oil can leak from plant machinery itself. Lubricant oil can leak from wheel bearings and the gear box. If a construction company is working near a water course, it is common for the contract to contain penalty clauses for contamination of the course.

#### 4.1.3.3 Fuel Cost

According to major contractor John Laing, gas oil represents approximately 1% of total costs in a building contract. This figure is based on the following:

Medium crawler crane using 6 litres/hour, 50 hours per week.

300 litres at 11p/l = £50 per week. This figure is less than 5% of cost of using equipment and operator. Depending on how capital intensive the project is (i.e. how much machinery is used in relation to labour), plant use may represent 30% of the total contract cost.

As gas oil represents a relatively small proportion of the total costs of building, the attractiveness of biodiesel may be dependent on the structure of the NRA's penalty payments.

### 4.1.4 Mining

#### 4.1.4.1 Background Information

There are currently 19 underground mines operating in the UK. They are all privately owned. Most are owned by three companies namely, R J Budge (in England), Celtic Energy (in Wales) and Mining Scotland.

The size of the gas oil market in UK mining (including open cast) has remained constant over the last five years at over 300,000 tonnes per annum (Institute of Petroleum, 1995). This figure is likely to contract as deep mines close.

Diesel is used to power vehicles which transport men, equipment and consumables to and from faces and headings (Good, ETSU, pers. comm., 1996).

In order to reduce the possible health risk to its underground workhorse, British Coal adopted a purchasing policy which discriminated against diesel powered locomotives and rubber tyred free steered vehicles (FSVs). This policy has been continued by R J Budge (Fox, R J Budge, pers. comm., 1996).

It has yet to be seen whether battery powered alternatives are therefore used where technically feasible, such as where gradients are not too steep and digging is not too arduous for the energy storage capacity of a battery powered machine. Battery operated locomotives have undertaken the majority of locomotive duties. FSVs operate under more adverse conditions than locomotives and so it is likely that a large number of diesel powered FSVs will remain in service and many new ones will be introduced (Morton, 1995).

In 1992, the total holding of diesel powered equipment was 200 locomotive and 320 FSVs for underground use.

A variety of power units are in use, both of the direct and indirect fuel injection types, in the power range 33 to 112 kW. The most recent equipment, and that most likely to be retained in the contracting industry, is of the indirect injection type.

#### 4.1.4.2 Regulations

Diesel engines used in mines are subject to regulations governing emissions of toxic gaseous compounds such as carbon monoxide and oxides of nitrogen. British Standard BS 6680.1985 specifies that new engines for use in diesel powered vehicles equating to a requirement that CO must not exceed 1500ppm and NOx must not exceed 1000ppm at any point in the engine's operating range. Only CO and NOx emissions are specified in the Standard (Morton, HSCE Ltd, pers. comm., 1995). Some countries also specify a smoke limit, usually around 3 on the Bosch smoke number system.

There are no regulations for particulate emissions from the raw exhaust of mining diesel engines or guidance as to what constitutes a feasible and safe exposure limit for diesel particulate matter (DPM) although this may have to be addressed in the near future to comply with COSHH Regulations (RJ Budge, pers. comm., 1996). Canada has limits for respiratory combustible dust which include oil mist, engine breathers and emissions. Germany has limits for non-coal mines, while the US presently has none.

#### 4.1.4.3 Potential for biodiesel

The British Coal Corporation have carried out trials with biodiesel. The trials have shown reduction in particulate emissions by up to 67%, but with some power loss. Further trials to optimise fuel system setting did not recover the power. Workers underground did not raise any objection to the odour. Biodiesel from two different sources was found to produce different emission levels and power outputs. It is therefore desirable that tests are done with standard formulations. Nevertheless, taking into account the results found and the fact that fuel costs represent a tiny fraction of overall operating mining costs (it is estimated that fuel represents 1p per tonne of mined coal (Alan Good, ETSU, per. comm., 1995), in the absence of a satisfactory filtering system for particulates from diesel, biodiesel may provide an effective and practical control measure (Morton, 1995).

### 4.1.5 Open cast mining

The main health and safety concern with regards to diesel fuel in open cast mining is transfer of diesel from bowser to unit. Spillage of diesel during the handling of the equipment can cause skin ailments. Providing the equipment is well maintained e.g. the fuel injectors are serviced, diesel is not perceived as a health and safety problem in open spaces where the smoke is dispersed. There are no confined spaces in which diesel machinery is used (Slaughter, pers. comm., 1996).

### 4.1.6 Golf

No figures exist on diesel and gas oil usage by golf clubs in the UK.

The majority of golf clubs are member owned although an increasing number are proprietor owned. Golf clubs use gas oil for most machinery. A golf course will usually have 2 or 3 agricultural tractors and 6 ride-on mowers. Chainsaws, fly-mos and strimmers run on petrol. There is a greater incentive to use diesel, as petrol is not delivered in small quantities by the companies and so has to be collected by course staff, which contravenes health and safety regulations on transport of fuel. Volumes of diesel use are higher during the summer when mowers are used every day as opposed to 2-3 times a week during winter. Diesel is stored in tanks on courses. The tanks are usually unbunded and subject to vandalism (James Albutt, pers. comm., 1996).

### 4.1.7 Airports

No figures exist on diesel and gas oil usage by airlines and airports in the UK.

The British Airports Authority (BAA) are presently consulting companies that have vehicles at UK airports about the type of fuel they use. BAA intend to phase out the use of petrol engines from British airports, although US companies favour it over diesel. Biodiesel is not, however, considered to be one of the alternative options.

BAA have a short term strategy to encourage the use of reformulated diesel and bring vehicles in line with Euro 2 (by 1996). Its long-term strategy is to convert fleets to near 100% electric power and over the longer term consider fuel cells. Electricity is a favoured option because of the safety concerns with respect to the close proximity of many vehicles (Steve Plent, BAA, pers. comm., 1995).

### 4.1.8 Ski resorts

Biodiesel is marketed in Austria for use in tractors and ski machinery in the Alps. Additives and fractionation technology is being developed by lubricant companies at the Agricultural Engineering Institute in Austria to lower the temperature at which biodiesel will perform.

In the UK, the Nevis range ski development consumes 10 t of diesel per annum. The machines using diesel include Drive 3 Kassbhorer tracked vehicles, one drag lift and a generator. All other plant are electric powered. The diesel distribution system is a sealed system between two storage tanks. If handling was a problem, then the biodegradability quality would be attractive to Nevis (Baird, pers.comm., 1996). Diesel consumption represents a 'small' part of the company's operating costs (Baird, Nevis Range, pers.comm., 1996). However there are no known reports of diesel pollution from ski resorts (Scottish Water Purification Board, pers. comm., 1995)

### 4.1.9 Agriculture

The agricultural sector consumed 6.4 Mt of gas oil in 1994. This is a slight fall from the 6.62 Mt consumed in 1990. In France and Austria where biodiesel price is at a similar level to fossil diesel, producers such as Elf Antar (in France) and Ohmule-Bruck (in Austria) especially market their biodiesel to farmers. Although some farmers appear to be supportive of the use of biodiesel in Agriculture, (see Chapter 5) even with a favourable taxation policy it is unlikely to be competitive with gas oil.

### 4.1.10 Fire Brigade

The Fire Service Training College use diesel for training fire fighters. Whilst LPG can be used to simulate diesel fires, the College prefers using 'the real thing'. It is interested in using a fuel that has lower soot and noxious emissions and is planning trials with RME. It consumes approximately 8 tonnes per year (Fire Service College, pers. comm., 1995).

### 4.1.11 Armed Forces

Biodiesel may be attractive to the Armed Forces because of the use of plant and vehicles indoors and the safety value of the fuel's high flash point. In Wisconsin, USA, a military base intends to use a blended biodiesel in its heavy-duty vehicles (National Biodiesel Board, no date).

In 1995, the UK based Armed Forces consumed 109,058 t of gas oil. No figures exist for its use of automotive diesel.

### 4.1.12 Conclusion for niche markets

In most smaller volume 'niche' markets, biodiesel must compete with gas oil, a fuel that is subject to very low taxation. Even tax free it would be difficult for biodiesel to compete with gas oil in terms of price. However, in some markets, particularly where fuel represents a small proportion of total operating costs, biodiesel may be attractive, for example in sailing boats, the construction industry and in mining operations. Environmental factors are important to most of the sectors studied, and it is likely that biodiesel will be marketed on the basis of its 'environmentally friendly' properties. However, it should be noted that for the leisure boating industry, there are laws and regulations in place that are seen by the authorities to sufficiently protect the waterways without the need to reglate for the compulsory use of biodiesel. Other industries such as forestry, mining and construction have developed health and safety regulations and 'best practices' for fuel usage and so see the environment as sufficiently protected. It is unlikely therefore that industry will pay a large premium for biodiesel, a fuel that is providing a solution (i.e. biodegradability and non-toxicity) to a problem that industry feels is already taken care of. However, it is possible that some companies may use biodiesel to improve their environmental image i.e. as a marketing tool. The market survey in Chapter 7 will analyse this potential demand.

## 4.2 Large Volume Users

The consumption of diesel by the remaining sectors surveyed may not fall into the category of 'niche' usage. However, the companies and local authorities are large volume users of DERV, possess strong purchasing power and potentially have environmental policies that include the use of alternative fuels. In France, biodiesel is sold as a blend to large volume users such as bus companies. It is therefore worth analysing these markets to evaluate the potential for the UK biodiesel industry to follow a similar strategy.

### 4.2.1 Buses

Biodiesel is used in blends with fossil diesel by bus companies in the USA and France. In the US, the market for biodiesel has been created by environmental regulation. In France, tax exemptions have given biodiesel equal retail price status to fossil diesel.

In the USA, the consumption of diesel by the urban bus sector was regulated as a result of the Clean Air Act Amendment of 1990. Approximately 80% of the country's 58,000 mass transit buses are subject to this rule which aimed to reduce particulate exhaust emissions from 1995, if technology is certified and affordable. The rule only pertains to particulate matter reductions, the category of pollution in which biodiesel attains reductions due to its low sulphur content (Howell & Weber, 1995).

