6.2 Production and use of biodiesel

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Biodiesel is produced from vegetable oils that have been chemically modified by esterification; an example is rapeseed oil methyl ester (RME), made by treating rapeseed (canola) oil with methanol. Biodiesel can be burned directly in diesel engines. Robert Diesel himself was the first person to use vegetable oil as fuel for an internal combustion engine, in 1912, but it was not until the oil crisis of the 1970s that biofuels attracted serious interest. Biodiesel is reported to release fewer solid particles than conventional diesel, and because it contains no sulphur, it does not create the SO_2 which contributes to acid rain. Potentially even more important is the low level of carbon dioxide generation associated with biodiesel, at a time when CO_2 emissions are falling in every industrial sector except transport. Life-cycle studies show that 1 kg of biodiesel can reduce greenhouse gas emissions by at least 3.2 kg CO_2 equivalent.

Modern biodiesel development started in Austria around 1982, with four aims:

- to provide a secure supply of liquid transport fuels;
- to create an environment-friendly fuel for diesel engines;
- to reduce health and safety risks; and
- to provide customers with a reliable fuel at a reasonable ratio of costs to benefits.

The first biodiesel to become commercially available was RME, in 1988. At this time the product was of questionable quality, but tremendous progress has been made since then. Developments include:

- broadening the feedstock beyond rapeseed oil;
- improving process technology through flexibility in processing multi-feedstocks (MFS) at high yields;
- developing sophisticated standards for assuring fuel quality;
- establishing biodiesel production in many countries all over the world;
- intelligent product positioning in defined fuel market segments;
- obtaining biodiesel warranties from diesel engine manufacturers and;
- implementing supportive legal measures and voluntary regulations.

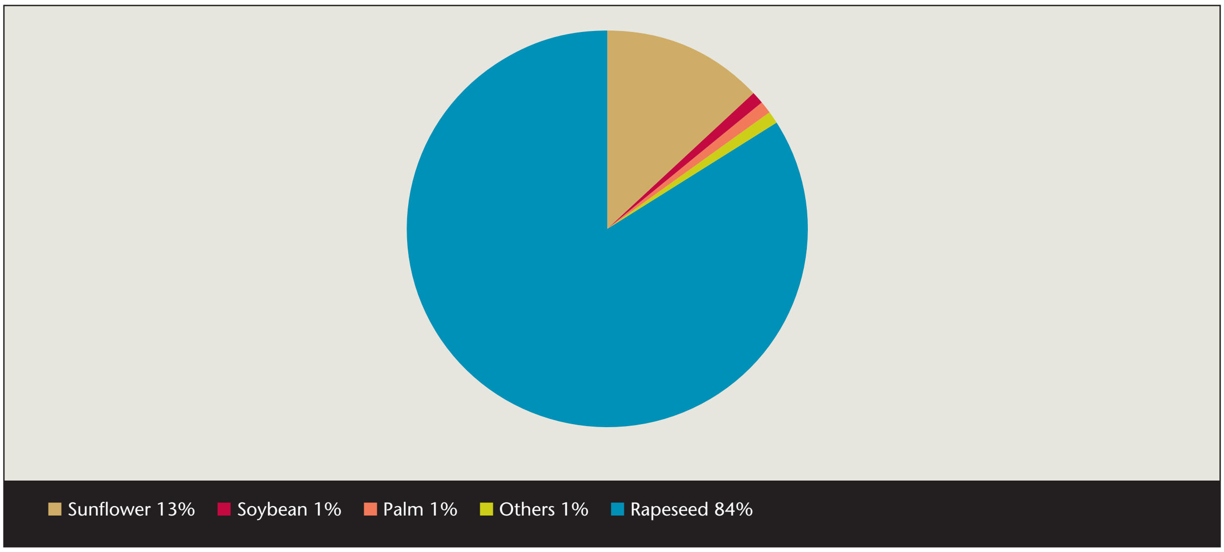
Feedstock

Oil from the rapeseed variety known as “00” was the first type of vegetable oil used for transesterification to produce biodiesel. Somewhat by chance, this oil is highly suitable, and it is still the main source of quality biodiesel (Figure 10).

