Publisher

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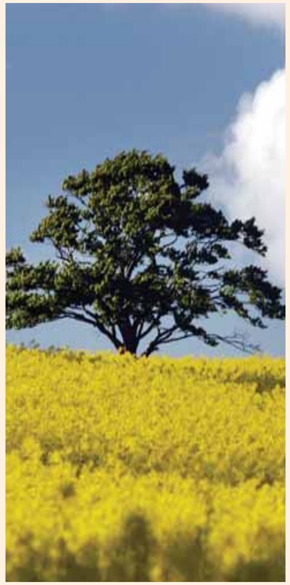
With financial promotion by the Federal Ministry
for Food, Agriculture and Consumer Protection

Printed with linseed oil-based ink

nachwachsende-rohstoffe.de

Biofuels



Plants
Raw materials
Products

Bundesministerium für
Ernährung, Landwirtschaft
und Verbraucherschutz

FACHAGENTUR NACHWACHSENDE ROHSTOFFE e. V.

Credits

Publisher:
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With financial aid from the Federal Ministry
for Food, Agriculture and Consumer Protection

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Fachagentur Nachwachsende Rohstoffe e. V. (FNR),
Union zur Förderung von Oel- und Proteinpflanzen e. V. (UFOP),
DaimlerChrysler, Arbeitsgemeinschaft Qualitätsmanagement
Biodiesel e. V. (AGQM), obs/Ford-Werke GmbH, BERU AG,
Vereinigte Werkstätten für Pflanzenöltechnologie, AGRAVIS
Raiffeisen AG, IBG Monforts, Fuchs Petrolub AG, Bio-Ölwerk
Magdeburg

Design and implementation:
WPR COMMUNICATION, Berlin

2006

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Why biofuels?

Humanity was never as mobile as it is now. Mobility is one of the central aspects of modern civilisation. Goods flowing to and from the entire world ensure a high life standard. The self-owned car is a symbol of freedom and the quality of life. However, the age of transport is based on weak foundations. The driving energy for our constantly growing fleet, considering that we consume over 50 million tons of fuel annually on German roads, is gained from mineral oil. But the reserves of mine-

ral oil which, like coal and natural gas, are counted among the fossil energy sources, are limited. Developing alternatives is essential for the future.

Nobody can say exactly when the last drop of oil will flow out of the pipelines. However, most experts agree that cheap mineral oil is becoming scarce - already. At the same time, “black gold” is in increasing demand world-wide. The uncurtailed, high demand of the industrial nations is being supplemented more and more by the demand from the populous and energy-hungry emerging nations of Asia and South America. The consequences of the shortage are reflected by the substantially rising prices for crude oil. Also, the most important oil reserves are concentrated in just a few regions which are mostly considered to be politically unstable.

Specialists are not only worried about the shortage of oil reserves. The increase in the greenhouse effect and the connected warming of the Earth’s atmosphere also sets limits which, if overstepped, can end in unpredictable changes in the climate and the conditions essential for life on Earth. These anthropogenic effects have been precipitated by the emission of carbon dioxide and other greenhouse gases caused by the combustion of fossil raw materials.

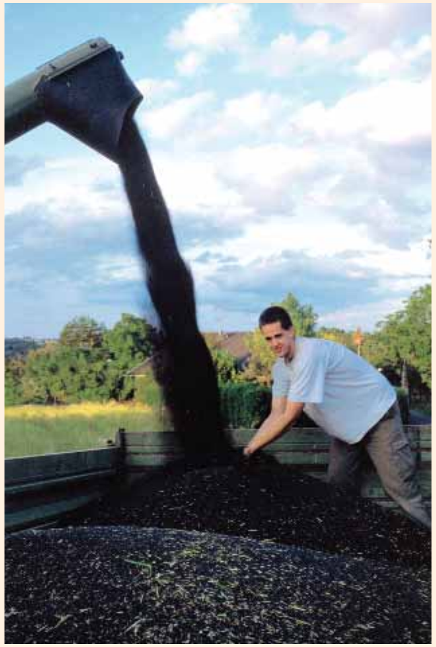
The principle that we require alternatives to fossil energy sources is undisputed, but whereas renewable energy has gained substantial market shares in heat and electricity generation, fuels are still gained almost exclusively from mineral oil. Also, the transport sector, which takes first place as Germany’s largest energy consumer ahead of private households and industry, has increased the emission of climate-changing gases against the trend since 1990 by ten percent, although a change in the trend has begun. Biofuels from oil-bearing plants, grain, wood and other regenerative raw materials provide alternatives and will make a substantial contribution to long-term mobility in the future. From a current point of view, vegetable raw materials provide the most important, technically verified and quickly viable option to substitute fossil energy sources. Hydrogen cannot be expected to achieve relevant market shares within the coming two to three decades. Because of its fossil origin, natural gas is not a source of energy which can be used in the long term or which will conserve the climate.

Apart from the use of alternative fuels, the consumption of fossil energy sources must also be reduced by more efficient exploitation concepts. In addition to biofuels, energy-saving strategies will gain substantially in significance in the coming years. Extensive market potentials and reasonable costs in conjunction with the political incentives indicate that the possibilities of biofuels will be fully exploited. In the development of renewable fuels, Germany, which is almost completely dependant on imports for oil and gas, has already taken a leading part world-wide. With the successful co-operation between science and industry and strong support by politicians and unions, the introduction of alternative fuels to the market to a significant extent has already been achieved. Beyond this, the conditions are currently being created for completely new fuel concepts which promise to ensure long-term mobility still viable in fifty years.

Biofuels – what are they?

To replace conventional drive concepts based on mineral oil in the interim, two alternative strategies are principally pursued, which differ mainly in the philosophy of the engines. A long-term approach favours a change to electric motors driven by fuel cells and which work without producing emissions. However, numerous technical and economical challenges must firstly be overcome. The other concept, which can be implemented in a short time, is based on further developments of today's combustion engine and the use of alternative fuels. Of course, numerous hybrids are also conceivable, of which hybrid vehicles (e.g. combinations of electric motors/combustion engines) are already available on the market.

The common denominator of all concepts is that they will function in the long term only with renewable energy sources, fulfil the high technical and logistical requirements and can adapt to modern engine developments. Also, they must be available at reasonable prices, contribute substantially to the reduction of CO_2 emission and exhibit a high potential as a substitute for conventional fuels.



These requirements are excellently fulfilled by biofuels such as biodiesel, rapeseed oil, ethanol, methane from biogas, or the synthetic or BtL (biomass-to-liquid) fuels which are currently in development. BtL fuels appeal to the automotive and mineral oil industries in that they are similar to petrol and diesel in many of their parameters and can be used in highly-developed combustion engines with relatively simple modifications. Apart from biomethane, which is chemically very similar to natural gas, biofuels are liquid and are thereby easy to store and can be distributed through the existing network of filling stations. They have a similarly high energy density as conventional fuels and therefore do not restrict the range of the vehicles. Finally, biofuels are easy to handle in storage and management and are a serious alternative with high public acceptance from the price aspect. High investments in new technology and infrastructure are not necessarily required for the use of biofuels.