In France, the main producers of biodiesel (Diester Industrie) market their product to local authorities who use it in their buses in a blend of 1-30%. Diester have established a 'club' of local authorities called Club des Villes Diester to exchange information and generate interest in the fuel's use. Club des Villes has a strong associate membership, including Elf Antar France, Total, Shell, Renault V.L. and the government environment and energy agency ADEME. Diester report that 10,000 buses now use biodiesel (Diester, 1996).

In the UK in 1994, the bus sector consumed 389,847 t of automotive diesel. The sector's consumption of the fuel has risen each year for the last five years.

The tax rebate that bus companies receive is fixed and not does encourage the use of more expensive alternative fuel such as biodiesel. Bus companies receive a tax rebate of 25p/l. It is set at the same rate for fossil diesel or biodiesel (see Table 4.1).

**Table 4.1 : Tax rebate (p/litre) for UK bus companies**

| | Diesel | Biodiesel |
|---|---|---|
| Retail net cost (excluding VAT) | 12 | 45 |
| Tax | 34.3 | 34.3 |
| Net total | **46.3** | **79.3** |
| Rebate | 25 | 25 |
| Net cost | **21.3** | **54.3** |

**Source : Reading Buses**

The only regulation that may favour the adoption of biodiesel by bus companies in the UK is that on engine emissions. The EC set baseline values for emission levels in 1988, to be reduced further in 1996 and 1999 as a result of new European Directives (93/12/EEC). The three stages (Euro 1, Euro 2 and Euro 3) specify progressively lower limits for emission pollutants and particulates.

Current levels of sulphur in diesel (about 0.2% by volume) contribute to heavy duty particulate emissions. This will allow engine designers to meet the most stringent standards. However, the mandatory limit on sulphur is set to be reduced to a maximum of 0.05% by 1 October 1996 (Cahm, 1995).

Another way to reduce emissions is to use biodiesel. Reading Buses, Kentish Bus and Maidstone and District have all tested the use of biodiesel. Reading Buses had favourable results with respect to particulate and smoke reductions. However, NOx emissions increased (Reading Buses, 1993).

### 4.2.2 Haulage & Delivery

DERV is used in this sector to fuel vans and HGVs, while gas oil is used to power refrigeration units in trailers that distribute food and in warehouses that process and store food. Automotive diesel consumption for light vans and HGVs in the period 1988 to 1994 increased from 8.52 Mt to 8.91 Mt. There are no figures available for gas oil consumption in this sector.

#### 4.2.2.1 Royal Mail

Royal Mail (RM) currently use 13,000 diesel engined light vans. It believes that diesel currently represents the best value, both in money and environmental terms, as a large fleet fuel source. However, as part of its environmental strategy, RM are looking in the medium term at a range of fuel options that include biodiesel, LPG, electricity, solar, hybrids and City Diesel.

RM perceive two problems for vehicle operators associated with testing RME. One is the availability of data appropriate to the smaller delivery vehicles. The other is the very high cost of exhaust emission analysis. To minimise the cost, RM is entering into partnerships with manufacturers and suppliers whereby both parties contribute and share the resulting project data. In conjunction with Ford, RM is undertaking a 30,000 km trial on the use of RME in both Escort and Transit vans used for urban delivery. The same vehicles are being used in the government sponsored trials of alternative fuels (Royal Mail, 1995).

#### 4.2.2.2 Food Processing

Forklift trucks powered by diesel present several problems in food processing: the trucks' cooling fan throws up dust from the factory floor that may be deposited on the food; oily particulate emissions block condensers in the factory and spillages occur through pipe leakages and hydraulic oil bursts. More sensitive fresh produce such as salads may not withstand this environment and show signs of contamination from fuel emissions. Consequently supermarkets prefer food to be processed in diesel free environments and forklifts may be electrically powered.

### 4.2.3 Electricity Utilities

There are 8 UK electricity utilities whose potential uses for biodiesel include vehicle fleets and plant.

### 4.2.4 Railways

There are 36 private UK rail companies. Potential uses for biodiesel in this sector include companies vehicle fleets, locomotive diesel engines and engineering plant.

### 4.2.5 Waste Management

Potential uses include truck and auxiliary fleets.

### 4.2.6 Car Manufacture

Car manufacturing companies have transport and auxiliary fleets which may run on diesel.

### 4.2.7 Local Government

Local authorities have vehicle fleets which may run on diesel.

## 4.4 Conclusion for large scale use

The structure of diesel tax relief for buses does not encourage the use of alternative fuels. It is therefore unlikely that bus companies will pay a high premium for biodiesel. The emissions advantage of biodiesel (low sulphur emissions) over fossil diesel is being reduced as EU emissions levels for conventional levels are tightened. However, the market survey in Chapter 5 will show whether bus companies and other large volume users may be willing to pay a lower price such as that offered by a blend strategy.

# 5 SURVEY OF FUEL MARKETS FOR BIODIESEL

## 5.1 The Survey

Almost 400 potential consumers of biodiesel (the 'sample') were identified. It was perceived probable that many companies might not know what biodiesel was. It was felt that a questionnaire approach would introduce people to the fuel - a task more difficult in a telephone survey. The questionnaires were sent to 17 different types of organisations. In the case of railways, boating organisations, electricity utilities and mining, all known companies were surveyed. In other sectors the companies selected represented only a sample of their respective industries. Questionnaires were sent to fuel purchasing managers or marketing executives.

## 5.2 The questionnaire

The questionnaire consisted of a one page introduction to the research project and the properties of biodiesel as a fuel, followed by 11 questions (see Appendix 1).

### 5.2.1 The response rate

From the sample of 395, one hundred and four (26.3%) questionnaires were returned.

### 5.2.2 The responses to individual questions

1. *With which areas are the main activities of your business concerned?*
   (Appendix 2, Table 1)

2. *Does the company have an environmental policy?*
   (Appendix 2, Table 2)

The purpose of this question was to ascertain whether the sample questioned had an environmental profile and have considered the environmental impact of their operations.

Eighty one respondents said they did have an environmental policy. Twenty four did not.

The responses indicate that companies and local authorities have considered the environmental impact of their operations, though this does not necessarily mean they will pay a premium for fuels they consider less damaging to the environment.

3. *How many litres of diesel fuel does your company/council consume per year*

In order to give an estimate of the minimum size of the potential fuel market for biodiesel, the respondent was asked for the size of diesel consumption (litres per year) within eight ranges from 'Under 1,000' to 'Over 5 million'. These figures are discussed in section 5.3 and figures for each sector shown in Appendix 2 (Tables 7-11).

4. *What proportion of the diesel used is Automotive Diesel (DERV fuel) or Gas Oil (dyed red)?*

Respondents were asked for the percentage of their diesel consumption that was DERV and gas oil. The two fuels are taxed differently and therefore have different prices, an essential consideration for any competitor such as biodiesel. The minimum size of consumption of potential biodiesel users is divided into automotive diesel and gas oil in the breakdown for each sector (see Tables 7-11 Appendix 2).

5. *Where do you currently buy your fuel?*

To give an indication to potential biodiesel producers of how diesel fuel is distributed to existing consumers of diesel, the respondents were asked how they buy their fuel. The majority received their fuel in bulk deliveries (Appendix 2, Table 3).

6. *Had you heard of biodiesel before receiving this questionnaire?*
   (Appendix 2, Table 4)

Eighty one respondents had heard of biodiesel. 24 had not.

7. *Have you previously explored the use of biodiesel, what was the outcome and why?*
   (Appendix 2, Table 5)

19 respondents had previously explored the use of biodiesel. 86 had not. Thirteen respondents said the cost was too prohibitive, 4 were concerned about availability of fuel supply, 3 about whether manufacturers warranted the use of biodiesel, 1 did not like the smell of the fuel, 4 questioned biodiesel's life-cycle environmental costs, and 1 (BR Policy Office) said they were currently exploring its use.

8. *The present price for 100% biodiesel is 45p/l (without duty & VAT). Is it likely that your company/council would be prepared to pay this price?*
   (Appendix 2, Tables 6 & 7)

Two respondents said they would be prepared to pay 45p/l for biodiesel. 68 said 'no' and 36 'maybe'.

For 'yes' respondents, this gives a total minimum potential consumption at 45p/l of 20 t for DERV users and 5,080 t for gas oil users.

For 'maybe' respondents, this gives a total minimum potential consumption at 45p/l of 55,642 t for DERV users and 3,528 t for gas oil users.

9. *The present price for a 20% mix of biodiesel with 80% conventional mineral diesel is 21p/l (without duty & VAT). Is it likely that your company/council would be prepared to pay this price?*
(Appendix 2, Tables 9-11).

The French strategy of marketing biodiesel is to blend it with fossil diesel at a rate of between 1-30% biodiesel. This approach aids consumption as it can be easily integrated into conventional fuel consumption, utilising well established distribution networks without any change in consumer behaviour (Staat, Diester Industrie, pers. comm., 1996).

A low blend strategy would be targeted at large volume users, namely bus companies, haulage and delivery and local authorities. These sectors would be looking for environmental benefits without paying a large premium, although it may be unclear how significant the environmental benefits of a 20% biodiesel blend are. Presumably, the impact of a 20% blend versus 100% biodiesel will be dependent on factors such as the number of vehicles using the fuel, and the concentration of those vehicles. It may be the case that companies and local authorities would pay a smaller premium for the green image that the fuel may provide.

In order to ascertain the likelihood of uptake of biodiesel if it were marketed using the French model and to test consumer response to a cheaply produced biodiesel (perhaps achievable through greater economies of scale in production (Walker, 1995)), the respondents were asked if they would pay 21p/l for a blend of 20% with 80% fossil diesel.

Eleven respondents said they would be prepared to pay **21p/l** for a 20% blend of biodiesel and conventional mineral diesel. Forty said 'no' and 58 'maybe'.

For 'yes' respondents, this gives a total minimum potential consumption of 22,315 t for DERV users and 1,400 t for gas oil users.