Biodiesel from “00” rapeseed oil shows good stability and winter performance because the oil contains around 60% mono-unsaturated oleic fatty acids and only around 6% saturated fatty acids. New varieties such as LZ 7632 contain up to 87% mono-unsaturated oleic fatty acids. Using “precision farming” techniques, yields of rapeseed oil have been demonstrated at up to 2.9 t/h in northern Germany.

Over time, many other oils have been used successfully

Figure 10. Raw materials for biodiesel.



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as biodiesel feedstocks (Figure 10). They include sunflower oil in southern France and Italy; soybean oil in the USA; and palm oil which fuels the buses of Kuala Lumpur, Malaysia. Recycled cooking oil can also be used; this technology was commercialised in 1998–9 during a time of high oilseed cost and record-low diesel prices.

Process technology

Soon after RME became established in the market, the search began for other feedstocks. A detailed screening of many types of oil and fat – virgin or waste, vegetable or animal origin – revealed that some feedstocks are unacceptable because they yield biodiesel with poor stability, winter performance, coking characteristics and so on. On the positive side, screening showed that good biodiesel can be made from a wide range of feedstocks and multi-feedstock (MFS) blends.

The key to producing low-cost biodiesel is to select clever blends of the cheapest feedstocks available, while maintaining acceptable product quality. Since the price and availability of different feedstocks can vary by the season or even by the day, it is a tremendous commercial advantage if production recipes can be changed quickly. In a modern biodiesel plant the cheapest blend of the day is selected from a range of recipes stored in the process control system.

After feedstock prices, yield is the second largest factor affecting profitability; a 10% drop in yield reduces profitability by approximately 25%. Early biodiesel plants had a transesterification yield of 85–95%, with the remaining 5–15% of the feedstock converted to less-profitable glycerine. Modern plants convert all the free fatty acids (FFAs) as well as the tricglycerides, and so achieve yields of 100%.

Fuel standards and quality assurance

In the early days of biodiesel it became obvious that winning the confidence of diesel engine manufacturers would be of key importance. A working group was set up within the Austrian Standardisation Institute and the first biodiesel fuel standard was issued in 1991 as ON C 1190 for RME. All the main tractor manufacturers went on to provide engine warranties based on this standard.

ON C 1190 was followed in July 1997 by ON C 1191 for FAME (fatty acid methyl ester). This sophisticated standard was the first to define the quality of a fuel by what goes into the tank, not what it is made from. Later in 1997 Germany published the DIN E 51606 standard, which covers both RME and FAME, and other national standards were established in the CSSR, France, Italy, Sweden and the USA. The most recent development is a CEN draft standard for biodiesel with validity all over Europe. The final CEN standard, EN 14214, is currently due to be published in mid-2003.

All these standards are the basis for building customer confidence, obtaining biodiesel warranties from manufacturers of engines and injectors, ensuring reliability and creating a positive image for biodiesel.

