BIODIESEL PRODUCTION:

TECHNOLOGIES AND EUROPEAN PROVIDERS

A REPORT TO IEA BIOENERGY TASK 39

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Report T39-B6 06 July 2007

Full Citation

Bacovsky, D., Körbitz, W., Mittelbach, M., Wörgetter, M. (2007). Biodiesel Production: Technologies and European Providers. IEA Task 39 Report T39-B6, 104 pp.

Editorial

IEA Bioenergy, an implementation agreement of the International Energy Agency and an international collaboration in Bioenergy, aims to accelerate the use of environmentally sound and cost-competitive bioenergy on a sustainable basis, and thereby achieve a substantial contribution to future energy demands. (www.ieabioenergy.com/)

The main objectives of Task 39 "Liquid Biofuels" is to provide participants with comprehensive information that will assist them with the development and deployment of biofuels for transportation fuel use. The Task builds upon the successes of previous efforts to deal with the complex technical and infrastructure issues related to biofuels in a coordinated manner.

IEA Bioenergy Task 39 "Liquid Biofuels from Biomass" is currently composed of 13 countries or regional associations, including Austria, Canada, Denmark, the European Union, Finland, Germany, Ireland, Italy, the Netherlands, South Africa, Sweden, the United States and the United Kingdom. The Task brings together leading researchers and industry pioneers in the bid to successfully introduce biofuels for transportation into the commercial marketplace.

The Task focuses on biodiesel, lignocellulosic ethanol, and on biofuels policy.

The biodiesel production is booming worldwide, with Europe accounting for the by far largest share of the global biodiesel production. European companies have gained much experience in biodiesel production technology, and an increasing number of engineering companies is offering its services for the engineering and construction of biodiesel production plants. Application of a well-operating production technology is crucial, both in means of economic performance of the production plant, as well as in means of the quality of the biodiesel delivered to the costumer.

This report describes the current status of biodiesel production technology, and lists those European biodiesel technology providers who can prove their experience by operating reference plants. The applied process technology is depicted by means of process steps, suitable feedstock sources and qualities, and achieved biodiesel quality. Full contact details of technology providers and reference plants are given, so as to enable the reader to get in touch.

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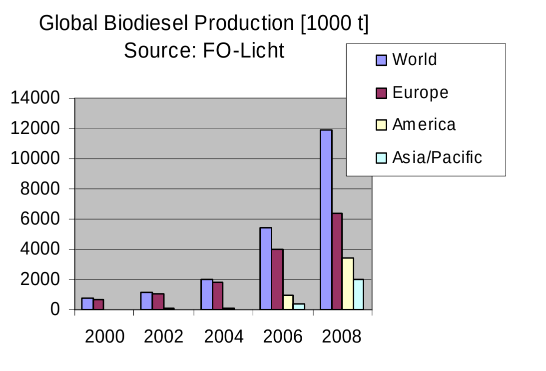
1 Introduction

The principles of methyl ester production from triglycerides of fatty acids have been known for a century. The use of vegetable oils as transport fuels in diesel engines has been proposed for the first time during World War II, but lack of feedstock and the development of the fossil oil market stopped this idea in the early stage.

Only after the oil crisis of 1973, research on methyl ester production technology and its application in diesel engines initiated worldwide. In Austria and France stake holders from agriculture and industry were inspired and interest of investors arose. Pilot projects were conducted in both countries by the end of the 80ies. One of the most important results was the publication of the world´s first standard for rape oil methyl ester ÖNORM C 1190, which laid the basis for the approval of fatty acid methyl esters as a transport fuel and for a number of international standards. In France the quality criteria were published first by ministerial order. More details are available in the report on Biodiesel Standardization, which can be downloaded from the task outputs/publications section of the task 39 website (http://www.task39.org).

The astonishing development of Biodiesel ever since is due to the efforts of organizations like Ademe, and Prolea (both France), and UFOP (Germany), and is described in more detail in the report "Worldwide Review on Biodiesel Production" (http://www.task39.org). Initiated by the activities of the oil mill "Ölmühle Leer" in Germany, several companies dealing with vegetable oils have invested into transport fuel production, hereby transferring know-how from their core businesses. A beneficial business environment has triggered a Biodiesel boom in Germany; established biodiesel producers have secured access to economic production technologies and hold strong market positions. Task 39 has identified and described "Biodiesel Production Best Case" examples – again published in the task output section of the task 39 website. The German success story was subject of a task 39 workshop in Potsdam, Germany, in 2006; the workshop proceedings are at present available for task 39 members only, but will be published on the website by the end of 2007.

Meanwhile the biodiesel production is booming worldwide, with Europe accounting for the by far largest share of the global biodiesel production. European companies have gained much experience in biodiesel production technology, and an increasing number of engineering companies is offering its services for the engineering and construction of biodiesel production plants.



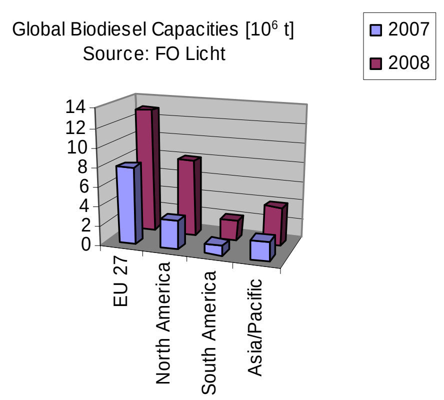


Figure 1: World Biodiesel Production

The European biodiesel industry has achieved a high level of maturity over the last years. The success is built on technological progress, diligent design and verification of investment decisions, high quality fuel production, and professional quality management.