For 'maybe' respondents, this gives a total minimum potential consumption of 90,124 t for DERV users and 18,853 t for gas oil users.

These responses indicate enough interest to research further the possibility of following this path of marketing biodiesel. In France, the low blend strategy has the co-operation of oil companies, national and local government and engine manufacturers. The same would be needed in the UK if a similar model were to be followed.

*10. Which of the following factors are likely to influence a decision on your use of biodiesel?*

(Appendix 2, Tables 12 & 13)

The purpose of this question was understand what factors were likely to influence a consumer's decision on the use of biodiesel. Such information would also help biodiesel producers to understand consumer concerns over alternative fuels. Respondents ticked the following factors that were suggested as important in influencing a decision on the use of biodiesel: cost (103), engine compatability (65), environmental benefits (78), availability (70), health and safety issues (64), business advantage in using 'green fuel' (55), anticipating changes in regulation (26) (see Appendix 2, Tables 12 & 13 for a breakdown by sector).

*11. Which of the following attributes of biodiesel do you consider attractive about the fuel?*

The purpose of this questions is understand which attributes of biodiesel are most important to each sector. This information would also help biodiesel producers to form marketing strategies. Respondents ticked the following as attributes of biodiesel that they consider very important about the fuel: low particulates (68 respondents), low sulphur content (52), non-toxicity (48), biodegradability (40), safety (high flash point) (36), renewable (33) and neutral carbon balance (22) (see Appendix 2, Tables 14-20 for a sector breakdown).

## 5.3 Sectors surveyed

### 5.3.1 Boats

Eleven companies and associations representing the perceived responses of companies and individual boat owners were approached. The Royal Yacht Associaton (RYA), the National Association of Boat Owners (NABO), a sea container company, a small Thames launch company and a holiday company responded.

The container company with an annual consumption of gas oil of 100-500 tonnes said 'no' to 45p/l and 'maybe' to 21p/l. All factors except 'business advantage' and 'anticipating changes in regulation' were likely to influence a decision on the company purchasing biodiesel.

The RYA based its answers on the perceived response by recreational boat users in the UK. It said 'no' to 45p/l and 'maybe' to 21/l. 'Cost', 'availability', 'environmental benefits' and 'engine compatability were considered to be important factors in influencing boat users purchasing of fuel.

The NABO said 'no' to both prices. 'Cost' and concern over the increased biological oxygen demand (BOD) if biodiesel was spilled and biodiesel's long term storage properties were reasons for not paying the premium on the fuel.

The Thames launch company with an annual consumption of 50-100 t said 'no' to 45p/l and 'yes' to 21p/l. It commented that there was little point in mixing such a small amount of biodegradable fuel and that the current price of biodiesel made it unviable for gas oil users. The factors likely to influence its purchasing decision was 'business advantage in using a 'green fuel'' and 'environmental benefits'.

The holiday company has an annual gas oil consumption of 1,000-5,000 tonnes and was not prepared to pay 45p/l for biodiesel, but said 'yes' to a blend of 21p/l. It had previously explored the use of biodiesel, but had found that it was expensive and caused problems in pumps, pipes and injectors.

Table 5.1 summaries the response of companies in this sector to the question of their willingness to pay a higher price for biodiesel.

**Table 5.1 : Boating organisations' and companies' willingness to pay 45p/l and 21p/l (as a blend) and minimum consumption of DERV and gas oil.**

| | Yes | Potential minimum consumption (tonnes/year) | Maybe | Potential minimum consumption (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0 | 0 | 0 | 5 | 5 |
| Biodiesel blend (20%) at 21p/l | 2 | 1,050 | 2 | 5,100 | 1 | 4 |

The 2 'maybe' respondents at 21p/l had a minimum diesel consumption range of 5,100-5,500 tonnes. The 2 'yes' respondent at this price had a minimum range of 1,050 t.

NABO were concerned about biodiesel storage qualities. A boat with a 40 gallon tank may not be filled over the year and so the organisation was interested to know if the fuel would degrade in this time.

In conclusion coastal (excluding fishing and oil exploration) and inland boat consumption of diesel amounted to 348,883 t in 1994 (Institute of Petroleum 1995). However the survey results indicate that biodiesel is likely to secure only a small proportion of this, with price of the fuel being a key issue.

Cost was not, however, the only factor. Long term storage properties as well as availability were considered to be important. For a boat fuel to be successfully adopted, it is necessary to have a distribution network on UK waterways that meet the needs of the consumer. Biodiesel supply would not have the same economies of scale that diesel supplies have resulting in higher distribution costs.

Regulatory bodies see the encouragement of good practice by boat owners as an essential factor in the protection of UK water courses from spillage of diesel fuel. This code of practice may be enough in the opinion of these bodies to preclude the use biodiesel. However the National Rivers Authority and British Waterways have said they would welcome any alternative that poses a lower threat to the environment.

### 5.3.2 Timber, paper & pulp

18 of the largest UK forestry contractors (selected by the Forestry Contracting Association in Inverness) were contacted. Seven responded.

**Table 5.2 : Timber companies' willingness to pay 45p/l and 21p/l (as a 20% blend) and minimum consumption of DERV and gas oil.**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0/0 | 3 | 168/745 | 4 | 7 |
| Biodiesel blend (20%) at 21p/l | 0 | 0/0 | 5 | 665/935 | 2 | 7 |

The 3 'maybe' respondents at 45p/l had a minimum DERV consumption of 168 t and 745 t of gas oil. The 5 'maybe' respondents at 21p/l had a minimum DERV consumption 665 t and 935 t of gas oil (see Table 5.2). Three contractors said the fuel was too costly.

Twenty five of the largest UK paper and pulp companies were contacted. Five responded.

**Table 5.3 : Paper and pulp companies' willingness to pay 45p/l and 21p/l (as a 20% blend) and minimum consumption of DERV and gas oil.**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0/0 | 1 | 0/1 | 4 | 5 |
| Biodiesel blend (20%) at 21p/l | 0 | 0/0 | 5 | 0/100 | 2 | 7 |

The 1 'maybe' respondent at 45p/l had a minimum DERV consumption of under 1 tonne. The 5 'maybe' respondents at 21p/l had a minimum gas oil consumption of 100 t (see Table 5.3).

The timber, paper and pulp industries consumed 55 Mt of gas oil in 1994. However, the largest forestry operation, Forestry Enterprise were not willing to pay a premium for biodiesel. Although none of the timber companies surveyed gave a 'yes' answer to biodiesel at either 45p or 21 p/l, quite a high proportion gave a 'maybe' response to both prices although the 'maybe' responses represent a small market.

The paper and pulp companies that responded 'maybe' represent a negligible size of market.

### 5.3.3 Construction and tunnelling

Eighty-five companies selected from the *New Civil Engineer* 1995 Contractors File were contacted. Fifteen responded. Table 5.4 summaries their willingness to pay for biodiesel and biodiesel blend priced at 45p and 21 p/litre, respectively.

**Table 5.4 : Construction companies' willingness to pay 45p/l and 21p/l (as a 20% blend) and minimum consumption of DERV and gas oil.**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0/0 | 6 | 2,916/534 | 9 | 15 |
| Biodiesel blend (20%) at 21p/l | 1 | 1,000/0 | 7 | 2,400/4,650 | 7 | 15 |

The 6 'maybe' respondents at 45p/l had a minimum DERV consumption of 2,916 t and 534 t of gas oil. The 7 'maybe' respondents at 21p/l had a minimum DERV consumption of 2,400 t and 4,650 t of gas oil (see Table 5.4). The 1 'yes' response at 21p/l had a minimum consumption of 1,000 t.

In conclusion the estimated consumption of gas oil in the construction industry fell between 1990 and 1994 from 641,000 t to 596,000 t. No figures exist on diesel consumption. More than half of the respondents indicated that they would definitely or would maybe be prepared to pay 21 p/l for a biodiesel blend. As discussed in Chapter 4, actual uptake of the fuel may be influenced by factors such as the NRAs penalty payment scheme.

### 5.3.4 Mining

Out of the 4 respondents 2 companies said they 'may' pay 45p/l and 2 said 'no'. The same response was received for biodiesel blend. Table 5.5 shows the total volume that this represents. The 2 'maybe' respondents at 45p/l had a minimum DERV consumption of 2,050 t and 3,000 t of gas oil. The 2 'maybe' respondents at 21p/l had a minimum DERV consumption of 2,000 t and 3,000 t for gas oil.

**Table 5.5 : Mining companies' willingness to pay 45p/l and 21p/l (as a 20% blend) and minimum consumption of DERV and gas oil.**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0 | 2 | 2,050/3,000 | 2 | 4 |
| Biodiesel blend (20%) at 21p/l | 0 | 0 | 2 | 2,000/3,000 | 2 | 4 |

Chapter 4 indicates that health and safety factors may create an opportunity for biodiesel in this sector. Although fuel costs are a small percentage of the total costs involved in mining, Table 5.5 indicates that cost of the fuel may in fact be a constraint, as none of the respondents said they would definitely be prepared to pay either 45 p/l for biodiesel, or 21 p/l for a blend. Two respondents, however, indicated that they would consider the fuel at both prices. If there was an uptake of the fuel by these companies the potential consumption would be around 5000 t per annum. However, in the long term this figure is likely to contract as deep mines close.

### 5.3.5 Golf

Eighteen greenkeepers at golf clubs in the UK were contacted. None responded. The survey has not therefore established whether any demand for biodiesel from golf clubs exists.

### 5.3.6 Fire Brigade

As indicated in Chapter 4, the Fire Brigade may adopt biodiesel for training purposes, but the market is very small indeed.

### 5.3.7 Airlines

The BAA does not consider biodiesel to be part of its long-term fuel strategy, although individual companies may take a different line. Five airlines at Heathrow airport were contacted. One company responded saying it may pay 21p and 45p. Its gas oil consumption is a minimum of 500 tonnes. The company said that in order of preference, cost, availability and environmental benefits were the three most important factors that influenced their decision to use biodiesel.