Also: Biofuels are available in large quantities as they are gained from vegetable raw materials. A wide range of oil-bearing plants, grain, sugar beet or cane, special energy-producing plants, forest and waste wood as well as wood from fast-growth plantations serve as the basis for the raw materials.

Biofuels also contribute to climate conservation because, when they are burnt, they only release the carbon dioxide consumed previously by the plants to grow. Even though their CO_2 balance is not completely neutral due to the production process, they can make a substantial contribution to reducing the greenhouse emissions in the transport sector.

For just these reasons, biofuels constituted around 3.6 percent of the total fuel consumption in terms of energy in Germany in 2005. The largest share in this is held by biodiesel, the most well-known biofuel, which is available in its pure form and also in mixtures with conventional diesel. Pure vegetable oil is also now used in specially refitted engines. Also, the mixing of bioethanol with petrol began in 2004 and approx. 230,000 tons of this were sold in 2005. Tests in the usage of methane from biogas in natural gas-driven vehicles have also been completed. BtL fuels will become available at public filling stations in five to ten years.

Biofuels are nothing new. Rudolf Diesel tested the use of groundnut oil in a diesel engine as early as 1912 – successfully. Even then, he predicted: "Vegetable oils may be currently unimportant for technical use, but they could certainly achieve the same significance as today's mineral oil and coal tar products in the course of time". In fact, vegetable oils are now used in pure forms as fuel or as raw materials for fuels.

The gasification vehicle made a brief historical appearance in Germany. When mineral oil became scarce during the Second World War, cars and lorries were successfully refitted to run on wood gas. The wood still was mounted on these vehicles and consumed around 15 kilograms of wood for 100 kilometres. Such vehicles would now be unpractical and inefficient, although great hopes are linked with wood as the basis for fuels.

Do we have enough biomass?

To further extend the production of biofuels, much larger areas must be cultivated in the future for the required energy-producing plants than now. However, concerns that these areas are sufficiently available and whether cultivation will restrict food production are currently unjustified.

The productivity of our agriculture has risen constantly for decades, a trend which will continue in the future. At the same time, the population in Germany is falling. Of the almost twelve million hectares of arable land in this country, an increasingly large share is being freed for non-food production in the industrial and energy sectors. In 2005, energy-producing plants, mainly rapeseed for biodiesel production and also rye and wheat for bioethanol, were cultivated on over one million hectares. Estimates of the areas available in the future for energy-bearing plant cultivation predict over four million hectares in the year 2030.

In the production of biomass for fuels, new methods of cultivation and harvesting such as mixed crop cultivation and double crops also promise an increasing productivity. These methods are also interesting under the aspects of nature and environmental conservation. Plant residues already being produced can be used for certain biofuels, which includes waste wood from forestry and landscape conservation, straw and also biological wastes.

Experts predict that the biofuel produced in Germany can reach a share of up to 25 percent of the total fuel supply in the year 2020. However, a 100 percent independent supply with vegetable-based fuels in the densely populated countries of Central Europe is hardly attainable even in the long term. Imports of additional raw materials and fuels can supplement domestic production. Because biomass is produced in many countries, the danger of dependency on just a few regions, as exists for mineral oil, is not anticipated. Also, in contrast to fossil raw materials, biomass is a practically endless resource and not subject to increasing shortage.

It should also be ensured for imports that the standards of constant availability remain assured in production and processing. The total world-wide annual production of biomass is several orders greater than the total human energy demand. However, large proportions of the biomass are in remote regions and are therefore only usable to a limited extent or not at all.

Apart from the limited available area, another factor can restrict the production of biofuels: fuels are not the only form of usage of biomass. Technically developed and established methods are also used to generate heat and electricity, such as wood-fired and biogas plants. Usage of the materials as such also makes increasing demands on regenerative raw materials, for example as building and industrial materials or as raw materials for the chemical and pharmaceutical industries. In contrast to the transport sector, other renewable energy sources are available for heat and electricity generation: wind power, hydroelectric power and photovoltaic plants can generate electricity, solar thermal plants produce heat and geothermal power plants both.

The long-term objective is a regeneratively supplied society. It is therefore necessary to develop as many options as possible for all fields of energy and material demands in due time.

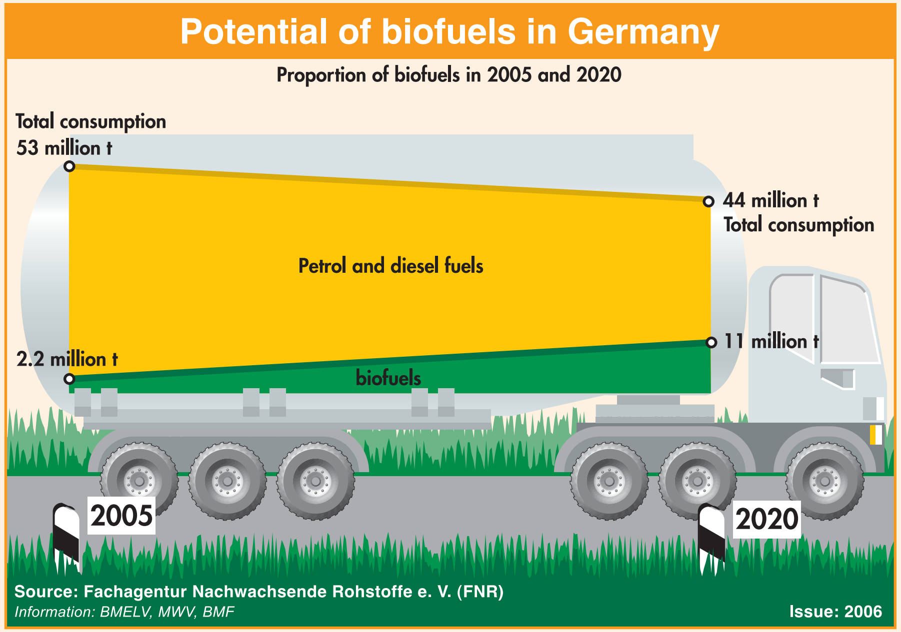


Illustration: The fuel consumption in Germany was about 53 million tons in 2005 and is anticipated to fall in the future. Experts estimate it at just 44 million tons in the year 2020. At the same time, increasingly large areas are available for energy-producing plant cultivation. This can be up to 3.5 million hectares by 2020. If this area were to be used exclusively for fuel production and the total consumption falls in the predicted way, this would cover 11 million tons or around 25 percent of the fuel demand. Other agricultural or arboricultural materials could also be used for electricity and heat generation from biomass, which are already produced as waste or have not yet been used. This includes green cuttings, waste and substandard wood, timber growth which was previously unused, straw and biogas from manure. 2.2 million tons of biofuels were produced in 2005. In terms of energy, Germany was thereby able to cover 3.6 percent of its total fuel consumption.