The report in hand first introduces to the chemical principles of biodiesel production, hereby also including methods that are not applied largely in the market. The main part of this report describes the technologies of established providers. These descriptions are based on the replies to a standardized questionnaire, discussions with the companies, and information available on the www. Questionnaires were sent to those technology providers who had already delivered a number of production facilities and proved their good market position. Elicitation of data was unexpectedly difficult; the reason probably being intellectual property considerations, and strong competition between companies. The obtained information was condensed into process technology descriptions, comprising listing of process steps, suitable feedstock sources and qualities, and achieved biodiesel quality. Full contact details of technology providers and reference plants are listed, so as to enable the reader to get in touch.

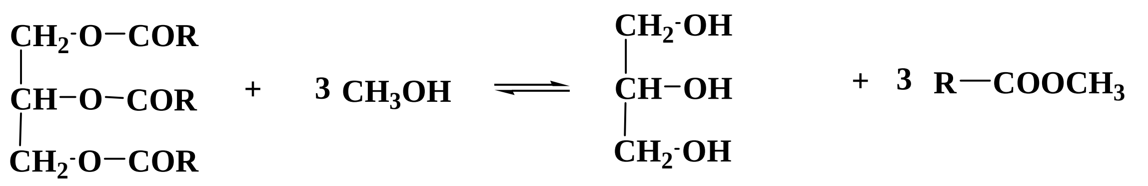
Europe´s experience with the development of biodiesel production technology is made available for all members of the Liquid Biofuels Task (IEA Bioenergy Task 39) by the report in hand, which can be seen as a tool for an informed decision. As the “single best biodiesel production technology” does not exist, it is up to the reader of this report to decide, which production technology suits best his or her specific investment plan.

2 Process Technologies for Biodiesel Production

2.1 Chemical Principles

[1]

Chemically, biodiesel is equivalent to fatty acid methyl esters or ethyl esters, produced out of triacylglycerols via transesterification or out of fatty acids via esterification. In Figure 1 the formula scheme for the production of fatty acid methyl esters (FAME) out of triacylglycerols is shown. Fatty acid methyl esters today are the most commonly used biodiesel species, whereas fatty acid ethyl esters (FAEE) so far have been only produced in laboratory or pilot scale.



triacylglycerol methanol glycerol (FAME)

R = fatty acid chain

Figure 2: Production of fatty acid methyl esters via transesterification

$$R\text{-}COOH + CH_3OH \rightleftharpoons R\text{-}COOCH_3 + H_2O$$

fatty acid methanol FAME water

R = fatty acid chain

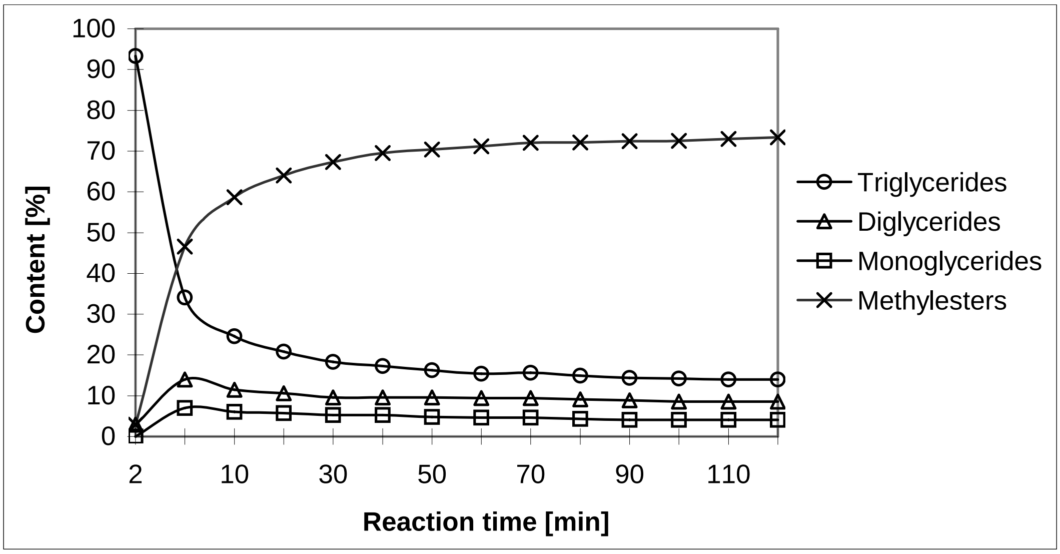
Figure 3: Production of fatty acid methyl esters via esterification

Figure 2 shows the chemical equations for a transesterification and Figure 3 for an esterification reaction. As vegetable oils or animal fats mainly consist of triacylglycerols (triglycerides) the main reaction for the production of biodiesel is the transesterification or alcoholysis reaction, whereas esterification is only necessary for feedstock with higher content of free fatty acids.