### 5.3.8 Ski resorts

One skiing holiday company in Scotland responded to the survey out of four sampled. The company said it may pay 45p/l for biodiesel and 21 p/l for a blend. An important requirment was that the fuel could be used in a temperature as low as -25C. It can therefore be concluded that the demand for biodiesel from Scottish ski resorts would be very small. Additives would need be blended with the fuel to allow its use at low temperatures.

### 5.3.9 Agriculture

Questionnaires were sent to 8 agricultural co-operatives. Five responded. Their response to the question of price was surprisingly positive, in view of the fact that farmers are eligible to purchase virtually tax-free 'red' diesel - this was the only sector in which a respondent stated that they would pay 45 p/l for biodiesel, and 3 out of the 5 respondents said that they would or would maybe pay 21 p/l for a blend (Table 5.6).

**Table 5.6 : Agricultural co-operatives responses to questions & range of potential minimum consumption of biodiesel at 45p/l and 21/l (as a blend)**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 1 | 20/80 | 1 | 963/33 | 2 | 4 |
| Biodiesel blend (20%) at 21p/l | 1 | 35/80 | 2 | 997/38 | 2 | 5 |

The one 'yes' respondent at 45p/l had a minimum consumption of 20 t DERV and 80t of gas oil. The one 'maybe' respondent at 45p/l had a minimum DERV consumption of 963 t and 33 t of gas oil.

The 2 'maybe' respondents at 21p/l had a minimum diesel consumption range of 997 t and 38 t of gas oil (see Table 5.6). The consumption of 'yes' respondent at 21p/l was 35 t of DERV and 80 t of gas at 21p/l. Agriculture may therefore provide a modest market for biodiesel, or biodiesel blends.

### 5.3.10 Armed forces

A questionnaire and two letters were sent to the Quarter Master Head Quarters who are responsible for the procurement of fuel for the Armed Forces. No response was received. The Armed Forces represent a large potential niche market, though the Quarter Master responsible for fuel purchasing did not respond to the survey and so it is unknown whether a market for biodiesel exists.

## 5.4 Large Volume Users

### 5.4.1 Bus companies

Questionnaires were sent to 75 bus companies, 22 of which responded. Although two thirds said 'no' to biodiesel at 45 p/litre, two thirds said 'yes' or 'maybe' to a biodiesel blend at 21 p/l. This is perhaps surprising in view of the fact that bus companies receive a 25 p/l tax rebate on fossil diesel (Chapter 4). The interest from bus companies could be attributable to environmental factors, although the demands of EC regulations on engine emissions can be met by modifications to engines and the use of reformulated (low sulphur) diesel, both of which would be more economical than the use of biodiesel.

**Table 5.7 : Bus companies' willingness to pay 45p/l and 21/l (as a blend) for biodiesel and minimum consumption.**

| | Yes | DERV/Gas oil consumption (tonnes/year) | Maybe | DERV/Gas oil consumption (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0 | 7 | 23,000/0 | 15 | 22 |
| Biodiesel blend (20%) at 21p/l | 4 | 11,050/0 | 11 | 41,850/252 | 7 | 22 |

The 7 'maybe' respondents at 45p/l had a minimum DERV consumption of 23,000 t. The 11 'maybe' respondents at 21p/l had a minimum DERV consumption of 41,850 t and 252 t of gas oil. The 4 'yes' respondents at this lower price had a minimum DERV consumption of 11,050 t (Table 5.7) making this one of the most promising potential markets for biodiesel blend.

However, Martin Fisher, the Group Technical Engineering Manager of West Midland Travel who consume over 40,000 t of fuel per year stated that "any rise in the cost of fuel has an immediate and significant impact on the whole economics of the operation. Similarly, to ensure continuity of supply demands that we deal with suppliers who have major resources to give the necessary back-up...(therefore)...it has not reached the point at which it would be suitable as a main-stream fuel for our operation...despite any environmental benefit." He stresses the importance of good quality fuels "to assist maintaining engines at their peak performance".

### 5.4.2 London taxis

London taxis consume over 5,000 t of fuel per year. A questionnaire was sent to the Secretary of the Licensed Taxi Drivers'Association who represent 'black cab' drivers in London. The Association responded that they would not be prepared to pay either rate for biodiesel (Table 5.8). They had previously explored the use of biodiesel and considered that it was "smelly and can damage engines". Their information came from the Taxi Association in Germany.

**Table 5.8 : London taxis responses to questions & range of potential minimum consumption of biodiesel at 45p/l and 21p/l (as a blend)**

| | Yes | Potential minimum consumption (tonnes/year) | Maybe | Potential minimum consumption (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0 | 0 | 0 | 1 | 1 |
| Biodiesel blend (20%) at 21p/l | 0 | 0 | 0 | 0 | 1 | 1 |

It therefore unlikely that biodiesel will find a market with taxi companies in the UK.

### 5.4.3 Haulage and delivery

Forty five haulage and delivery companies were contacted. Their clients included the major supermarket chains. Eleven responded. No respondents were prepared to pay 45p/l and only 2 said 'maybe'. As with the bus sector, the haulage and delivery industries appear reluctant to pay 45p/l, but are more willing to buy a blend at 21p/l. The minimum annual consumption of diesel was is 5,500 tonnes for 'yes' respondents and 21,000 tonnes for 'maybes'. There is potentially a large market for biodiesel at the lower price of 21p/l (Table 5.9).

**Table 5.9 : Haulage and delivery companies' willingness to pay 45p/l and 21p/l (as a blend) and minimum consumption.**

| | Yes | DERV/Gas oil consumption (tonnes/year) | Maybe | DERV/Gas oil consumption (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0 | 2 | 5,475/75 | 9 | 11 |
| Biodiesel blend (20%) at 21p/l | 2 | 5,375/125 | 7 | 16,430/1,570 | 3 | 12 |

The 2 'maybe' respondents at 45p/l had a minimum DERV consumption of 5,475 t and 75 t of gas oil.

### 5.4.4 Electricity utilities

The 8 UK electricity utilities were contacted. Five responded. Interest was expressed in biodiesel at both prices (Table 5.10) with none of the respondents saying that they would have no interest in biodiesel blends at 21 p/litre.

**Table 5.10 : Electricity utilities' willingness to pay 45p/l and 21p/l (as a blend) and minimum consumption.**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0/0 | 4 | 6,245/355 | 1 | 5 |
| Biodiesel blend (20%) at 21p/l | 1 | 4,850/150 | 5 | 6,506/394 | 0 | 6 |

The Electricty Utilities would therefore appear to be a good potential market for biodiesel and biodiesel blends.

### 5.4.5 Railways

Of the the 36 companies sent questionnaires, 9 responded (Table 5.11).

**Table 5.11 : Railway companies' willingness to pay 45p/l and 21p/l (as a blend) and minimum consumption.**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0/0 | 1 | 600/400 | 8 | 9 |
| Biodiesel blend (20%) at 21p/l | 0 | 0/0 | 2 | 600/1,400 | 7 | 9 |

The response was unfavourable with 7/9 companies saying 'no' to biodiesel at 21p/l and 8/9 saying 'no' to 45p/l. It is therefore unlikely that railways represent a niche market for biodiesel.

### 5.4.6 Waste management

The 11 major waste management companies in the UK (selected from the *Waste Management Yearbook 1993/4*) were surveyed. Three responded.

Two companies said they 'may' pay 45p/l and all 3 said they 'may' pay 21p/l (Table 5.12).

**Table 5.12 : Waste management companies' willingness to pay 45p/l and 21p/l (as a blend) and minimum consumption.**

| | Yes | Potential minimum consumption DERV/gas oil (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0/0 | 2 | 9,250/750 | 1 | 3 |
| Biodiesel blend (20%) at 21p/l | 0 | 0/0 | 3 | 10,300/800 | 0 | 3 |

This sector may therefore offer a small potential market for biodiesel.

### 5.4.7 Car manufacturing

The top five UK car manufacture companies were contacted to see if their transport fleets would use biodiesel. One responded (Table 5.13).

**Table 5.13 : Car manufacturing companies' willingness to pay 45p/l and 21p/l (as a blend) and minimum consumption.**

| | Yes | Potential minimum consumption (tonnes/year) | Maybe | Potential minimum consumption DERV/gas oil (tonnes/year) | No | Total replies |
|---|---|---|---|---|---|---|
| Biodiesel at 45p/l | 0 | 0 | 0 | 0/0 | 1 | 1 |
| Biodiesel blend (20%) at 21p/l | 0 | 0 | 1 | 5,000/0 | 0 | 1 |

Although the one respondent said that they might use a biodiesel blend at 21 p/l, it is difficult to draw any conclusion about the whole sector from such a small response.

### 5.4.8 Local government

Questionnaires were sent to 50 environmental policy officers in local authorities to see if local government would purchase biodiesel for their vehicle fleets. Eleven responded. None of the respondents said 'yes' to biodiesel at 45 p/l or 21 p/l. However the 'maybe' responses amounted to a potentital minimum of 1025 t of DERV and 25 t gas oil, for biodiesel priced at 45 p/l, and 33,375 t of DERV and 175 t gas oil for biodiesel blend at 21 p/l.

There may be demand for biodiesel at 21p/litre from local authorities. No demand is likely to exist for biodiesel at the higher price.

## 5.5 Conclusions

### 5.5.1 Factors influencing use of biodiesel

A total of 378 questionnaires were sent to potential consumers of biodiesel in industry and services. One hundred and four responded.

The order of importance of factors likely to influence a decision on the use of biodiesel was as follows: cost (103), engine compatability (65), environmental benefits (78), availability (70), health and safety issues (64), business advantage in using 'green fuel' (55), anticipating changes in regulation (26).

Low particulates (68 respondents) was considered to be most important attribute of the fuel followed by low sulphur content (52), non-toxicity (48), biodegradability (40), safety (high flash point) (36), renewable (33) and neutral carbon balance (22).

### 5.5.2 Low blend strategy

A low blend strategy would be targeted at large volume users of diesel such as bus companies, local authorities and haulage and delivery firms.