Political and legal circumstances

Today's motorised transport is dependant world-wide on the limited supply of mineral oil and is regarded as one of the main causes of the anthropogenic greenhouse effect. To counter this, the European Union has laid down the future proportion of biofuels in its Directive 2003/30/EC. The share of biofuels used in the member states of the EU is to rise to two percent of all fuels by the year 2005 and to 5.75 percent by 2010 (in relation to the energy yield). Supportive measures are necessary to achieve these objectives, because biofuels are pioneers on the fuel market and as such are more expensive then fossil energy sources. To prevent their spread from failure from the outset due to the cost barrier, the EU resolved Directive 2003/96/EC. This permits the EU member states to exempt all biofuels from mineral oil duties. This ruling applies both to pure fuels and pro rata to the mixing of biogenic components with fossil fuels.

Germany exempted pure biogenic fuels from mineral oil duties as early as the nineties. With the amendment of the Mineral Oil Duty Act, tax exemption was extended to mixtures with effect from 1.1.2004.

Several mineral oil corporations take advantage of this and add biogenic components to the fuels which they sell. The added amount is limited by the respectively applicable fuel standards: According to the diesel standard DIN EN 590, diesel may be supplemented by up to five percent by volume of biodiesel. The DIN EN 228 standard is applicable for petrol, which permits an ethanol proportion of up to five percent by volume. In the case of ethyl tertiary butyl ether (ETBE, a chemical derivative of bioethanol), which is also mixed with premium and super, up to 15 percent by volume are permitted.

The biodiesel standard DIN EN 14214 has also been in force since 1.1.2004, which defines the quality of the biofuel and permits its listing in the 10th Emission Protection Ordinance. The preliminary standard DIN V 51605 for vegetable oil also exists. Beyond this, all standards and regulations for the manufacture, storage, transport and usage of fuels are also obligatory for biofuels.

Biofuels are also affected by the stricter EU exhaust gas standards, which apply for diesel vehicles since 2005 (EURO IV) and from 2008 (EURO V) and for utility vehicles since 2005/2006 (EURO IV). Compliance with these requirements makes technical adjustments necessary, particularly for biodiesel and vegetable oil as pure fuels.

Vegetable oil

Vegetable oil fuel in brief	
• Raw materials:	Rapeseed oil (and other non-drying vegetable oils)
• Annual yield per hectare:	1,480 l/ha
• Fuel equivalent:	1 l of rapeseed oil substitutes approx. 0.96 l of diesel
• Market price:	Approx. 0.55 – 0.75 EUR/l
• CO_2-reduction*:	> 80 %
• Technical information:	Engine refit necessary

* In relation to the diesel equivalent

Vegetable oils are not only raw materials for biodiesel production, but can also be used in native, unchanged form in specially refitted diesel engines. Rudolf Diesel, the inventor of the diesel engine, knew: pure vegetable oil with which we dress our salads, is suitable as a fuel for diesel engines.

Raw materials

Diesel experimented with groundnut oil, but today native oil-bearing plants are used as fuel providers. Rapeseed is the most economically cultivated and processed plant in this country due to the climate. Sunflower is also a possibility, but its oil is significantly more expensive to produce. Soy and palm oils have substantial potentials world-wide.

Production

There are two fundamental production processes for vegetable oil: industrial or decentralised cold pressing, which is often conducted directly on farms or in co-operatives, and centralised production by refining in large industrial plants. In cold pressing, the cleaned oil seeds are pressed by exclusively mechanical force at maximum temperatures of 40 °C. Suspended solids are removed by filtration or sedimentation. Apart from the oil, the press cake is left with a remaining oil content of over ten percent, which is used as a protein-rich fodder.

In centralised oil extraction, the oil seed is pressed at higher temperatures after pre-treatment. The remaining oil is extracted from the press cake with solvents at temperatures of up to 80 °C. A so-called extraction grist is left, which is also used as fodder. The solvents are then separated from the oil by evaporation. After these steps of the process, the oil has more undesired components as in cold pressing, and these are then removed by refining. The end product is then an oil designated as fully refined in edible oil quality.

Fuel properties and quality

Pure vegetable oil has specific properties which makes it different from diesel and its use in combustion engines possible only after refitting. The viscosity of vegetable oil, particularly at low temperatures, is up to ten times higher than fossil diesel, which leads to technical challenges in winter running and when cold starting in conventional engines. At around 240 °C , the flashpoint is significantly higher than that of normal diesel. Vegetable oil is therefore particularly safe in storage and transport, easy to handle and is not included in any hazard classes according to the Ordinance for Flammable Liquids.

The quality of the vegetable oil is decisive to smooth running. To define the quality of rapeseed oil, the Bavarian State Institute for Agricultural Technology at Weihenstephan published the so-called

RK Quality Standard 5/2000 for rapeseed oil as a fuel in 2000. These requirements formed the basis for the preliminary standard DIN 51605.

Refitting

Before unmodified vegetable oil is used as a fuel, the engine must be refitted for the fuel to correspond to the viscosity and combustion properties of the vegetable oils. Several suppliers in Germany have developed different refitting concepts for this. These either pre-heat the fuel and the injection systems or are equipped with a so-called "2-tank system" in which the engine is started with diesel and only changes to vegetable oil when the operating temperature has been reached.

The various methods of refitting currently used in practice cost between over one and several thousand Euros according to the engine type. A guarantee is not always granted on the modifications to the engine. In particular, modifications to older precombustion chamber diesel engines are well proven, whereas all problems are not regarded as fully solved in

modern common-rail or pump/injector systems. Also, vegetable oil escaping into the engine oil often requires substantially shorter oil change intervals. Vegetable oil should not be used either in pure form or mixed with diesel in unadapted engines, as its combustion properties differ too widely from those of diesel and damage to the injection systems and deposits in the engine may occur.

Availability

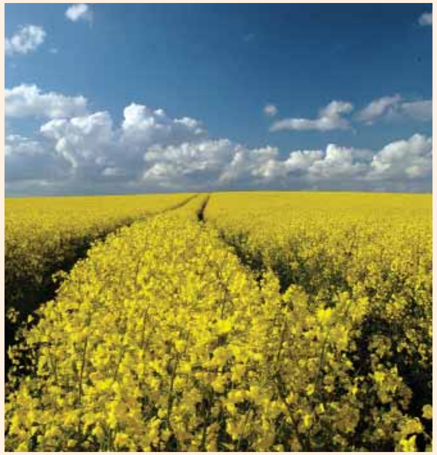
Vegetable oil is currently regarded as a niche application. Due to the small market share in comparison with biodiesel, the infrastructure is less pronounced and the network of public vegetable oil fil-

ling stations in Germany consists of about 250 stations. Many users of vegetable oil therefore use their own storage tanks. The pure fuel costs are significantly lower than those for diesel, but because additional costs for refitting and more frequent oil changes are incurred, driving cars with vegetable oil fuel becomes economically viable from about 100,000 kilometres of driving.

The development and series manufacture of vegetable oil-driven engines by the automotive industry is not anticipated in the near future. The production of biodiesel is conducted by ester interchange of vegetable oil. Methanol is required for this, which is mixed with the vegetable oil in a ratio of 1:9. Vegetable oil as an agricultural fuel has been supported by a promotion programme of the Federal Ministry for Agriculture since 2005.

Environmental aspects

Due to the relatively simple production principle, requiring little energy, pure vegetable oil has a clearly positive energy balance. With this, vegetable oil as a fuel has a substantial CO_2-saving effect. Also, vegetable oil is biodegradable in a short time in soil and waters and, correspondingly, is not classified in any water hazard class under German law.