In a transesterification or alcoholysis reaction one mole of triglyceride reacts with three moles of alcohol to form one mole of glycerol and three moles of the respective fatty acid alkyl ester. The process is a sequence of three reversible reactions, in which the triglyceride molecule is converted step by step into diglyceride, monoglyceride and glycerol. In order to shift the equilibrium to the right, methanol is added in an excess over the stoichiometric amount in most commercial biodiesel production plants. A main advantage of methanolysis as compared to transesterification with higher alcohols is the fact that the two main products, glycerol and fatty acid methyl esters (FAME), are hardly miscible and thus form separate phases – an upper ester phase and a lower glycerol phase. This process removes glycerol from the reaction mixture and enables high conversion.

Ester yields can even be increased - while at the same time minimizing the excess amount of methanol – by conducting methanolysis in two or three steps. Hereby only a portion of the total alcohol volume required is added in each step, and the glycerol phase produced is separated after each process stage [2]. Finally, regardless of the type of alcohol used, some form of catalyst has to be present to achieve high ester yields under comparatively mild reaction conditions.

Figure 4 illustrates the schematic course of a typical methanolysis reaction. Whereas the concentration of triglycerides as the starting material decreases and the amount of methyl esters as the desired product increases throughout the reaction, the concentrations of partial glycerides (i.e. mono- and diglycerides) reach a passing maximum.



Reaction conditions: sunflower oil: methanol = 3:1 (mol/mol), 0.5% KOH, T=25°C (adapted from [3])

Figure 4: Schematic course of a methanolysis reaction;

The esterification reaction according to Figure 3 is a typical equilibrium reaction, thus, in order to increase the yield of fatty acid alkyl esters it is necessary to use an excess of alcohol or to remove one of the end products out of the equilibrium, e.g. the water by distillation or by the use of concentrated sulphuric acid.

In order to increase the reaction rate of both transesterification and esterification reactions, in most cases catalysts are used.

2.2 Catalysts for transesterification and esterification reactions

Homogeneous catalysts for transesterification and esterification reactions

Alkaline catalysis

Alkaline or basic catalysis is by far the most commonly used reaction type for biodiesel production. The main advantage of this form of catalysis over acid-catalyzed transesterifications is high conversion under mild conditions in comparatively short reaction times [4]. It was estimated that under the same temperature conditions and catalyst concentrations methanolysis might proceed about 4000 times faster in the presence of an alkaline catalyst than in the presence of the same amount of an acidic equivalent [5]. Moreover, alkaline catalysts are less corrosive to industrial equipment, and thus enable the use of less expensive carbon-steel reactor material. The main drawback of the technology is the sensitivity of alkaline catalysts to free fatty acids contained in the feedstock material. Therefore alkali-catalyzed transesterifications optimally work with high-quality, low-acidic vegetable oils, which are however more expensive than waste oils. If low-cost materials, such as waste fats with a high amount of free fatty acids, are to be processed by alkaline catalysis, deacidification or pre-esterification steps are required.

Today most of the commercial biodiesel production plants are utilizing homogeneous, alkaline catalysts. Traditionally the alkoxide anion required for the reaction is produced either by using directly sodium or potassium methoxide or by dissolving sodium or potassium hydroxide in methanol. The advantage of using sodium or potassium methoxide is the fact that no additional water is formed and therefore side reactions like saponification can be avoided. The use of the cheaper catalysts sodium or potassium hydroxide leads to the formation of methanolate and water, which can lead to increased amounts of soaps. However, because of the fact that glycerol separates during alcoholysis reactions, also water is removed out of the equilibrium, so under controlled reaction conditions, saponification can be kept to a minimum.

The amount of alkaline catalyst depends on the quality of the oil, especially on the content of free fatty acids. Under alkaline catalysis free fatty acids are immediately converted into soaps, which can prevent the separation of glycerol and finally can lead to total saponification of all fatty acid material. So the alkaline catalysis is limited to feedstock up to a content of approx. 3 % of fatty acids.

There are also other alkaline catalysts like guanidines or anion exchange resins described in literature, however, no commercial application in production plants is known so far.

Type of Catalyst	**Comments**
Sodium hydroxide	Cheap, disposal of residual salts necessary
Potassium hydroxide	Reuse as fertilizer possible, fast reaction rate, better separation of glycerol
Sodium methoxide	No dissolution of catalyst necessary, disposal of salts necessary
Potassium methoxide	No dissolution of catalyst necessary, use as fertilizer possible, better separation of glycerol, higher price

Table 1: Overview of homogenous alkaline catalysts

Acid catalysis

Acid catalysis offers the advantage of also esterifying free fatty acids contained in the fats and oils and is therefore especially suited for the transesterification of highly acidic fatty materials.

However, acid-catalyzed transesterifications are usually far slower than alkali-catalyzed reactions and require higher temperatures and pressures as well as higher amounts of alcohol. The typical reaction conditions for homogeneous acid-catalyzed methanolysis are temperatures of up to 100°C and pressures of up to 5 bars in order keep the alcohol liquid [6]. A further disadvantage of acid catalysis – probably prompted by the higher reaction temperatures – is an increased formation of unwanted secondary products, such as dialkylethers or glycerol ethers [7].