53.6% of respondents said they 'may' pay 21p/l for a blend, 36.1% said 'no' and 9.7% said 'yes'. Large markets for biodiesel at this price potentially exist from bus companies, haulage and delivery and electricity utilities. There is possible interest from local authorities, construction, mining, waste management and car manufacturers (Table 5.15). Table 5.14 shows the total potential market size indicated by the survey.

**Table 5.14 : Total minimum consumption potential biodiesel consumers of DERV and Gas oil at 21p/l**

| | DERV | Gas oil |
|---|---|---|
| Total minimum consumption 'Yes' | 22,315 | 400 |
| Total minimum consumption 'Maybe' | 90,124 | 18,963 |

The survey indicated that enough interest exists for preliminary research by oil companies, engine manufacturers and government in marketing biodiesel in this way. Clearly, however, there are major institutional barriers to the fuel's adoption and in light of the government's unwillingness to grant tax relief on biodiesel, one must remain sceptical of this strategy's chances of success.

**Table 5.15 : Likelihood of biodiesel use at 21p/l (as a blend) by sectors surveyed**

| Sector | Unlikely | Possible | Probable |
|---|---|---|---|
| Construction | | * | |
| Buses | | * | |
| Haulage & Distribution | | * | |
| Timber, Paper & Pulp | * | | |
| Local government | | * | |
| Trains | | * | |
| Golf+ | | | |
| Waste | | * | |
| Boating organisations | | | * |
| Motoring | * | | |
| Agriculture | | * | |
| Airlines | * | | |
| Electricity | | * | |
| Mining | | * | |
| London Taxis | * | | |

+no response

### 5.5.3 Pure use strategy

Thirty two (32.6%) respondents said they 'may' pay 45p/l for biodiesel. Two (2.1%) said 'yes' and 62 (63.3%) said 'no'. Table 5.16 shows the potential market for pure biodiesel priced at 45 p/l, indicated by the survey.

**Table 5.16 : Total minimum consumption potential biodiesel consumers of DERV and Gas oil at 45p/l**

| | DERV | Gas oil |
|---|---|---|
| Total minimum consumption 'Yes' | 20 | 5,080 |
| Total minimum consumption 'Maybe' | 51,693 | 6,467 |

At a price of 45p/litre, the most promising sectors for the pure use of biodiesel are forestry and construction.

There is minor interest from large volume users namely haulage and delivery and bus companies. This is summarised in Table 5.17.

Should biodiesel be produced at a price lower than 45p/litre, it is likely that this interest would increase according to the reduction in price. The response to the blend price of 21p/l was strong from large volume users and smaller niche markets, in particular, boats, mining and quarrying and construction.

**Table 5.17 : Likelihood of biodiesel use at 45p/l by sectors surveyed**

| Sector | Unlikely | Possible | Probable |
|---|---|---|---|
| Construction | | * | |
| Buses | | * | |
| Haulage & Distribution | | * | |
| Timber, Paper & Pulp | * | | |
| Local government | * | | |
| Trains | * | | |
| Golf | * | | |
| Waste | | * | |
| Boating organisations | | * | |
| Motoring | * | | |
| Agriculture | * | | |
| Airlines | * | | |
| Electricity | | * | |
| Mining | * | | |
| London Taxis | * | | |

# 6 NON-FUEL MARKETS FOR BIODIESEL

Non-fuel applications may exist for biodiesel where there are advantages to be found in properties such as non-toxicity, biodegradability and non-evaporation. In the US the non-fuel uses constitute the majority (about 70%) of the market for soya methyl ester (SME) (Watson, National Soyabean Development Board pers. comm., 1996), though this is likely to be surpassed as environmental regulation promotes the use of SME in the public transport sector. Non-fuel applications in the US include the following: printing cleansers, paint and graffiti removal, release agent, metal cutting lubricant. (Pickering, AG Environmental Products, pers. comm., 1996)

Existing and potential producers of industrial applications were consulted to identify potential niche industrial markets for RME.

## 6.1 Printing cleansers

Cleansers are used after each print run to remove dried inks from the rollers. Concern about the use of mineral-based cleansers containing volatile organic compounds has lead to their partial substitution by vegetable-based fluids. In Denmark, vegetable based cleaning agents (VCAs) are used in 50% of printing presses.

The EU Subsprint project was set up in 1992 to transfer the technology of cleaning-up printing presses with vegetable oil-based products from Denmark to the rest of the EU. Subsprint say that the advantages of VCAs are (Subsprint, 1996):

- safe for the printer's health
- better for the environment
- no more expensive, sometimes cheaper
- high performance

The disadvantages are:

- require more effort during cleaning
- require training in their use

Government printing presses and News International are currently testing the use of VCAs.

The two major UK producers of printing solvents are Varn and Hydraulic Dynamic Products (HDP). Both companies are leaders in developing synthetic and vegetable ester-based alternatives to conventional hydrocarbon solvents (Geary, Picon, pers. comm., 1996).

In the UK, the potential market size for RME based solvents is estimated by one producer to be 20-30,000 tonnes (Rollins, Varn Ltd, pers. comm., 1996). HDP think this estimate is in the 'upper range' (Sheard, HDP, pers. comm., 1996). Varn markets a synthetic cleanser with a similar chemistry to RME called *Biosolv*. Those consumers that have tried it have switched away, because of the following problems in the use of RME-based solvents (Rollins, Varn Ltd, pers. comm., 1996):

- Ageing of rubber based rollers
- Stripping of paint on the side of printing press
- When spilt it was very slippery on the floor
- The smell of 'stale chips' induced nausea

One food processing customer was very happy with Biosolv for use in conjunction with machinery that comes into contact with food products.

HDP produce a synthetic cleanser using by-products from the nylon industry. They are very interested to test ester-based solvents, but are waiting for legislation to promote their use in order to overcome consumer reluctance to pay the likely higher price.

Another company marketing biodegradable alternatives is more confident about the advantages of vegetable based cleansers and the prospect for growth in sales. The price of its RME-based cleanser is approximately twice that of the mineral-based equivalent.

However, this constraint could be offset by educating the consumer to use less product for each application. Because the RME-based cleaner is non-evaporative, one can use a third of the amount and get similar results. This company was unable to make an estimate of potential market size. Its feedstock originated in Germany (John Waters, Pomeroy Pressroom Products Ltd, pers. comm., 1996).

In conclusion, the growth of an RME-based cleanser market is likely to be dependent on legislation promoting its use. Consumers are sensitive to price and are conservative in their adoption of new types of cleansers. The potential size of the market is a maximum of 30,000 tonnes.

## 6.2 Pesticide solvents

Societe Robbe in France are developing a pesticide adjuvant with a RME base. No information is available as the project is commercially confidential (Charlier, Societe Robbe, pers. comm., 1996). The Agro-Linz company is using RME as a base for pesticides in Austria. It expects to use 2,000 tonnes of RME per annum within four years.

An adjuvant producer in the UK (Newman) are planning to produce and market RME-based adjuvants in the next two years. Newman estimate the market size to be approximately 500 tonnes and expect to source their biodiesel in the UK.
The price of Newman's adjuvant will be approximately the same as a mineral oil based one. The company see price as the most important factor in the product's uptake (Cameron, Newman, pers.comm., 1996).

A UK herbicide producer AgEvro is planning to market a RME-based adjuvant developed by Robbe in France. The product is not yet registered with MAFF. AgEvro

say that the benefits of using rape oil are increasing the penetration of the herbicide, increasing the spectrum of fungicides and the biodegradability of the product. Its pricing structure has not been finalised and the company does not say how big the market is or where the biodiesel will be sourced from (Vernier, AgEvro, pers. comm., 1996).
In conclusion, it appears likely that RME-based adjuvants will be marketed in the UK in the next two years. The market is estimated by one company at 500 tonnes. The likely price at which the products will be marketed has not been fully determined.

## 6.3 Drilling muds

Drilling fluids are used in offshore drilling as lubricating 'muds' to remove drilling cuttings, provide lubrication, prevent 'blow outs' and to cool the drill bit.

The use of mineral oil based muds is being substituted by synthetic muds due to the introduction of stricter environmental legislation on the discharge of mineral oil-based mud drill cuttings onto the sea-floor. Synthetic muds are being evaluated by the Paris Commission for their environmental performance. The Paris Commission is a body of North Sea states looking at shared environmental problems. The Commission will review the tests in 1998 when regulations will be drafted limiting the use of those deemed to be environmentally destructive. These 'decisions' are non-binding and it is up to individual states to sign up or not.

Synthetic muds include linear alpha olophines (LAOs) and poly alpha olophines (PAOs) and esters (such as rape methyl ester). Ester-based muds have been patented by one company, Henkel Organics in Germany. Henkel argue that LAOs are very destructive to marine ecology. Ester-based muds degrade anerobically and aerobically, thus providing an environmental benefit to marine ecology in drilling operations (Henkel, pers. comm., 1996). Whilst the environmental case for the banning of LAOs may be convincing, the producers and marketers of ester based muds do not envisage that regulations will tighten to this extent (Cameron, pers. comm., 1996). A factor to consider is that the outlawing of other synthetic muds such as LAOs by the UK government may well be politically impossible as the supply of ester muds would be controlled by a virtual monopoly.

Ester-based muds are used in the Gulf of Mexico where environmental regulation promotes its use. In the North Sea, they are used by Norway's state drilling company Statoil. Wilkinson (1994) estimates the potential market for the use of drilling muds at 40-50,000 t for the UK. The market for alternative drilling fluids is growing as the use of mineral oil-based fluids is due to be phased out by 1997. The number of drilling rigs using muds remains constant at around 340 per year. However, in the UK sector, drilling companies have not used ester-based muds since March 1995, due to lower cost of other muds such as LAOs (Helmey, pers. comm., 1996).