Energy balance

The energy balance takes account of the entire life cycle from cultivation of the vegetable raw materials through harvesting and processing to its use in the engine.

Renewable fuels contribute to the net energy gain if the energy yield (output) exceeds the energy expenditure for their manufacture (input). Usually, biofuels have positive energy balances, meaning that the fuel provides more energy for use in engines than was expended previously for its production.

For a better comparison of the energy efficiency, the so-called output/input ratio is used. The lower the energy required to manufacture the fuel, the better is the net energy gain. Vegetable oil has an output/input ratio of approx. 3-5:1, for biodiesel this is still about 3:1.

Biodiesel

Biodiesel is the best known and most widespread biogenic fuel in this country. Adapted to the diesel engine, biodiesel already contributes 1.8 million tons per annum to the fuel consumption in Germany. Several manufacturers approve their vehicles directly from the factory for use with biodiesel, others offer corresponding solutions as extras or accessories. Since 2004, mineral oil corporations also add biodiesel to conventional diesel by up to five percent, without the need for vehicle owners to fulfil specific technical requirements.

Raw materials

Many people envision flowering rapeseed fields when thinking about biodiesel, and in fact, it is gained from rapeseed in Germany. However, other vegetable oils and used edible and animal fats are possible as the basis.

Production

For the chemist, biodiesel is a vegetable oil methyl ester or a fatty acid methyl, also known as FAME. The abbreviation RME for rapeseed oil methyl ester has also become common. Biodiesel should not be confused with vegetable oil, but is made from it.

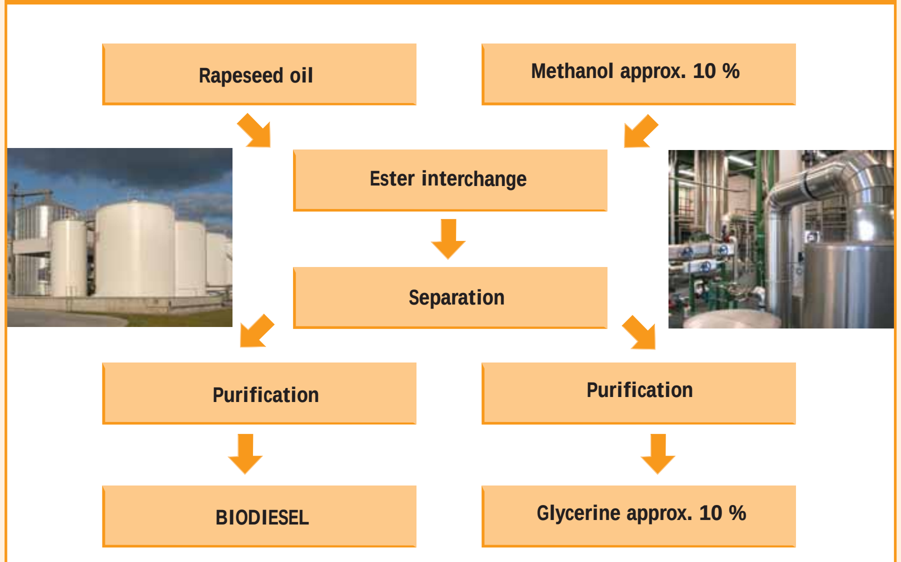
The production of biodiesel is conducted by ester interchange of vegetable oil. Methanol is required for this, which is mixed with the vegetable oil in a ratio of 1:9. In addition, 0.5 to one percent of a catalyst is added at a temperature of 50 to 80 °C. In the chemical reaction which then occurs, the vegetable oil molecule,

Biodiesel in brief

• Raw materials:	Rapeseed oil (and other non-drying vegetable oils)
• Annual yield per hectare:	1,550 l/ha
• Fuel equivalent:	1 l biodiesel substitutes approx. 0.91 l of diesel
• Market price:	Approx. 0.75 – 0.95 EUR/l
• CO_2-reduction*:	Approx. 70 %
• Technical information:	Biodiesel in pure form: manufacturer's approval required; mixtures up to 5 % without refitting the engine

* in relation to the diesel equivalent

Ester interchange of rapeseed oil to create biodiesel



Source: UFOP, photo: Bio-oil mill Magdeburg

consisting of glycerine and three fatty acid chains, is broken down. The fatty acids combine with the methanol to form biodiesel. Glycerine is also produced, an alcohol which is used in many fields such as the pharmaceutical and food industries and in oleochemistry.

Fuel properties and quality

Whereas the engine must be adapted to the fuel when vegetable oil is used as described in the chapter above, ester interchange to form biodiesel is an adjustment of the fuel to the engine. In its viscosity and ignition properties, biodiesel is similar to fossil diesel. By mixing additives, as is normal with conventional fuel, winter compatibility is also achieved – biodiesel can be used without difficulty down to minus 20 °C.

The lubricating effect of biodiesel, important in avoiding wear to the engine, is in fact significantly higher as with fossil fuel. The energy yield per litre is slightly lower, which can lead to an increase in consumption of up to five percent.

In vehicles which have not been approved, biodiesel can attack plastic and rubber components such as seals and fuel lines due to its properties, which are similar to solvents. If a vehicle is filled with biodiesel for the first time after a long mileage with mineral oil diesel only, it is also possible that residues of the fuel may be released, causing the filter to become blocked. It is therefore advisable to change the fuel filter after several tank fillings with biodiesel.

The requirements necessary for the fuel quality are defined in the Europe-wide standard DIN EN 14214, which has been legally implemented in Germany by listing in the Fuel Quality and Designation Ordinance, the 10th Federal Emission Protection Ordinance. Biodiesel is thereby the first biofuel to be counted amongst the so-called commonly available fuels and is subjected to unannounced inspections by the State authorities. Public filling stations are obliged to verify the standard quality of the fuel by attaching the DIN label to the fuel pumps.

Also a large number of the German and Austrian biodiesel manufacturers have amalgamated in the Workgroup for Biodiesel Quality Management (Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e. V. (AGQM) to ensure that the standard is fulfilled by their own measures. Numerous biodiesel filling stations are also members and can be identified by a validation mark on the fuel pumps.

Label DIN EN 14214 for biodiesel

Label Biodiesel Quality Management on fuel pumps (AGQM)

Approval

The German preliminary standard was the basis for several automotive manufacturers to approve many of their models for biodiesel. Particularly the Volkswagen corporation, but also other manufacturers have declared many of their models to be suitable for biodiesel. In the approved series, susceptible plastic and rubber components are replaced by the manufacturer with more resistant materials.

More recently, approvals have been granted only in conjunction with special biodiesel packages. The main reason is the new EU exhaust gas standard Euro IV, which came into force in 2005. Due to the higher nitrogen oxide emissions (NO_X), biodiesel as a pure fuel can no longer comply with the stricter values of this standard without further measures. Using a sensor, which detects the different fuels or mixtures, the engine management system can be adjusted to the respective fuel mix ratio and combustion can be optimised accordingly. In this way, the exhaust gas limits of Euro IV can be fulfilled without difficulty. The biodiesel sensor is now available as extra equipment for several new VW models. No approval has yet been issued for the combination of biodiesel with soot filters in cars. The necessary investigations are still in progress.