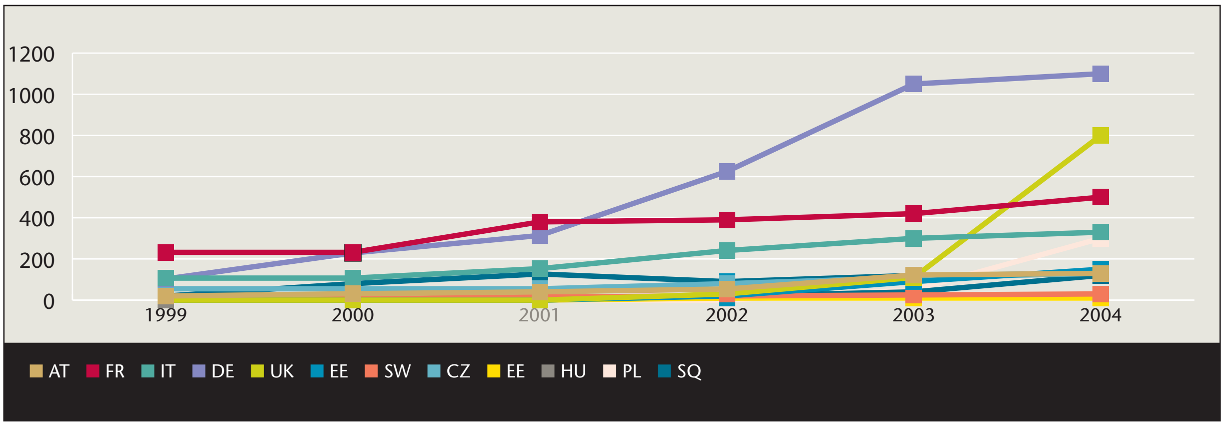
Production

Biodiesel production began in Austria in 1988 with a 500 t/y plant owned by a farmers' co-operative. Other plants soon followed, and the first industrial-scale biodiesel plant, with a capacity of 10,000 t/y, started up in Austria in 1991.

In the following years larger plants were established all over Europe. Examples are Livorno, Italy (up to 80,000 t/y), Rouen, France (at 120,000 t/y, the world's largest plant to date), Germany and Sweden. With 16 biodiesel plants, the Czech Republic is the leader in number of sites. The largest producer is Germany, which had capacity for 90,000 t/y in 1999 and plans 1,000,000 t/y by 2003, much of this in the former GDR (Figure 11).

The study *Review on Commercial Biodiesel Production Worldwide* was commissioned by the International Energy Agency, carried out by the Austrian Biofuels Institute and published in April 1998. It identified 21 countries around the world where commercial biodiesel projects had been implemented. Europe remains the leader in biodiesel by

Figure 11. Biodiesel production in the EU-25. Copyright: Austrian Biofuels Institute 2003.



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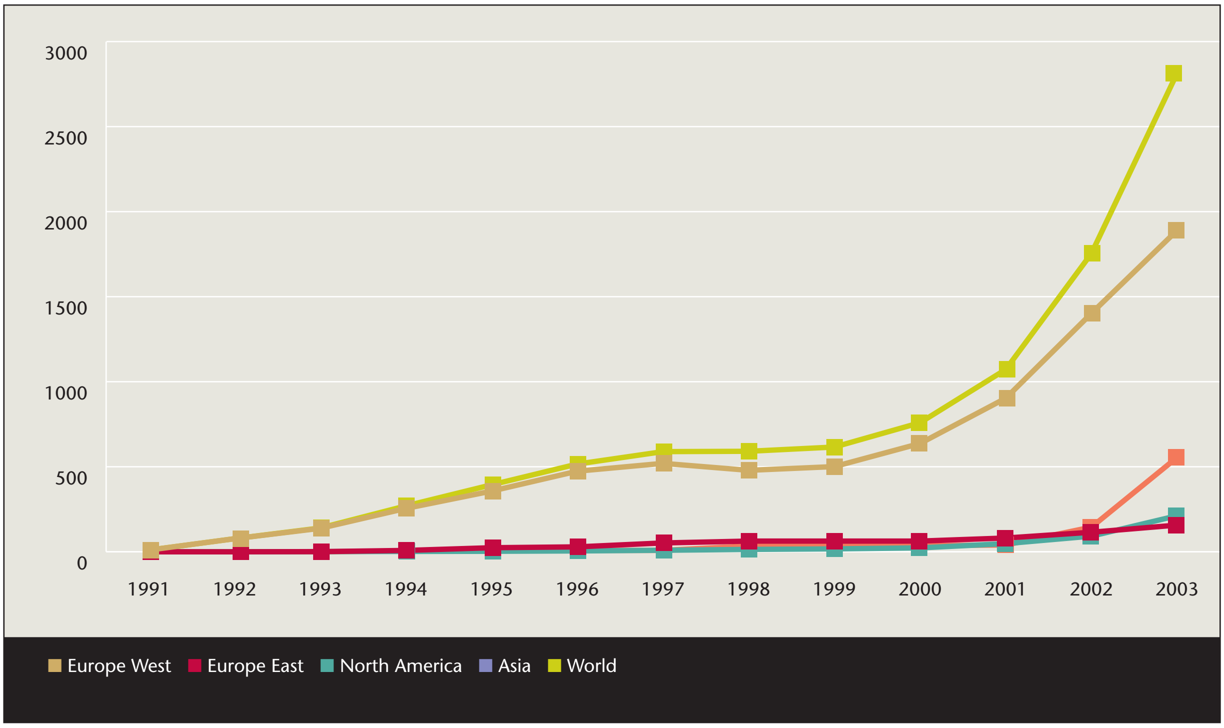