**Table 6.1: Approximate prices for base fluids for drilling muds**

| Base fluid | Cost (£/barrel) |
|---|---|
| Oil | 30 |
| LAO | 120 |
| PAO | 180 |
| Biodiesel | 250 |

**Source: Sammy Helmey, UK Sales Manager, Baroid**

It is therefore unlikely that ester based muds will be adopted unless legislation forces British oil companies to use them or the price drops nearer to synthetic mud prices.

## 6.4 Lubricants

The market for rape oil based lubricant markets has recently been reviewed (Carruthers *et al.*, 1995).

The British Lubricant Federation (BLF) have identified Fuchs and Smallman as companies in the UK being potentially interested producing and/or marketing RME-based lubricants (Margaroni, BLF, pers. comm., 1996). Fuchs Lubricants see lower viscosity products (such as RME) as clearly suited to use for lighter lubricant applications, with largest potential volumes perhaps in the area of concrete mould release applications. No market size or price estimates have been made by Fuchs at this stage (Lea, Fuchs Lubricants, pers. comm., 1996). Price would be a major consideration in developing a RME-based concrete mould release lubricant. Major consumers buy mineral-based products at approximately 13p/litre. Fuchs envisage blending and distribution costs of a RME-based product to be 45p/litre, in addition to the cost of RME production. No figures for this market are available (Lea, Fuchs Lubricants, pers. comm., 1996b)

Smallman Lubricants markets a hydraulic oil containing RME that is manufactured in Sweden. The company does give any market estimates for the product nor consider sales to be very strong without legislation to promote its use. The product is approximately three times the price of its mineral equivalent (Neadle, Smallman Lubricants, pers. comm., 1996).

In conclusion no information is readily available on the market size for RME-based lubricants in the UK. Lubricants may be up to 7 times the price of fossil diesel-based lubricants. This could act as constraint in the oil's adoption by industry.

## 6.5 Biosurfactants

Surfactants are substances consisting of a hydrophilic part and hydrophobic part. They can be used in detergents, dispersing agents, emulsifiers, wetting agents, foaming and anti-foaming agents and solubilisers (Piorr 1987, quoted in Carruthers *et al.*, 1994).

Surfactants can be manufactured chemically from petroleum based products, but there is a trend towards more "natural" products in this sector which has two main aspects - the use of vegetable oil to make the hydrophobic group of the molecule and the use of plant derived carbohydrates (like starch) to make the hydrophillic part. Biosurfactants are surfactants made by a biological process.

EU consumption of surfactants is estimated at 1.7 Mt per year. The market was analysed by Carruthers *et al.*, (1995). In 1990, in the US, petrochemical-based surfactants had 52% of US production, oleo-based surfactants had 21% and mixed 27% (USDA, 1993).

The Institut Francais du Petrole (IFP) in France have tested the manufacture of surfactants through fermentation, rather than conventional chemical methods. They fed a type of yeast with oils and oil esters e.g. RME to produce a surfactant type molecule. Different types of surfactant can be made in this way and it might be possible to produce a product targeted at a specific market.

The IFP researchers used different types of oil substrate as a feedstock for the fermentation process The substrates used were rapeseed esters, rapeseed oil, sunflower esters, sunflower oil, palm ester, palm oil, linseed ester and fish oil. They concluded that rapeseed esters gave the best result in terms of quantity produced in comparison to the other oil substrates that were tested. Rapeseed oil performed better than other oils and rapeseed ester performed better than rapeseed oil (Davila *et al.*, 1994). It is not known how the Institute will commercially deploy its findings and what the implications may be for demand for RME.

In conclusion, RME performs better than other substances as a substrate in the production of biosurfactants. However, it is unclear what the demand implications are for RME as research and development is at a relatively early stage.

## 6.7 Conclusions

In some respects, the non-fuel use of methyl esters appears to be further developed commercially than fuel use in the UK, with industry actively exploring the use of the substance, for example as a pesticide adjuvent. A similar situation can be seen in the US where 70% of soya methyl ester is used in non-fuel applications. Potential uses for biodiesel include printing cleansers, drilling muds, lubricants and biosurfactants. An immediate market exists for the use of RME in the production of pesticides, while the use of RME in printing solvents may require some more development work or the introduction of supportive legislation in order to secure a market. Development of the market for RME in lubricants and drilling muds appears to be limited by the high cost of the products, and legislation may be required to secure the market.

Table 6.2 summaries the potential for those four markets. For the longer term, the use of RME as a feedstock for the production of biosurfactants may present an interesting opportunity, although at this stage it is difficult to predict what the potential for this product would be.

**Table 6.2 Likelihood of biodiesel use in non-fuel applications**

| Use | Unlikely | Possible | Probable |
|---|---|---|---|
| Pesticide solvent | | | * |
| Printing solvent | | * | |
| Drilling mud | * | | |
| Lubricant | | * | |

# 7 CONCLUSIONS

## 7.1 Fuel markets

### 7.1.1 Niche markets

The lack of end-use fiscal and legislative support for biodiesel will make it very difficult to successfully market the fuel in the UK.

In most smaller volume 'niche' markets, biodiesel must compete with gas oil which is subject to very little taxation.

For the leisure boating industry, there are regulations in place that are seen by the authorities as sufficiently protecting the waterways without the need for the compulsory use of biodiesel. Other industries such as forestry, mining and construction have developed health and safety regulations and 'best practices' for fuel usage and also see the environment as sufficiently protected. It is unlikely therefore that industry will pay a large premium for biodiesel, a fuel that is providing a solution (i.e. biodegradability and non-toxicity) to a problem that industry feels is already taken care of. However, it is possible that some companies may use biodiesel to improve their environmental image i.e. as a marketing tool. The market survey confirmed that where biodiesel has its clearest environmental advantage over fossil diesel i.e. in terms of its biodegradability and non-toxicity, there were potential market opportunities. These sectors are boats, forestry and construction.

### 7.1.2 Large volume users

The structure of tax relief for buses does not encourage the use of more expensive alternative fuels. It is therefore unlikely that bus companies will pay a high premium for biodiesel. The emissions advantage of biodiesel (low sulphur emissions) over fossil diesel is being reduced as EU emissions levels are tightened. The market survey shows that there was substantial interest in biodiesel at 21p/litre from bus companies and other large volume users like haulage and delivery and utilities. Biodiesel producers therefore need to explore further whether this interest will translate to real demand. Institutional barriers exist to marketing biodiesel as a blend. Oil companies, engine manufacturers and the Government must be involved for this strategy to succeed.

## 7.2 Non-fuel markets

Non-fuel applications may exist for biodiesel where there are advantages to be found in properties such as non-toxicity, biodegradability and non-evaporation. Potential uses for biodiesel include printing cleansers, drilling muds, lubricants and biosurfactants. Potential and present producers were consulted.

The development of RME-based printing cleansers is constrained by performance of RME against mineral based and other vegetable-based products and price. A maximum figure for the market is 30,000 t.

The market for ester-based drilling muds is estimated at 40-50,000 tonnes. Without legislation or a drop in price, it is unlikely they will be used by British oil companies.

An imported lubricant containing RME is presently marketed in the UK. There may be unquantified markets for light lubricants, in particular concrete mould release applications. The price of blending and distribution of an RME based product is estimated to be 45p/l, in addition to the cost of RME. This compares to a mineral oil-based product price of 13p/l.

RME performs better than other substances as a substrate in the production of biosurfactants. It is not known at this stage what the demand implications are for RME or how RME biosurfactants will compare in price with petrochemical-based surfactants.

## 7.3 Environmental impact of biodiesel production and consumption

There are a diverse range of environmental impacts for both biodiesel and diesel production and use (see Table 3.11). This study has sought only to highlight impacts associated with the different systems. A full LCA would be needed to quantify these impacts and compare systems.

Whilst there is a lack of corroborative data, information available indicates that biodiesel has lower emissions than fossil diesel for CO, HC and PM, whilst emissions of NOx can increase (see Table 3.11). In most vehicular uses, life-cycle emissions for biodiesel are less than diesel for $CO_2$, CO and PM, whilst they are greater for HC, NOx and $SO_2$

There are $CO_2$ emissions savings when substituting biodiesel for fossil diesel. Higher $CO_2$ emissions savings are made with woody biomass, although the two types of crops are not strictly comparable as they would not be competing for the same land or market.

The clearest environmental advantage that biodiesel has over fossil diesel is in terms of its biodegradability and low toxicity.

# 8 RECOMMENDATIONS

## 8.1 Production

Studies have found that the cost of biodiesel production is most sensitive to the price of rapeseed. Double low rapeseed prices have been rising for the last three years. Biodiesel producers must therefore investigate alternative feedstocks such *Camelina,* beef tallow and waste vegetable oil. The viability in the UK of local waste oil collection schemes such as in County Cork and southern Austria needs research.

## 8.2 Niche fuel markets

Boat users, forestry and construction companies have been identified as the most likely consumers of biodiesel at 45p/l (excluding tax and VAT). Biodiesel producers should therefore continue negotiations with these groups to use the fuel. Engine manufacturers for these sectors need to give clearance for biodiesel use.

## 8.3 Large volume fuel markets

Substantial markets in excess of UK biodiesel capacity may exist for use of biodiesel as a blend (20%) with fossil diesel (80%) and sold at 21p/l. For this market to be developed, producers should have talks with oil companies, engine manufacturers and the UK Government. The project could not be feasible without all these parties' co-operation.

## 8.4 Niche non-fuel markets

Markets may exist for RME to used in industrial applications such as pesticide adjuvants, light lubricants, drilling muds, printing cleansers and biosurfactants. RME producers in the UK should therefore have exploratory talks with the companies involved in these sectors with regard to providing the feedstock RME.