Because of the slow reaction rates and high temperatures needed for transesterification, acid catalysts are only used for esterification reactions. Thus for vegetable oils or animal fats with an amount of free fatty acids larger than approx. 3 % two strategies are possible. The free fatty acids can either be removed by alkaline treatment, or they can be esterified under acidic conditions prior to the alkaline catalyzed transesterification reaction. This so-called pre-esterification has the advantage that prior to the transesterification most of the free fatty acids are already converted into FAME, thus the overall yield is very high. If the free fatty acids are simply removed prior to the transesterification (similar to the deacidification of vegetable oils during refining) on the one side the transesterification conditions don´t have to be changed, however, on the other hand, these fatty acids are lost in the overall yield unless these fatty acid are esterified in a separate step.

The cheapest and best known catalyst for esterification reactions is concentrated sulphuric acid. The main disadvantage of this catalyst is the possibility of the formation of side products like dark colored oxidized or other decomposition products. The organic compound p-toluene sulphonic acid can also be used, however the high price of the compound so far prevented broader application. As heterogeneous catalyst also cationic ion exchange resins can be used in continuous reaction columns, however, this approach has only be used so far in pilot plants.

Type of Catalyst	**Comments**
Conc. sulphuric acid	Cheap, decomposition products, corrosion
p-Toluene-sulphonic acid	High price, recycling necessary
Acidic ion exchange resins	High price, continuous reaction possible, low stability

Table 2: Overview of acidic catalysts

Heterogeneous catalysis

Whereas traditional homogeneous catalysis offers a series of advantages, its major disadvantage is the fact that homogenous catalysts cannot be reused. Moreover, catalyst residues have to be removed from the ester product, usually necessitating several washing steps, which increases production costs. Thus there have been various attempts at simplifying product purification by applying heterogeneous catalysts, which can be recovered by decantation or filtration or are alternatively used in a fixed-bed catalyst arrangement. The most frequently cited heterogeneous alkaline catalysts are alkali metal- and alkaline earth metal carbonates and oxides (confer table 3). For the production of biofuels in tropical countries, Graille et al. recommended utilizing the ashes of oil crop waste (e.g. coconut fibers, shells and husks) [8]. The resulting natural catalysts are rich in carbonates and potassium oxide and have shown considerable activity in transesterifications of coconut oil with methanol and water free ethanol.

Among the catalysts listed in table 3, the application of calcium carbonate may seem particularly promising, as it is a readily available, low-cost substance. Moreover, the catalyst showed no decrease in activity even after several weeks of utilization [9]. However, the high reaction temperatures and pressures and the high alcohol volumes required in this technology are likely to prevent its commercial application. The reaction conditions described sometimes are so drastic, that there might be also conversion without any use of catalyst. Mostly, comparison experiments without any catalyst are missing in the experiments.

Similar drawbacks have to be attested for alkali metal or alkaline earth metal salts of carboxylic acids. The use of strong alkaline ion-exchange resins, on the other hand, is limited by their low stability at temperatures higher than 40°C and by the fact that free fatty acids in the feedstock neutralize the catalysts even in low concentrations. Finally, glycerol released during the transesterification process has a strong affinity to polymeric resin material, which can result in complete impermeability of the catalysts [10]. Most recently, the first technology using heterogeneous catalysts like zinc oxides or zinc aluminates, has been used in a commercial biodiesel production plant in France. [11a, b]. The so-called Esterfip-H process was developed by the Institut Français du Pétrole (IFP) and was designed and commercialized by Axens. The main advantages of the process are described as the production of high quality glycerol and no need for disposal of salts resulting form the catalyst [11a]. However, the overall economic advantages have to be proved in long term operation.

Catalyst type	**Examples**
Alkali metal carbonates and hydrogen carbonates	Na_2CO_3, $NaHCO_3$ K_2CO_3, $KHCO_3$
Alkali metal oxides	K_2O (produced by burning oil crop waste)
Alkali metal salts of carboxylic acids	Cs-laurate
Alkaline earth metal alcoholates	Mixtures of alkali/alkaline earth metal oxides and alcoholates
Alkaline earth metal carbonates	$CaCO_3$
Alkaline earth metal oxides	CaO, SrO, BaO
Alkaline earth metal hydroxides	$Ba(OH)_2$
Alkaline earth metal salts of carboxylic acids	Ca- and Ba- acetate
Strong anion exchange resins	Amberlyst A 26, A 27
Zink oxides/ aluminates	
Metal phosphates	ortho-phosphates of aluminum, gallium or iron (III)
Transition metal oxides, hydroxides and carbonates	Fe_2O_3 (+ Al_2O_3), Fe_2O_3, Fe_3O_4, FeOOH, NiO, Ni_2O_3, $NiCO_3$, $Ni(OH)_2$ Al_2O_3
Transition metal salts of amino acids	Zn- and Cd-arginate
Transition metal salts of fatty acids	Zn- and Mn-palmitates and stearates
Silicates and layered clay minerals	Na-/K-silicate Zn-, Ti- or Sn- silicates and aluminates
Zeolite catalysts	Titanium-based zeolites, faujasites

Table 3: Overview on heterogeneous catalysts (for references see [1])

Enzymes as catalysts

In addition to the inorganic or metallo-organic catalysts presented so far, also the use of lipases from various microorganisms has become a topic in biodiesel production. Lipases are enzymes which catalyze both the hydrolytic cleavage and the synthesis of ester bonds in glycerol esters. Their application in FAME production dates back to Choo and Ong [12], filing a patent application on lipase-catalyzed methanolysis in the presence of water, and to Mittelbach, reporting on the first water-free process for lipase-catalyzed biodiesel production [13].