Figure 12. World biodiesel production. Copyright: Austrian Biofuels Institute.

a long way. US production has only very recently begun to increase, but the country is home to the very modern MFS plant operated by Griffin Industries in Kentucky (Figure 12).

Marketing

The present diesel market is completely dominated by fossil fuel. Biodiesel is an environment-friendly fuel with clear and substantial advantages over conventional diesel, but even at full production it could only ever meet around 8% of the diesel market. It is therefore up to professional marketers to identify market niches where the distinctive benefits of biodiesel will be best appreciated.
Indicators of niche markets for biodiesel include environment-conscious customers who are prepared to pay more for a "green" product, and strict regulations on exhaust emissions, toxicity and biodegradability. Alternatively, biodiesel can simply be blended with fossil diesel, as in France. This approach retains many of the overall advantages of biodiesel, without requiring customers to be aware of what they are buying. With regard to upcoming environmental regulations e. g. EURO 4 (2005) and EURO 5 (2008), the future use of pure biodiesel in cars is uncertain. The improvement of the biodiesel quality as the new quality rule EN 14214 demands, is a right measure for the compatibility of biodiesel.

Diesel engine warranties

Historically, biodiesel was seen as a fuel for tractors and other agricultural machinery. As a result, the first engine warranties covering the use of biodiesel were given by manufacturers of tractors and combine harvesters, including Same, Steyr, John Deere, Massey Ferguson, Lindner and Mercedes-Benz.
With the development of more sophisticated marketing strategies, warranties were extended to other diesel vehicles such as buses, taxis, boats and private cars. The most recent warranties cover the use of biodiesel in common-rail and other high-pressure fuel injection systems such as those supplied by Mercedes-Benz, Peugeot and Volkswagen.

Legal framework and regulations

The legal framework and regulations covering biodiesel have seen step-by-step progress that has taken very different paths in different countries. Among the observed motives for encouraging biodiesel are:

- increasing the security of energy supply;
- reducing dependence on fossil fuels;
- reducing greenhouse gas emissions;
- reducing local air pollution;
- protecting the soil and groundwater through the use of biodegradable products; and
- reducing health hazards by using non-toxic products.

The professional literature on biodiesel has grown impressively over the last 14 years. Publications now cover the spectrum from feedstock suitability to the performance of modern diesel engines, and from environmental advantages to experience in public bus fleets. The list of references includes some key publications.