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# Appendix 1

SURVEY

1. **With which area are the main activities of your business concerned?**

| | | | | | |
|---|---|---|---|---|---|
| Energy | --- | Metal manufacturing | --- | Mechnical engineering | --- |
| Electrical Engineering | --- | Car manufacturing | --- | Textiles | --- |
| Construction | --- | Haulage | --- | Agriculture | --- |
| Forestry | --- | Paper & Pulp | --- | Packaging | --- |
| Chemicals | --- | Mining & Quarrying | --- | Leisure services | --- |
| Petroleum | --- | Plastics | --- | Waste Management | --- |
| Water | --- | Airline | --- | Buses & Taxis | --- |
| Conservation | --- | Local Government | --- | Trains | --- |
| Fire services | --- | Armed services | --- | Other (please state) | |

2. **Does the company have an environmental policy?**

Yes - No -

3. **How many litres of diesel fuel does your company/council consume per year**

| | | | |
|---|---|---|---|
| Under 1,000 litres | - | 1,000-10,000 litres | - |
| 10,000-50,000 litres | - | 50,000-100,000 litres | - |
| 100,000-500,000 litres | - | 500,000-1 million litres | - |
| 1-5 million litres | - | Over 5 million litres | - |

4. **What proportion of the diesel used is Automative Diesel (DERV fuel) or Gas Oil (dyed red)?**

Automative Diesel -% Gas Oil -%

5. **Where do you currently buy your fuel?**

| | | | |
|---|---|---|---|
| Bulk deliveries | - | High street garages | - |
| Company/council garage | - | Other (please specify) | - |

6. **Had you heard of biodiesel before receiving this questionnaire?**

7. **Have you previously explored the use of biodiesel, what was the outcome and why?**

8. **The present price for 100% biodiesel is 45p/litre (without duty &VAT). Is it likely that your company/council would be prepared to pay this price?**

Yes - No - Maybe -

9. **The present price for a 20% mix of biodiesel with 80% conventional mineral diesel is 21p/litre (without duty & VAT). Is it likely that your company/council would be prepared to pay this price?**

Yes - No - Maybe -

10. **Which of the following factors are likely to influence a decision on your use of biodiesel?**

Cost -
Health & Safety Issues -
Availability -
Business advantage in using 'green fuel' -
Environmental benefits -
Engine compatability -
Anticipating changes in regulation -

11. **Which of the following attributes of Biodiesel do you consider attractive about the fuel?**

| **Fuel qualities** | **Not Important** | **Important** | **Very Important** |
|---|---|---|---|
| Low sulphur content | | | |
| Low particulates and smoke | | | |
| Biodegradable | | | |
| Non-toxic | | | |
| Safety (High flash point) | | | |
| Renewable | | | |
| Neutral carbon balance | | | |

THANK YOU FOR YOUR HELP

Name of Business/ Council...............................

Your Name.............................................

Your Position..........................................

THE INFORMATION GIVEN IN THIS SURVEY WILL REMAIN CONFIDENTIAL

PLEASE RETURN THE QUESTIONNAIRE USING THE FREEPOST LABEL PROVIDED

IF YOU WOULD LIKE MORE INFORMATION ABOUT BIODIESEL, PLEASE TICK THIS SPACE ---

## Appendix 2

**Table 1 : Sectors surveyed and responses received** ***(Question 1)***

| Sector | Number sent | Number returned | Response rate (%) |
|---|---|---|---|
| Construction | 85 | 13 | |
| Buses | 67 | 22 | |
| Haulage & Distribution | 45 | 12 | |
| Timber, Paper & Pulp | 43 | 12 | |
| Local Authorities | 40 | 10 | |
| Railways | 36 | 9 | |
| Golf | 18 | 0 | |
| Waste | 14 | 4 | |
| Boating organisations | 11 | 5 | |
| Motoring | 10 | 1 | |
| Agriculture | 8 | 5 | |
| Airlines | 5 | 1 | |
| Electricity | 8 | 5 | |
| Mining & Quarrying | 4 | 4 | |
| London Taxis | 1 | 1 | |
| **TOTAL** | **395** | **104** | **26.3%** |

**Table 2: Respondents with an environmental policy** ***(Question 2)***

| Sector | Number with environmental policy | Number without environmental policy |
|---|---|---|
| Construction | 10 | 5 |
| Buses | 14 | 7 |
| Haulage & Distribution | 11 | 1 |
| Timber, Paper & Pulp | 8 | 3 |
| Local Authorities | 7 | 3 |
| Railways | 9 | 0 |
| Golf | 0 | 0 |
| Waste | 4 | 0 |
| Boating organisations | 3 | 2 |
| Motoring | 1 | 0 |
| Agriculture | 4 | 1 |
| Airlines | 0 | 1 |
| Electricity | 5 | 0 |
| Mining | 4 | 0 |
| London Taxis | 1 | 0 |
| **TOTAL** | **81** | **24** |

**Table 3 : Consumer purchasing of diesel fuel** ***(Question 5)***

| SECTOR | Bulk deliveries | Company/ council garages | High street garages | Other |
|---|---|---|---|---|
| Bus companies | 22 | 0 | 0 | 0 |
| Construction | 14 | 2 | 9 | 0 |
| Haulage | 12 | 1 | 2 | 0 |
| Trains | 9 | 0 | 0 | 0 |
| Timber | 6 | 1 | 2 | 0 |
| Paper & pulp | 5 | 0 | 1 | 0 |
| Local Government | 8 | 1 | 1 | 0 |
| Mining | 4 | 1 | 1 | 0 |
| Agriculture | 5 | 0 | 3 | 0 |
| Airlines | 1 | 0 | 0 | 0 |
| Waste management | 4 | 0 | 1 | 0 |
| Marine/boating | 3 | 0 | 0 | 2 |
| Ski resorts | 1 | 0 | 0 | 0 |
| Electricity utilities | 3 | 0 | 4 | 0 |
| Car manufacturing | 0 | 1 | 0 | 0 |
| London taxis | 0 | 0 | 1 | 0 |
| **TOTAL** | **97** | 7 | **25** | **2** |

Notes
Other: Marine users buy their fuel from water side pumps.

**Table 4: Respondents who had heard of biodiesel before receiving the questionnaire** ***(Question 6)***

| Sector | Number with environmental policy | Number without environmental policy |
|---|---|---|
| Construction | 10 | 5 |
| Buses | 14 | 7 |
| Haulage & Distribution | 11 | 1 |
| Timber, Paper & Pulp | 8 | 3 |
| Local Authorities | 7 | 3 |
| Railways | 9 | 0 |
| Golf | 0 | 0 |
| Waste | 4 | 0 |
| Boating organisations | 3 | 2 |
| Motoring | 1 | 0 |
| Agriculture | 4 | 1 |
| Airlines | 0 | 1 |
| Electricity | 5 | 0 |
| Mining | 4 | 0 |
| London Taxis | 1 | 0 |
| **TOTAL** | **81** | **24** |

**Table 5: Respondents who had explored the use of biodiesel** ***(Question 7)***

| Sector | Explored the use of biodiesel | Not explored the use of biodiesel |
|---|---|---|
| Construction | 2 | 13 |
| Buses | 6 | 14 |
| Haulage & Distribution | 3 | 8 |
| Timber, Paper & Pulp | 2 | 10 |
| Local Authorities | 0 | 10 |
| Railways | 1 | 8 |
| Golf | 0 | 0 |
| Waste | 0 | 4 |
| Boating organisations | 1 | 4 |
| Motoring | 0 | 4 |
| Agriculture | 2 | 3 |
| Airlines | 0 | 1 |
| Electricity | 1 | 3 |
| Mining | 0 | 4 |
| London Taxis | 1 | 0 |
| **TOTAL** | **19** | **86** |

**Table 6: Responses to 45p/l of biodiesel *(Question 8)***

| Yes | No | Maybe |
|---|---|---|
| 1 | 68 | 36 |

**Table 7: Minimum consumption (tonnes) of automotive diesel and gas oil by respondents who answered 'yes' to 45p/l *(Question 8)***

| **Sector** | **DERV** | **Gas oil** |
|---|---|---|
| Buses | 0 | 0 |
| Haulage & delivery | 0 | 0 |
| Timber, paper & pulp | 0 | 0 |
| Timber | 0 | 0 |
| Local government | 0 | 0 |
| Construction | 0 | 0 |
| Mining & Quarrying | 0 | 0 |
| Agriculture | 20 | 80 |
| Boats | 0 | 0 |
| Ski resort | 0 | 0 |
| Airlines | 0 | 0 |
| Electricity utility | 0 | 0 |
| Waste | 0 | 0 |
| Car manufacturers | 0 | 0 |
| Trains | 0 | 0 |
| London taxis | 0 | 0 |
| **TOTAL** | **20** | **80** |

**Table 8: Minimum consumption (tonnes) of automotive diesel and gas oil by respondents who answered 'maybe' to 45p/l *(Question 8)***

| Sector | DERV | Gas oil |
|---|---|---|
| Buses | 23,000 | 0 |
| Haulage & delivery | 5,475 | 75 |
| Paper & pulp | 0 | 1 |
| Timber | 168 | 745 |
| Local government | 1,025 | 25 |
| Construction | 2,916 | 534 |
| Mining & Quarrying | 2,050 | 3,000 |
| Agriculture | 963 | 33 |
| Railways | 600 | 400 |
| Golf | 0 | 0 |
| Boats | 0 | 0 |
| Ski resort | 1 | 49 |
| Airlines | 0 | 500 |
| Electricity utility | 6,245 | 355 |
| Waste | 9.250 | 750 |
| Car manufacturers | 5,000 | 0 |
| London taxis | 0 | 0 |
| **TOTAL** | **51,693** | **6,467** |

**Table 9: Responses to 21p/l blend of biodiesel *(Question 9)***

| Yes | No | Maybe |
|---|---|---|
| 10 | 40 | 58 |

**Table 10: Minimum consumption (tonnes) of automotive diesel and gas oil by respondents who answered 'yes' to 21p/l of blended biodiesel *(Question 9)***

| Sector | DERV | Gas oil |
|---|---|---|
| Buses | 11,050 | 0 |
| Haulage & delivery | 5,375 | 125 |
| Paper & pulp | 0 | 0 |
| Timber | 0 | 0 |
| Local government | 0 | 0 |
| Construction | 1,000 | 0 |
| Mining & Quarrying | 0 | 0 |
| Agriculture | 35 | 80 |
| Boats | 5 | 1,045 |
| Ski resort | 0 | 0 |
| Airlines | 0 | 0 |
| Electricity utility | 4,850 | 150 |
| Waste | 0 | 0 |
| Car manufacturers | 0 | 0 |
| Trains | 0 | 0 |
| London taxis | 0 | 0 |
| **TOTAL** | **22,315** | **1,400** |