As compared to other catalyst types, biocatalysts have several advantages. They enable conversion under mild temperature-, pressure- and pH-conditions. Neither the ester product nor the glycerol phase has to be purified from basic catalyst residues or soaps. Therefore phase separation is easier, high-quality glycerol can be sold as a by-product, and environmental problems due to alkaline wastewater are eliminated [14]. Moreover, both the transesterification of triglycerides and the esterification of free fatty acids occur in one process step. As a consequence, also highly acidic fatty materials, such as palm oil or waste oils, can be used without pre-treatment [15]. Finally, many lipases show considerable activity in catalyzing transesterifications with long or branched-chain alcohols, which can hardly be converted to fatty acid esters in the presence of conventional alkaline catalysts.

However, lipase-catalyzed transesterifications also entail a series of drawbacks. As compared to conventional alkaline catalysis, reaction efficiency tends to be poor, so that biocatalysis usually necessitates far longer reaction times and higher catalyst concentrations. The main hurdle to the application of lipases in industrial biodiesel production is their high price, especially if they are used in the form of highly-purified, extra cellular enzyme preparations, which cannot be recovered from the reaction products. One strategy to overcome this difficulty is the immobilization of lipases on a carrier, enabling the removal of the enzymes from the reaction mixture and their reuse for subsequent transesterifications. Immobilization could furthermore be advantageous inasmuch fixed lipases tend to be more active and stable than free enzymes. Traditional carrier materials (such as anion exchange resins or polyethylene) can be replaced by renewable, readily available substances like corn cob granulate [16].

Transesterification without catalysts

Basically, transesterification of triglycerides with lower alcohols also proceeds in the absence of a catalyst, provided reaction temperatures and pressures are high enough. Ester conversion surpassed 85% (m/m) after ten hours of reaction for non-catalytic methanolysis of soybean oil at 235°C and 62 bars [17]. The advantages of not using a catalyst for transesterification are that high-purity esters and soap-free glycerol are produced. Especially in the last years reactions using supercritical methanol without any catalyst have been reported, however, the reaction conditions are very drastic [18]. The high excess of methanol which has to be used during supercritical transesterification seems to make the process not economically feasible, however, a two-step process has been described, which in the first step hydrolyzes the glycerides into fatty acid with an excess of water, and in the second step esterification takes place, which requires lower amounts of methanol [19].

2.3 Overview on Process Technologies

In the oleo chemical industry the production of fatty acid methyl esters has a long tradition, because these products are an important intermediate for the further production of fatty alcohols and fatty alcohol ethoxylates. These production units mainly use sodium methoxide as catalyst under more drastic reaction conditions like higher pressure and high temperatures [5]. Under these reaction conditions also free fatty acids are converted into fatty acid methyl esters. For the use as intermediates for fatty alcohol production the esters have to be distilled.

At the beginning of the biodiesel development these technologies, however, where too expensive and needed too high investment costs. Therefore the so-called low temperature and low pressure processes where developed, which use temperatures up to 60°C at ambient pressure and there is no need for distillation of the final product. These processes can be applied in very small production units, with rather simple equipment. Over the past years an enormous number of small scale producers (so-called “garage” producers) has emerged worldwide, producing biodiesel without any safety precautions or quality control of the product, and without further processing of the glycerol layer, which contains excess methanol and is therefore considered as special waste. In most cases, the biodiesel produced does not meet the high quality standards defined in the European specifications EN 14214 or ASTM specifications D 6584, and therefore it is possible that this quality can lead to serious injection pump or engine problems.

In the following only those technologies with industrial applications are described.

There are different possibilities to classify the different biodiesel production technologies. One can distinguish according to the type of catalyst between homogenously or heterogeneously catalyzed processes; one can distinguish according to the reaction conditions between low and high temperature and pressure reactions; or between continuous or batch operation. On the other side it also possible to classify according to the type of feedstock. The so-called single feedstock technologies are using half or fully refined vegetable oils like rape seed, soybean, sunflower etc. With these technologies the content of free fatty acids should be very low, so the formation of soaps is limited. Normally alkaline catalysts like sodium methoxide or potassium hydroxide are used, and the soaps formed as side products during the reaction are either removed by water washing steps or recycled by esterification with acid catalysts after work up of the glycerol phase. With this technology also a small amount of other feedstock like recycled frying oil or higher acidic palm oil can be blended to the refined vegetable oils.

The so-called multi-feedstock technologies are additionally capable of processing feedstock with higher amounts of free fatty acids. Here a so-called pre-esterification of the free fatty acids is necessary, or during a high pressure and temperature process all fatty material is directly converted in FAME in one step. These processes are capable to process any type of feedstock, including acid oils, animal fat, high acidic palm oil or even fatty acids. The reaction conditions can easily be adapted to the change of feedstock.