Illustration: Biodiesel Sensor

Availability

Until now, biodiesel is the only biofuel for which a pronounced infrastructure exists. It is now available nation-wide in Germany at over 1,900 filling stations.

Biodiesel is less expensive than fossil diesel, but the price difference is lower than for vegetable oil. On the other hand, apart from slightly higher maintenance expenditure for filters and oil changes, no costs are incurred for refitting. Not least due to these economical advantages, biodiesel has gained a notable share in the fuel market in the last twelve years, which was around three percent of the total consumption or 1.8 million tons in Germany in 2005. Apart from private car drivers, who buy at private filling stations, biodiesel is also used by the operators of larger vehicle fleets such as taxi companies and haulagers with their own filling facilities.

In 2005, approx. 45 percent of the biodiesel was delivered to this clientele and 15 percent to independent filling stations and agricultural clients. Since the beginning of 2004, several large mineral oil corporations mix biodiesel with the conventional diesel sold by them to a proportion of up to five percent. Their share in biodiesel consumption in 2005 was 40 percent. According to the mineral oil and automotive industries, mixing is not anticipated to cause problems in compliance with the Euro IV exhaust gas standard. The refitting of tractors and agricultural machinery for biodiesel has been supported by the Federal Ministry for Agriculture in a promotion programme since 2005.

Biodiesel sales (in tons) in Germany

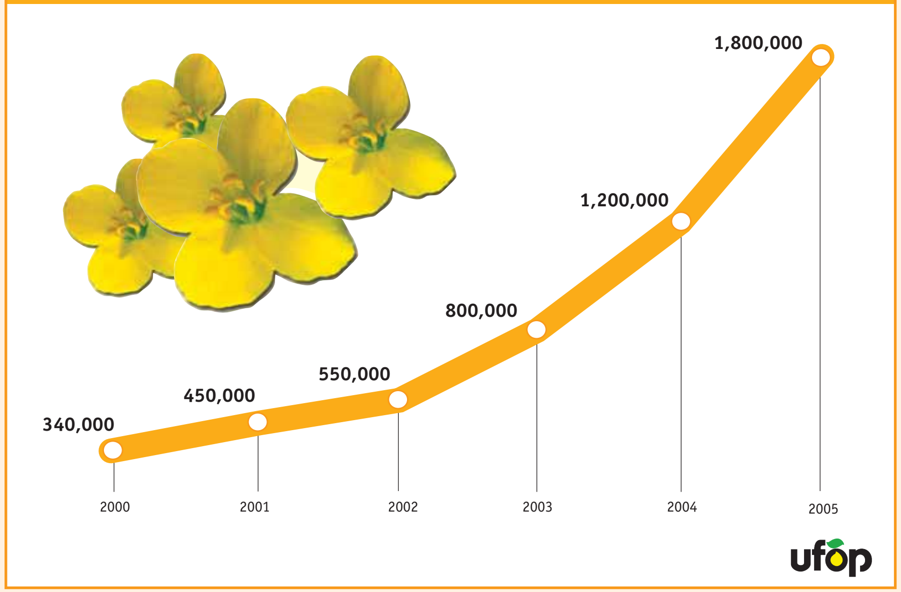


Illustration: Development of biodiesel sales

Environmental aspects

With its positive energy balance – the net energy gain is about three times the energy consumed for production and logistics – biodiesel conserves large quantities of mineral oil and also fossil CO_2 emissions. Biodiesel has been classified by the Federal Environment Agency (UBA) in water hazard class 1 for low water hazard substances, where as diesel is in class 2 "water hazard" and petrol is in class 3 "high water hazard". In a study on the biodegradability, it was found that biodiesel is degraded by over 98 percent in 21 days.

Bioethanol

Ethanol fuel in brief	
• Raw materials:	Grain, sugar (wood)
• Annual yield per hectare:	2,560 l/ha (from grain)
• Fuel equivalent:	1 l ethanol substitutes approx. 0.66 l of petrol
• Market price:	Approx. 0.50 – 0.60 EUR/l
• CO_2-reduction*:	30 – 70 %
• Technical information:	Can be mixed with fuel by up to 5 %

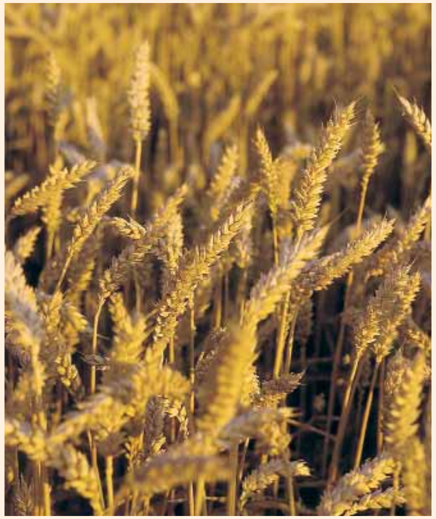
* In relation to the petrol equivalent

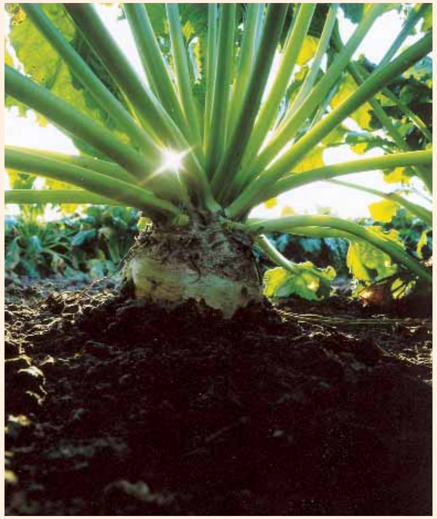
Whereas vegetable oil and biodiesel are suitable for diesel engines, bioethanol can substitute petrol such as premium, super and LRP. In Germany, the biofuel was introduced to the fuel market when the first large ethanol factories were put into operation. This can be mixed with petrol from mineral oil manufacturers in quantities of up to five percent, which was conducted in 2005 with around 230,000 tons. Series vehicles which run with a higher proportion of ethanol have been available in this country since 2005.

Raw materials

Ethanol is gained by fermenting the sugar contained in plants. In principle, sugar, starch and cellulose-bearing plants are suitable, mainly wheat, rye and sugar beet. In the USA and Europe, ethanol is manufactured mainly from maize and grain, whereas Brazil favours the fermentation of cane sugar.

By the development of suitable enzymatic processes, wood, energy-producing plants and straw could also be fermented. These new concepts are currently subject to intensive research.





Manufacture

The raw material is the sugar contained in plants, which is fermented by yeast and enzymes to form ethanol. With starch-bearing plants, the starch is firstly converted into sugar, also by enzymes. The same applies to cellulose-bearing plants.

In the fermentation of sugar and starch-bearing plants, the so-called mach is formed as a by-product in large quantities and can be used as fodder or as a substrate for biogas plants.

At the moment substantial capacities for the manufacture of ethanol are being created in Germany. In addition, imports, mainly from Brazil, are entering the European fuel market.