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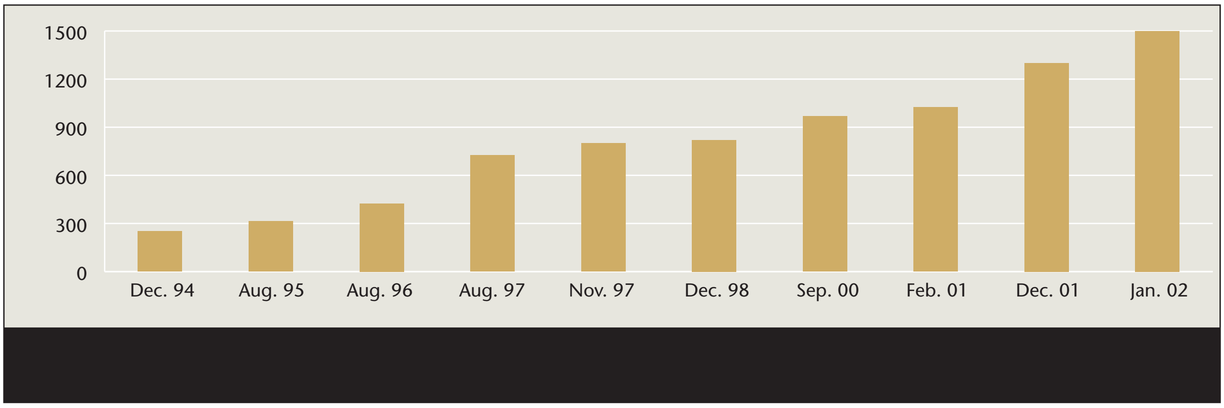

Figure 13. Development of the biodiesel filling station network in Germany, 1994–2002. Copyright: Austrian Biofuels Institute 2003.

Potential for biodiesel in the transport sector

The European Commission's Directive for the Promotion of Biofuels aims to raise biodiesel's market share to 2% by 2005 and 5.75% by 2010. These goals are widely seen as realistic and feasible; in Germany, biodiesel already has a 3% share of the diesel market and an increasing density of biodiesel filling stations (Figure 13).

The only limit to the production and use of biodiesel is generally the availability of feedstock. This does not have to be grown locally, but can be imported. Examples are North American soya oil, Malaysian palm oil, French sunflower oil, Greek cottonseed oil, Polish rapeseed oil and Danish cooking oil – recycled from McDonalds and other restaurants, and used for many years to produce biodiesel in Austria.

Denmark is well-suited to biodiesel for several reasons. The country's highly-qualified farmers and ideal climate produce high yields of rapeseed oil. A well-developed environmental consciousness will encourage Danish citizens to buy biodiesel and will allow effective cooking oil recycling schemes to be set up quickly.

Diesel engine technology for biodiesel

Recent years have seen impressive improvements in diesel engine technology to improve energy efficiency and reduce emission levels, driven by the EU Directive on Fuel Quality and the voluntary agreements defined in the Auto Oil programmes.

Modern diesel engines achieve their excellent performance through the use of high-pressure precision fuel injection equipment such as common rail systems. This requires fuels of correspondingly high quality, regardless of their origin.

European fuel standard EN 14214, which was developed in close co-operation with the automotive, oil and biodiesel industries, ensures that biodiesel is suitable for even the most modern engines. The standard forms the basis for warranties from leading car manufacturers, including Audi, BMW, Daimler-Chrysler, MAN, Seat, Skoda, Volvo and Volkswagen.

The latest technical development from vehicle manufacturers is a fuel sensor that measures the ratio of biodiesel to fossil diesel in the tank. By continuously optimising the injection timing to suit the fuel mix, it reduces emissions. The future of pure biodiesel use is not clear and must be specified by the car producer industry.

Driving forces and practical limits to the growth of biodiesel

The key driving forces for biodiesel in the EU today are the Directive for the Promotion of Biofuels and the Directive on Fuel Quality. The former is motivated by the need to cut greenhouse gas emissions in the transport sector and increase energy security by reducing dependence on imported oil. Also encouraging the growth of biodiesel are useful properties such as less local air pollution, rapid biodegradability, low toxicity to people and the environment, and high flashpoint.

The supply of biodiesel is limited, however, by the availability of oilseed crops. A biodiesel plan for Denmark should begin with a careful study of existing experience, followed by a survey of feedstock options – including recycled cooking oil. The next step is to identify those market segments in which the particular advantages of biodiesel can be put to best use. This will help to maximise the benefit to Danish citizens of a limited resource.