Though a differentiation of these two technologies often is not very easy, especially with newer developments of technology, the terms single- and multi-feedstock technologies are broadly used in the biodiesel terminology, and therefore will be used in the following.

Single Feedstock Technologies

The biggest biodiesel production units with a capacity of over 100.000 tons mainly use fully refined vegetable oils with low content of water and free fatty acids. In that case they use a solution of sodium methoxide or sodium hydroxide in methanol in order to get very low formation of soaps. After a continuous transesterification process, which mostly is conducted in 2 steps at moderately elevated temperature and ambient pressure, the glycerol layers, which are formed at the bottom layer of the reaction mixture, are separated and the raw methyl ester phase is further purified, mainly by different water washing steps.

The final product is dried and can be used directly, without distillation, as biodiesel. Most of these biodiesel plants are combined with an oil seed crushing and refining facility, so it is possible to use highly refined oils as raw material. Also these big facilities mainly have an own glycerol purification technology including distillation of raw glycerol into pharmaceutical grade glycerol. Today the biggest biodiesel production plants mainly are not adapted to use oils with high content of free fatty acids like palm oil or waste oils.

In most single feedstock production plants the glycerol phase is further processed in order to get pharmaceutical grade glycerol. Excess methanol is removed by distillation and the glycerol is distilled under high vacuum and treated with charcoal. The yields for these single feedstock technologies are almost 100 %, because side reactions like saponification are kept to a minimum due to low water and free fatty acid content in the starting material.

Multi Feedstock Technologies

The so-called multi feedstock technologies are capable of processing all kinds of various feedstock, including vegetable oils with higher content of free fatty acids like unrefined oils or palm oil but also waste oils or animal fats. The main difference to single feedstock technologies is the use of additional reaction steps, like pre-esterification of free fatty acids. So in a first step free fatty acids are pre-esterified with the use of acidic catalysts, followed by one or two alkaline catalyzed transesterification steps. The raw fatty acid methyl esters are purified by water washing steps and additionally can be further refined by vacuum distillation. The main advantage of this technology is the fact that the yield of conversion of fatty acid material into fatty acid methyl esters is almost 100 %. The highest yield can be obtained, when remaining soaps in the glycerol layer are recycled by acidification of the glycerol and separation of free fatty acids, which can be reintroduced into the pre-esterification step or first step of transesterification [20]. Another approach for converting high acidic oils into fatty acid methyl esters is the conversion of fatty acids into glycerides, followed by traditional transesterification [21].

The use of animal fats has gained a major interest in special countries like Australia. In Europe the use of animal fat from rendering companies will reach a specific market share, especially because most recently it has been proved that infectious prions, responsible for BSE, are destroyed during the biodiesel process effectively [22].

Small scale production units

Many production plants have a production capacity of up to 5.000 t/a, using different feedstock and different production technologies. Mostly these plants have not been built by big biodiesel technology companies, but the technology has been developed by individual groups and organizations based on own experience and development. The glycerol layer mostly is used directly without any purification e.g. as substrate for biogas plants, or will be purified to be sold as raw glycerol. The catalyst for transesterifications is mainly potassium hydroxide, because it leads to the highest conversion rates. Several of these production plants are organized as co-operatives, using vegetable oils produced locally, and also the biodiesel will be used by the members directly. Most of the very small production units don’t have their own facilities for quality control, so the quality of the product might vary and it is not guaranteed to meet EN 14214 representing a serious risk to diesel engines.

2.4 References

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3 Process Technology Providers

3.1 Method of Investigation

In order to describe the European biodiesel technology providers in this report, data had to be collected. For this purpose a questionnaire was developed. It was then passed on to nine European companies that are well-known for their experience in the planning and construction of biodiesel plants.

These companies are (in alphabetical order):

- Agrartechnik
- Axens
- BDI
- CD-Technology:
  - ⇨ GEA Westfalia
  - ⇨ Cimbria Sket
- CMB
- DeSmet Ballestra
- Energea
- Lurgi

Due to the actual high demand for biodiesel production facilities and the strong competition between the technology providers, it proved difficult to obtain data from all companies. But finally, all of them provided data, either by filling out the questionnaire, or by discussing and accepting company descriptions based on texts from the companies´ websites. All data provided was then summarized by the authors and is displayed in chapter 3.2.

The full questionnaire as handed out to the biodiesel technology providers can be found in Annex A. A brief description reads as follows:

Description of Questionnaire

The main points are (1) general data on the company, (2) detailed data on the process technology applied, and (3) references.

General data

This part includes the name of the company, ownership, and contact details. Furthermore the companies define their industry sector, as sometimes offering of biodiesel technology is only a small part of a company's business, and synergies can be found between e.g. waste collection and biodiesel production.

Process Technology

First of all some data on the biodiesel sector of the company is gathered: detailed description of the biodiesel related services (e.g. project development, engineering and design, general contractor), number of employees in the biodiesel sector, and the annual turnover of this sector.

Then the companies provide details on the process technology they offer:

- Feedstock: a list of suitable feedstock, feedstock recipes, feedstock quality required, appropriate FFA contents of feedstock
- Conversion: process steps applied (esterification, trans-esterification), patents held, catalysts applied, by-products generated, biodiesel process yield according to feedstock quality, energy input, and waste accumulation
- Capacity range of plants offered
- Compliance with biodiesel standards

Finally the companies cite their opinion on the production of fatty acid ethyl esters (FAEE), and whether they have already conducted research in this field or not.