Fuel properties

Ethanol has properties which improve the quality of petrol. The alcohol has a higher octane value than conventional petrol. The octane number designates the antiknocking property of the fuel. Knocking describes uncontrolled combustion which puts heavy mechanical and thermal loads on the engine. A high octane number stands for an antiknocking fuel.

On the other hand, the energy yield of ethanol is about one third lower than petrol; one litre of ethanol substitutes only about 0.66 litres of petrol. As a mixed component, ethanol also increases the vapour pressure of the fuel. This must be countered by suitable measures, particularly in summer.

Availability

In Germany, series vehicles have been available since 2005 which can run with an ethanol proportion of up to 85 percent. These so-called flexible-fuel vehicles (FFV) are supplied in Europe mainly by Ford and Saab. In Sweden, the USA and Brazil, flexible-fuel models have been sold for several years, so that extensive experience has been gained in these countries with the admixture of ethanol to petrol. In Brazil, the national Proalcool programme commenced in 1975 due to the first mineral oil crisis, with the objective of constantly increasing ethanol production from native raw materials, particularly sugar cane. The ethanol was used as a pure fuel or in a mixture with petrol. There are now about 14 million ethanol-compatible cars in Brazil. Also, a substantial and growing proportion of new vehicles are equipped with flexible-fuel technology.

The petrol fuel standard DIN EN 228 permits mixing of up to five percent of ethanol with the fuel. If the five percent by volume of all petrol fuels were to be replaced by ethanol in Germany as permitted by the standard, this would represent just less than 1.3 million tons per year.

Environmental aspects

Conventional ethanol production is a relatively energy-intensive process. Despite this, the energy balance for the fuel is positive.

Due to its good biodegradability, ethanol is not a hazard for soil and waters.

MTBE and ETBE

MTBE (methyl tertiary butyl ether) is mixed with petrol as an additive to improve the octane number. Because MTBE has toxic properties, MTBE is more and more frequently replaced by ETBE (ethyl tertiary butyl ether). ETBE is produced from ethanol and isobutene, a by-product of fuel production, and may be mixed in maximum quantities of 15 percent with petrol. Until now, the mixing ratio is between 0.4 percent for premium petrol and ten percent for LRP.

Methane from biogas

Biomethane in brief	
• Raw materials:	Maize and other energy-producing plants, manure and organic waste
• Annual yield per hectare (from maize silage):	4,950 m³ or 3,560 kg
• Fuel equivalent:	1 kg of methane substitutes approx. 1.4 l of petrol
• Market price:	Not specified
• CO_2-reduction*:	Not specified
• Technical information:	Biomethane can be used in natural gas vehicles without adjustments

* In relation to the petrol or natural gas equivalent

Cars which use a gaseous energy source in place of a liquid already exist: they run on natural gas. Pure or bivalent natural gas vehicles are now supplied as standard models by many automotive manufacturers. Biomethane from biogas can be used in these without further technical adjustments.

However, the corresponding treatment processes for biogas to reach the quality of natural gas are relatively new and therefore connected with high costs.

Raw materials

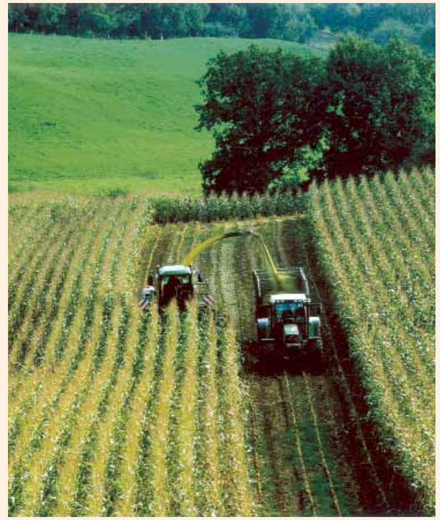
The raw material for biomethane is biogas, which is now primarily gained in Germany in agricultural facilities, mainly by the fermentation of manure and maize silage.

Production

Apart from a methane content of approximately 55 percent, biogas also contains substantial amounts of carbon dioxide. In addition, there are small quantities of hydrogen sulphide and other trace gases. However, only the methane is usable as a fuel, which is chemically very similar to natural gas. The separation of the remaining components of biogas is therefore a decisive prerequisite. The technical processes existing for this are not yet economical.

Fuel properties

Gaseous energy sources are far more difficult to store and transport than liquid fuels and require more storage space due to their substantially lower energy density. In natural gas vehicles, the methane must be stored in specially installed pressure tanks at a pressure of 200 bar. However, these fundamental disadvantages are offset by positive combustion properties. In comparison with petrol and diesel, the emission of several toxic substances such as nitrogen oxides and reactive hydrocarbons can be reduced by up to 80 percent. Biomethane also contributes to climate conservation because a large proportion of the CO_2 released by combustion was previously bound in green plants in the production chain of the biogas.



Availability

Of the nearly 56 million motor vehicles in Germany, only about 35,000 run with natural gas until now. These vehicles could run on biomethane without further technical adjustments, but there are currently no public filling stations. In Sweden and Switzerland, biomethane has been used in busses and lorries for a longer period.

Biomethane can reach the consumer by two routes. One means is to feed it into the existing natural gas network, to which the approximately 650 existing natural gas filling stations are connected. The difficulty of this is the technical barriers, as treatment to reach the quality of natural gas and supply into the natural gas network still present high requirements. Also, the gas infeed must be provided with a stable legal basis.

Biogas plant operators therefore currently choose a second route: the construction of decentralised biomethane filling stations directly at biogas plants.

Synthetic biofuels (BtL fuels, Sunfuel®)

Synthetic fuels from biomass are a relatively new development not yet available on the market. At the moment, there are only small research and pilot plants, but great hopes are already linked with the fuel designated as biomass-to-liquid (BtL, also Synfuel or Sunfuel®), one reason being that synthetic fuels can be ideally adapted to current engine concepts.

Raw materials

A great advantage of BtL fuel is that very many different raw materials can be used. The range extends from waste materials already produced, such as straw, biological wastes and wood offcuts to energy-producing plants which can be specially cultivated for fuel production and fully utilised.

Production

BtL fuels can be gained from biomass in a two-stage process. In the first stage, a synthetic gas is produced. For this purpose, the biomass is placed in a reactor and broken down in the presence of heat, pressure and a gasification agent, for example oxygen. This process is also known as gasification. The produced synthetic gas is composed mainly of hydrogen, carbon monoxide and carbon dioxide. In the second stage, fuel components are synthesised from this, which can be processed to the BtL end product, optionally with diesel or petrol properties. The best-known synthesising process is the Fischer-Tropsch (FT) synthesis, but the methanol-to-synfuels synthesis is also regarded as a promising option. In Germany and Europe, several companies and research institutes are co-operating to test the production of BtL fuels on a pilot scale.