**Table 11: Minimum consumption (tonnes) of automotive diesel and gas oil by respondents who answered 'maybe' to blended biodiesel at 21p/l *(Question 9)***

| Sector | DERV | Gas oil |
|---|---|---|
| Buses | 41,850 | 252 |
| Haulage & delivery | 16,430 | 1,570 |
| Paper & pulp | 0 | 100 |
| Timber | 665 | 935 |
| Local government | 3,375 | 175 |
| Construction | 2,400 | 4,650 |
| Mining & Quarrying | 2,000 | 3,000 |
| Agriculture | 997 | 38 |
| Boats | 0 | 5,100 |
| Ski resort | 1 | 49 |
| Airlines | 0 | 500 |
| Electricity utility | 6,506 | 394 |
| Waste | 10,300 | 800 |
| Car manufacturers | 5,000 | 0 |
| Trains | 600 | 1,400 |
| London taxis | 0 | 0 |
| **TOTAL** | **90,124** | **18,963** |

**Table 12: Factors influencing consumer decisions to use biodiesel : Cost; Health & Safety; Changes in regulation** ***(Question 10)***

| **Sector** | **Cost** | **Health & Safety** | **Changes in regulation** |
|---|---|---|---|
| Construction | 14 | 10 | 3 |
| Buses | 22 | 15 | 7 |
| Haulage & Distribution | 12 | 6 | 4 |
| Timber, Paper & Pulp | 11 | 5 | 0 |
| Local Authorities | 10 | 6 | 3 |
| Railways | 9 | 7 | 6 |
| Golf | 0 | 0 | 0 |
| Waste | 4 | 2 | 2 |
| Boating organisations | 4 | 1 | 0 |
| Motoring | 1 | 1 | 0 |
| Agriculture | 5 | 2 | 0 |
| Airlines | 1 | 1 | 0 |
| Electricity | 5 | 5 | 1 |
| Mining & Quarrying | 4 | 2 | 0 |
| London Taxis | - | - | - |
| **TOTAL** | **103** | **64** | **26** |

**Table 13: Factors influencing consumer decisions to use biodiesel : Availability; Business Advantage; Environmental benefits; Engine compatability** ***(Question 10)***

| **Sector** | **Availability** | **Business advantage** | **Environmental benefits** | **Engine compatability** |
|---|---|---|---|---|
| Construction | 5 | 3 | 4 | 5 |
| Buses | 13 | 20 | 16 | 18 |
| Haulage & Distribution | 12 | 8 | 11 | 8 |
| Timber, Paper & Pulp | 7 | 3 | 8 | 8 |
| Local Authorities | 6 | 4 | 8 | 8 |
| Railways | 7 | 5 | 8 | 6 |
| Golf | 0 | 0 | 0 | 0 |
| Waste | 3 | 2 | 4 | 3 |
| Boating organisations | 3 | 2 | 2 | 4 |
| Motoring | 1 | 1 | 1 | 1 |
| Agriculture | 3 | 0 | 2 | 2 |
| Airlines | 1 | 0 | 1 | 1 |
| Electricity | 5 | 3 | 4 | 5 |
| Mining | 1 | 0 | 3 | 1 |
| London Taxis | - | - | - | - |
| **TOTAL** | **70** | **55** | **78** | **65** |

**Table 14: Factors influencing consumer decisions to use biodiesel : Low particulates *(question 11)***

| Sector | Not important | Important | Very important |
|---|---|---|---|
| Construction | 2 | 6 | 6 |
| Buses | 0 | 3 | 19 |
| Haulage & Distribution | 0 | 3 | 9 |
| Timber, Paper & Pulp | 3 | 3 | 4 |
| Local Authorities | 0 | 1 | 9 |
| Railways | 0 | 3 | 4 |
| Golf | 0 | 0 | 0 |
| Waste | 0 | 1 | 3 |
| Boating organisations | 1 | 1 | 3 |
| Motoring | 0 | 0 | 1 |
| Agriculture | 1 | 0 | 3 |
| Airlines | 0 | 0 | 1 |
| Electricity | 0 | 1 | 4 |
| Mining | 2 | 1 | 1 |
| London Taxis | - | - | - |
| **TOTAL** | **9** | **24** | **68** |

**Table 15: Factors influencing consumer decisions to use biodiesel : Low sulphur content *(question 11)***

| Sector | Not important | Important | Very important |
|---|---|---|---|
| Construction | 3 | 7 | 4 |
| Buses | 1 | 4 | 17 |
| Haulage & Distribution | 0 | 6 | 6 |
| Timber, Paper & Pulp | 2 | 4 | 4 |
| Local Authorities | 0 | 1 | 9 |
| Railways | 0 | 3 | 3 |
| Golf | - | - | - |
| Waste | 0 | 3 | 1 |
| Boating organisations | 1 | 2 | 1 |
| Motoring | 0 | 0 | 1 |
| Agriculture | 1 | 3 | 0 |
| Airlines | 0 | 0 | 1 |
| Electricity | 0 | 1 | 3 |
| Mining | 1 | 1 | 2 |
| London taxis | - | - | - |
| **TOTAL** | **9** | **35** | **52** |

**Table 16: Factors influencing consumer decisions to use biodiesel : Non-toxicity *(question 11)***

| Sector | Not important | Important | Very important |
|---|---|---|---|
| Construction | 0 | 7 | 8 |
| Buses | 0 | 9 | 9 |
| Haulage & Distribution | 1 | 7 | 4 |
| Timber, Paper & Pulp | 1 | 1 | 3 |
| Local Authorities | 1 | 4 | 5 |
| Railways | 2 | 2 | 4 |
| Golf | - | - | - |
| Waste | 0 | 1 | 2 |
| Boating organisations | 1 | 4 | 0 |
| Motoring | 0 | 0 | 0 |
| Agriculture | 1 | 1 | 2 |
| Airlines | 0 | 0 | 1 |
| Electricity | 1 | 0 | 3 |
| Mining | 1 | 0 | 3 |
| London Taxis | - | - | - |
| **TOTAL** | **10** | **39** | **48** |

**Table 17: Factors influencing consumer decisions to use biodiesel : biodegrability *(question 11)***

| Sector | Not important | Important | Very important |
|---|---|---|---|
| Construction | 3 | 3 | 8 |
| Buses | 1 | 13 | 4 |
| Haulage & Distribution | 2 | 6 | 4 |
| Timber, Paper & Pulp | 0 | 6 | 4 |
| Local Authorities | 2 | 3 | 5 |
| Railways | 0 | 3 | 4 |
| Golf | - | - | - |
| Waste | 0 | 1 | 2 |
| Boating organisations | 2 | 1 | 2 |
| Motoring | 0 | 1 | 0 |
| Agriculture | 1 | 0 | 3 |
| Airlines | 0 | 0 | 1 |
| Electricity | 1 | 2 | 1 |
| Mining | 1 | 2 | 1 |
| London Taxis | - | - | - |
| **TOTAL** | **13** | **41** | **40** |

**Table 18: Factors influencing consumer decisions to use biodiesel : safety (high flash point)** ***(question 11)***

| Sector | Not important | Important | Very important |
|---|---|---|---|
| Construction | 3 | 8 | 3 |
| Buses | 0 | 2 | 5 |
| Haulage & Distribution | 4 | 7 | 1 |
| Timber, Paper & Pulp | 4 | 4 | 1 |
| Local Authorities | 2 | 2 | 6 |
| Railways | 0 | 2 | 5 |
| Golf | - | - | - |
| Waste | 0 | 1 | 3 |
| Boating organisations | 1 | 1 | 3 |
| Motoring | 1 | 0 | 0 |
| Agriculture | 0 | 2 | 1 |
| Airlines | 0 | 0 | 1 |
| Electricity | 0 | 1 | 3 |
| Mining | 2 | 0 | 2 |
| London taxis | - | - | - |
| **TOTAL** | **20** | **37** | **36** |

**Table 19: Factors influencing consumer decisions to use biodiesel : neutral carbon balance** ***(question 11)***

| Sector | Not important | Important | Very important |
|---|---|---|---|
| Construction | 2 | 10 | 2 |
| Buses | 4 | 8 | 6 |
| Haulage & Distribution | 4 | 5 | 2 |
| Timber, Paper & Pulp | 1 | 5 | 3 |
| Local Authorities | 1 | 2 | 5 |
| Railways | 0 | 4 | 1 |
| Golf | - | - | - |
| Waste | 1 | 1 | 1 |
| Boating organisations | 1 | 0 | 0 |
| Motoring | 0 | 1 | 0 |
| Agriculture | 1 | 2 | 0 |
| Airlines | 0 | 0 | 1 |
| Electricity | 1 | 2 | 1 |
| Mining | 3 | 1 | 0 |
| London taxis | - | - | - |
| **TOTAL** | **19** | **41** | **22** |

**Table 20: Factors influencing consumer decisions to use biodiesel : renewable *(question 11)***

| **Sector** | **Not important** | **Important** | **Very important** |
|---|---|---|---|
| Construction | 0 | 9 | 6 |
| Buses | 5 | 7 | 5 |
| Haulage & Distribution | 1 | 7 | 4 |
| Timber, Paper & Pulp | 2 | 4 | 5 |
| Local Authorities | 0 | 4 | 5 |
| Railways | 1 | 6 | 1 |
| Golf | - | - | - |
| Waste | 1 | 2 | 1 |
| Boating organisations | 0 | 2 | 0 |
| Motoring | 0 | 1 | 0 |
| Agriculture | 1 | 1 | 2 |
| Airlines | 0 | 0 | 1 |
| Electricity | 1 | 1 | 2 |
| Mining | 2 | 2 | 0 |
| London taxis | - | - | - |
| **TOTAL** | **14** | **46** | **33** |