References

All companies may provide a list of reference plants in operation and a list of reference plants under construction as by the end of 2006. Furthermore up to three reference plants can be cited. Only one exception to this limitation to three plants has been accepted, as in that case the fourth reference plant produces FAEE instead of FAME.

Each of the cited reference plants has to be described as follows:

- General: contact details, date of start-up, space requirement of production unit, nominal capacity, and actual production
- Process: feedstock in use, recipes, FFA content of feedstock, process steps, catalysts, by-products, energy input, and compliance with standards

Additionally, the companies can provide pictures to be included into the report.

3.2 Results of Investigation

The results of the questionnaire interrogation and of the multiple discussions with the technology providers were summarized by the authors of this report into the company descriptions on the following pages. Some general statements can be made:

1. All companies contacted have profound knowledge of the biodiesel production technology. This is proven by operating reference plants.
2. All companies contacted are currently planning and building several new production facilities.
3. All companies contacted will enable the investor to produce FAME according to EN 14214; however, depending on the raw material, CFPP and/or Iodine Value may be off specifications. Appropriate blending with other raw materials is required in order to meet the specified limits.
4. According to the technology providers, in general the production process should also be suitable for the production of FAEE.
5. Only few companies have gained experience on FAEE production so far.

AT Agrar-Technik GmbH & Co. KG
represented by AT AGRAR-TECHNIK Verwaltungs- GmbH,

corporate management:
CEO Mr. Hans-Joachim and Mrs. Margarete Gaede

Nürtinger Straße 62
D-72667 Schlaitdorf / Germany

phone: + 49 71 27 / 93 94 - 0

fax: + 49 71 27 / 93 94 - 95

www.at-agrartechnik.de

agrodiesel@at-agrartechnik.de

History:

The company, with its headquarters in Schlaitdorf near Stuttgart, was founded in 1982 with the purpose of manufacturing and whole selling of equipment and machinery for the agricultural sector, particularly in the area of seed preparation and seed drying.

With the increasing importance of alternative fuels, produced from renewable raw materials, AT has successfully established itself in this market sector as a biodiesel plant engineering and construction company.

At the beginning of the 1990s, AT intensified its research and development work, with its main focus on rapeseed oil methyl ester (RME) process engineering and process technology.

AT is actively involved in international associations and expert committees.

Among others, partner Moritz Gaede is President of the EBB (European Biodiesel Board in Brussels) - www.ebb-eu.org.

Company's scope of work:

- Engineering and construction of oilseed crushing facilities
- Biodiesel process technology development
- Project development and business plan for biodiesel plants
- Basic and detailed engineering of biodiesel plants
- General construction management for turn-key biodiesel plants

Employees: 28 in the biodiesel sector

Suitable feedstock:

Virgin vegetable oils, used oil, rendered fats;

- Fully refined oils
- Degummed vegetable oils
- Up to 25 % free fatty acid content

These feedstock sources can be used straight or in blends at any ratio.

Process type and process steps applied:

Depending on feedstock properties the biodiesel production process operates optionally with

- AT refinery,
- trans-esterification and purification
- post-esterification, fertilizer production, methanol-rectification,
- pharma-glycerin production,

using potassium hydroxide and sulfuric acid as homogenous catalysts in the process.

The process yield reaches a level of approx. 99 % for fully refined vegetable oil as well as for oils with high FFA contents.

The process requires 350 kg steam and 35 kW electric energy per ton of produced Biodiesel for 250.000 t Biodiesel per year.

There is only very limited waste accumulating from biodiesel production.

Patents:

The process technology is based on the patent EP1183225 of June 1999.

Co-partnerships:

AT offers not only its services in plant engineering and construction but also acts as co-partner in Biodiesel companies e.g.:

- Campa Biodiesel GmbH & Co. KG in Ochsenfurt / Germany
- Bionet Europa S.L. in Reus / Spain
- Marina Biodiesel GmbH & Co KG in Brunsbüttel / Germany
- Biodiesel Süd GmbH & Co KG Marbach / Germany

AT cooperates with Uhde as a company of the ThyssenKrupp Group in Far East countries.

Biodiesel quality:

According to EN 14214; many parameters show however an even better quality performance.

By-products:

Glycerol, in concentrations according to costumer needs, usually 90 % up to 99,7%

Fertilizer salt

Plant sizes offered:

Biodiesel plants are offered within a capacity range of 2.000 t/a to 250.000 t/a biodiesel according to EN14214 or better.

References:

AT has so far established 31 Biodiesel production plants across Europe, in Thailand and the USA.