BtL fuel in brief

• Raw material:	Energy-producing plants and wood
• Annual yield per hectare:	Approx. 4,030 l/ha*
• Fuel equivalent:	1 l of BtL fuel substitutes approx. 0.97 l of diesel*
• Market price:	Not specified
• CO_2-reduction**:	> 90 %*
• Technical information:	Can be used in pure form or in mixtures without adjustment of the engine

* Information results from calculations ** In relation to the diesel equivalent

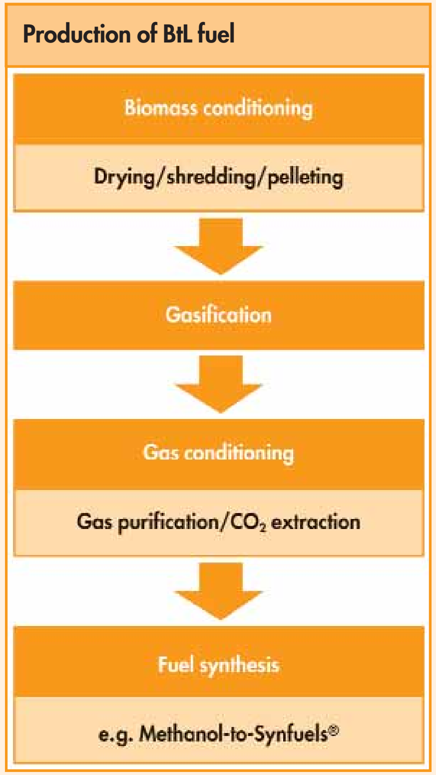


Illustration: BtL process diagram

Fuel properties

The chemical properties of the hydrocarbons in BtL fuel permit efficient and complete combustion with low exhaust gas emission. In particular, the properties of the fuel can be influenced by changes in specific parameters such as the pressure, temperature and catalysts during synthesis and the subsequent treatment and can be "fine-tuned". Synthetic fuels are therefore also known as tailored fuels. They therefore comply completely with the trends: modern fuels and combustion engines are already highly developed and adapted to each other to be able to fulfil the constantly increasing requirements for less emission and improved energy efficiency. Similar to CtL and GtL fuels (see box), BtL fuels offer much more extensive possibilities, but in contrast to these are synthesised from renewable resources and therefore permit substantial savings in climate gas emission.

BtL fuel can be used immediately and without technical modifications to the engine and logistics are possible using the existing infrastructure.

Synthetic gas for the production of plastics and other chemical products has been gained from coal, mineral oil and natural gas for a long time. Synthesis to fossil fuels is already in practice. The novelty of the BtL process is particularly the use of biomass, for which several technical problems remain to be solved. For example, issues are unclarified regarding the quality of the synthetic gas and the logistics. In contrast with mineral oil and natural gas, vegetable raw materials occur very heterogeneously over wide areas, or decentralised. Depending on the size and distribution of the future plants, it may possibly be necessary to develop new systems for raw material collection, storage and transport.

CtL and GtL fuels

Whereas BtL fuels represent a new development, CtL (coal-to-liquid, based on coal) and GtL fuels (gas-to-liquid, by synthetic natural gas liquidisation) have been produced for a long time as synthetic fossil fuels.

The first production of CtL fuels on an industrial scale was conducted in Germany from 1938 due to the shortage of mineral oil. Fischer-Tropsch synthesis is used as the synthesising process, which was developed in 1925 at the Kaiser-Wilhelm Institute for Coal Research. Today's plants for GtL and CtL fuels are operated by the mineral oil industry in South Africa, Malaysia and other countries. China, with its rapidly growing fuel demand, is also employing the CtL method and intends to construct two plants with an annual output of 60 million tons.

Potential

Because a very wide range of raw materials using all parts of plants is available for BtL fuel, its potential significantly exceeds that of other biofuels. Estimates predict that the equivalent of 4,000 litres of BtL fuel can be produced on an area of one hectare. If four million hectares can be made available in the long term in Germany for the cultivation of energy-producing plants, approximately 25 percent of today's fuel consumption could be replaced with BtL fuels. Throughout Europe, the potential is estimated at 40 percent of the total fuel demand.

Environmental aspects

Recent studies give a positive report to BtL fuels with regard to their environmental and energy balance.

According to current knowledge, it will be possible in the future to transfer about 50 percent of the energy contained in vegetable raw materials to BtL fuels under optimum conditions. This should result in substantial potential CO_2 savings.

Overview of biofuels

According to current knowledge, the five described options, vegetable oil, biodiesel, ethanol/ETBE, biomethane and BtL fuels offer the greatest potentials of the biofuels. BtL fuels are a promising option for the future, but will not achieve relevance to the market before 2010. Apart from these five options, other concepts exist such as the production of methanol and dimethyl ether from biomass. The latter are still far removed from technical implementation, so that they are not described in detail here.

Vegetable oil, biodiesel, ethanol, methane from biogas and BtL fuels differ in their properties, technical requirements, economical aspects and potentials quite widely in part, but are all justified in the way to long-term mobility.

The technical specifications of vegetable oil, biodiesel and BtL fuels are compared with those of diesel in Table 1. The high viscosity and flashpoint of rapeseed oil are apparent. In contrast, biodiesel and BtL fuels differ from diesel only marginally.

In its properties, ethanol is comparable with petrol. The data can be seen from Table 2. The substantially lower calorific value of ethanol is offset by its octane number of over 100. Methane from biogas is gaseous and chemically identical with natural gas, therefore not differing in its parameters. The most important characteristic values are listed in Table 3.

	Density [kg/l]	Calorific value [at 20 °C MJ/kg]	Calorific value [MJ/l]	Viscosity [mm^2/s]	Cetane-number	Flash-point [°C]	Fuel-equivalence [l]
Diesel	0.84	42.7	35.87	5	50	80	1
Rapeseed oil	0.92	37.6	34.59	74	40	317	0.96
Biodiesel	0.88	37.1	32.65	7.5	56	120	0.91
BtL*	0.76	43.9	33.45	4	> 70	88	0.97

*Table 1: Parameters of biofuels in comparison with diesel (*Values represent Fischer-Tropsch fuels}*

	Density [kg/l]	Calorific value [at 20 °C MJ/kg]	Calorific value [MJ/l]	Viscosity [mm^2/s]	Octane-number [ROZ]	Flash-point [°C]	Fuel-equivalence [l]
Petrol	0.76	42.7	32.45	0.6	92	< 21	1
Bioethanol	0.79	26.8	21.17	1.5	> 100	< 21	0.65

Table 2: Parameters of bioethanol in comparison with petrol

Biodiesel and BtL fuels are suitable for use in highly developed combustion engines without major adjustments. Vegetable oil can be used in diesel engines after refitting, ethanol and ETBE are possible substitutes for petrol. For ethanol, there are also the so-called flexible-fuel concepts which tolerate an ethanol content in the fuel of up to 85 percent. Biomethane can be used in natural gas vehicles without adjustments.

BtL fuels have the highest area-related potentials in comparison with all other biofuels (Table 4). With a calculated yield of over 4,000 litres per annum, substantial-

	Density [kg/l]	**Calorific value** [MJ/kg]	**Calorific value at 20 °C** [MJ/l]	**Octan number** (ROZ)	**Fuel equivalence** [l]
Methane	0.72	50	36	130	1.4

Table 3: Parameters of methane (from biogas or natural gas)

ly more BtL fuel can be produced per hectare than any other biofuels. This and the wide range of raw materials, coupled with the favourable combustion properties and comparatively simple introduction to the market using the existing infrastructure, justify the hopes linked with BtL fuels.