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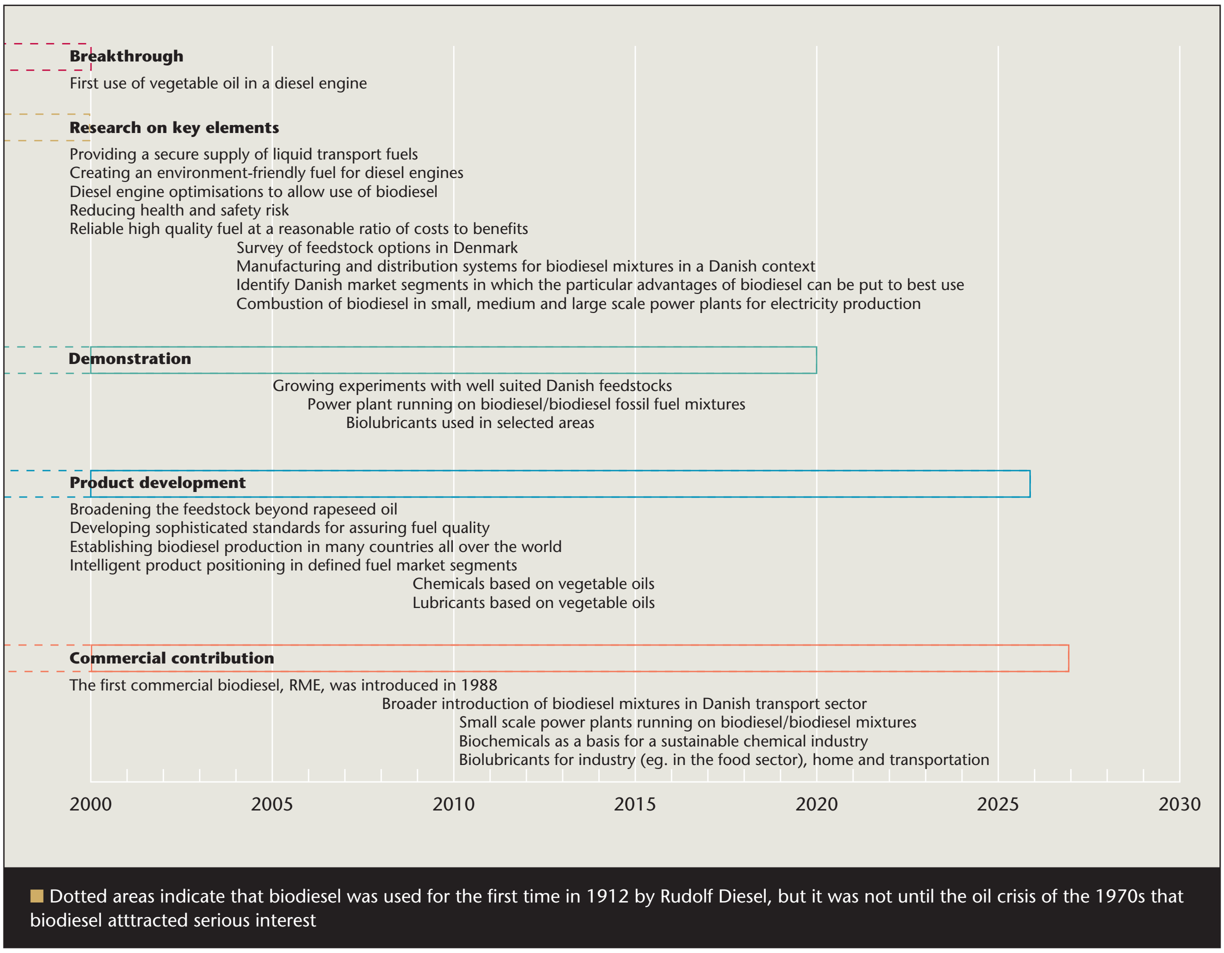

Figure 14. Time scale from breakthrough to commercial contribution