	Yield [l/(ha a)]	**Fuel equivalence** [l/(ha a)]	**GJ**/(ha a)
Rapeseed oil	1,480	1,420	51
Biodiesel	1,550	1,410	51
BtL	4,030	3,910	135
Bioethanol*	2,560	1,660	54
Biomethane**	3,560***	4,980***	178

*Table 4: Potential yields of biofuels (*production from wheat, **on the basis of maize, ***[kg/(ha a)])*

Outlook

Despite the promising potentials of biofuels, the combustion engine in combination with fossil diesel and petrol fuels will dominate the transport sector in the coming decades. Biofuels will only expand slowly on the market and are not the only strategy to save or replace fossil fuels.

In co-operation with a group of experts, the German government has identified four options which have the greatest potential for the future. According to this, more efficient diesel and petrol engines, new engine concepts such as hybrid drives, BtL fuels and hydrogen in fuel cell vehicles offer the greatest opportunities to save fossil fuels.

Apart from these four options, some of which will have immediate effect, some later, the biofuels biodiesel and bioethanol are making a large contribution to substituting fossil fuels. In the short term, they will make the greatest contribution of all alternative fuels with a market share of about five percent by the year 2010, which will be achieved mainly by mixing with conventional fuels.

Of all biofuels, BtL fuels offer the greatest potential quantities in the long term, but will only make a significant contribution to the fuel supply after 2010, as production capacities on an industrial scale do not yet exist and a series of technical issues remain to be solved. Until the year 2020, their share in the overall consumption can then be increased successively to up to eight percent. The greater the share held by BtL, the more the significance of biodiesel and bioethanol will recede.

Other biofuels such as pure vegetable oil or other options not described in this brochure, methanol and dimethyl ether, are not anticipated to make a substantial contribution as a replacement for fossil fuels in the foreseeable future.

The opportunities of the above named saving and substitute options will not occur automatically. The state is creating suitable conditions by tax incentives, the promotion of research and development, support in the construction of demonstration and pilot plants and by setting technical and legislative standards. Not only actions by the state are required. Science, the mineral oil and the automotive industries must take part in the tasks confronting us. In particular, the construction of pilot plants and the implementation of the gained knowledge in a large-scale technical production is essential as a substantial contribution of businesses. Not least, consumers can support the necessary transformation by a positive approach to the upcoming changes.

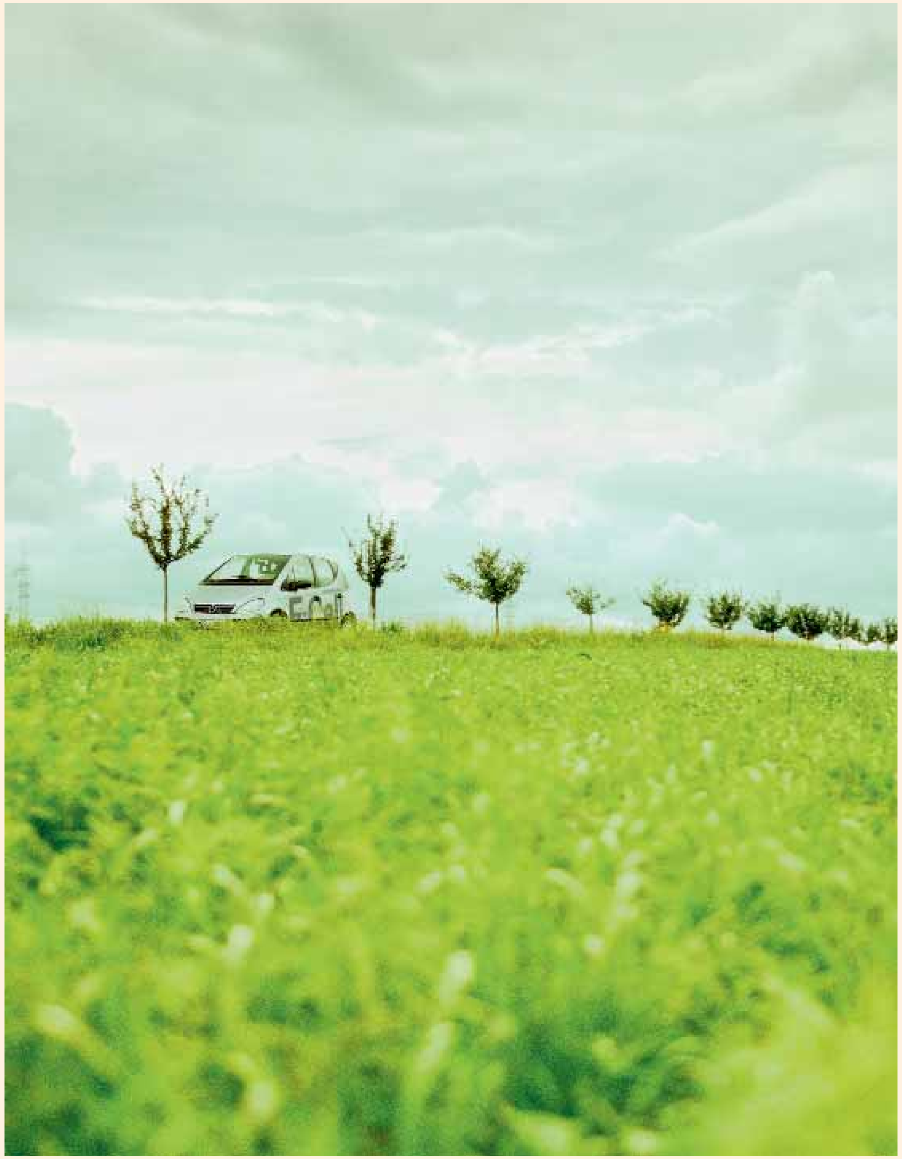
With tax incentives, important fundamental decisions have already been made by the state. In the exemption from mineral oil duties for biofuels, initially limited until 2009, the German government intends to press nationally and in Europe for an extension.

In research and development, numerous projects focussing on the fields of hybrid drives, biodiesel, vegetable oil and BtL fuels as well as fuel cell drives have already been supported.

Action is still required in the construction of pilot plants. This applies particularly to plants to produce BtL fuels. In addition to the existing pilot plant in Freiberg, the German government is currently preparing the construction of a second plant in which alternative production processes are to be tested.

To summarise: the transformation of the fossil age which has dominated the western world for around 150 years is not only one of the greatest tasks of the century, is has already begun! The share of renewable energy in energy supplies is increasing constantly and awareness of the necessity of change is growing in all levels of the populace. There is still much to do, especially in the transport sector.

The breakthrough into a circulating economy and a future characterised by responsible management will only be successful, including in transport, if it is supported jointly by all groups of society.



Addresses

Fachagentur Nachwachsende Rohstoffe e. V. (FNR)
www.fnr.de
www.bio-kraftstoffe.info
www.btl-plattform.de

Arbeitsgemeinschaft Qualitätsmanagement Biodiesel e. V. (AGQM)
www.agqm-biodiesel.de

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www.tfz.bayern.de

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