	Project	Country	Biodiesel	Glycerol		Oil mill[1]
			t/a	t/a	%	t/a
1.	Kutna Hora	CZ				30.000
2.	Biodieselanlage / Güssing	AT				6.000
3.	Nyíregyháza	HU				6.000
4.	RME Starrein / I u. II	AT	2.000	360	55	3.000
5.	Krakow	PL				6.000
6.	ATN / Asperhofen	AT	1.000	180	55	3.000
7.	Agropodnik / Jihlava I u. II	CZ	35.000	4.000	55	60.000
8.	Midlovary	CZ				18.000
9.	Bio-Kraftstoff / Vogtland	DE	2.000	360	55	6.000
10.	Eco Energie / Etoy	CH	2.000	360	55	6.000
11.	Campa Biodiesel / Ochsenfurt I u. II	DE	150.000	16.900	88	
12.	BDS / Schwarzheide	DE	100.000	30.000	99,7	
13.	Bionet Europa S.L. / Reus	ES	150.000	16.900	88	
14.	RBE / Neuss	DE	150.000	16.900	80	
15.	Wittinger Biodiesel	DE				45.000
16.	ECODASA GmbH	DE	50.000	5.600	60	
17.	BDK Biodiesel / Kyritz I BDK Biodiesel / Kyritz II	DE	80.000	5.600 2.500	90 99,7	70.000
18.	Orlen Biodiesel / Trzebinia	PL	100.000	15.000	99,7	
19.	Marina Biodiesel / Brunsbüttel	DE	130.000	11.300	88	
20.	Campa Süd / Straubing	DE	200.000	16.800	90	700.000
21.	BDS Madison / Chicago	USA	150.000	9.500	99,7	
22.	SUNOIL B.V	NL	60.000	10.000	60	
23.	INTER-TRAM KFT.	HU	10.000	1.700	60	
24.	TOL-Thailand, (Uhde-ThyssenKrupp)	TH	200.000	36.000	99,7	
25.	DBD / Eberswalde	DE	250.000	20.000	98	
26.	Ecodasa AG Magdeburg	DE	250.000	24.000	98	
27.	Ecodasa AG Perl	DE	250.000	24.000	98	
28.	BDS Madison / St. Louis	USA	150.000	9.500	99,7	
29.	BDS / Süd Marbach	DE	150.000	13.500	90	
30.	SKOTAN / Torun	PL	150.000	16.800	90	
31.	SKOTAN / Krakau	PL	150.000	16.800	90	
	total capacity		**2.922.000**	**324.560**		

Table 4: AT References (Period: 1992 - September 2006)

[1] Seed capacity

AT – Reference 1:

Campa® Biodiesel GmbH & Co. KG

Marktbreiter Straße 74

97199 Ochsenfurt
Germany

phone: +49 (0) 9331 / 9815 - 0
fax: +49 (0) 9331 / 9815 - 50

http://www.campa-biodiesel.de

info@campa-biodiesel.de

Company:

The company Campa®- Biodiesel GmbH & Co. KG was founded as early as August 1998 in Ochsenfurt, which is located close to the city of Würzburg in Bavaria. Shareholders are

1. Verwertungsgesellschaft für nachwachsende Rohstoffe (VNR) GmbH & Co. KG in Bergtheim / Opferbaum in Bavaria as a kind of rapeseed growing farmers' coop, and
2. AT Agrar-Technik GmbH, Schlaitdorf near Stuttgart as the process technology supplier and Biodiesel plant constructor.

Both companies are involved in production and marketing of RME (rapeseed-methyl-ester) or Biodiesel since more than 10 years.

VNR represents 13 cooperatives in the field of rapeseed production with a total number of 3.500 farmers, assuring the continuous supply of rapeseed to the oil mill and biodiesel plant.

Feedstock:

Virgin rapeseed oil

Products:

Biodiesel according to EN14214;

Crude glycerol.

Capacity:

The nominal capacity today after capacity enlargements is 150.000 t/a biodiesel.

Figure 5: Campa Biodiesel Plant

AT – Reference 2:

Bionet Europe S.L. / Reus, Spain

Poligon Agro-Reus
Adria Gual 4

43206 Reus
Spain

phone: +34 977 328 229
fax: +34 977 316 860

http://www.bioneteuropa.com/

bionet@bioneteuropa.com

Products:

Biodiesel according to EN14214

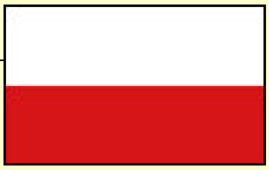
Crude glycerol (88 %).

Capacity:

The nominal capacity is 150.000 t/a biodiesel and 16.900 t of 88 % glycerine.

Figure 6: Tank farm of the Bionet Biodiesel plant

AT – Reference 3:



PKN ORLEN

www.orlen.pl

Company:

A Polish company and one of Central Europe's largest refiners of crude oil.

PKN Orlen specializes in processing crude oil into world-class unleaded petrol, diesel, heating oil, and aviation fuel as well as plastics and other petroleum related products.

PKN ORLEN operates 6 fossil oil refineries, of which 3 are located in Plock, Trzebinia and Jedlicze (Poland) and another 3 in Litvinov, Kralupy and Pardubice (Czech Republic). The total processing capacity of the refineries reaches 21,7 million t/a.

Figure 7: Main building and tank farm of the Biodiesel plant in Trzebinia, Poland

Products:

Biodiesel according to EN14214;

Pharmaceutical glycerin of 99,7 % purity.

Capacity:

The nominal capacity is 100.000 t/a biodiesel and 15.000 t of glycerine.

Axens – IFP Group Technologies

Mr. Michel Bloch
Marketing Manager, Renewable Energies

89, Boulevard Franklin Roosevelt
BP 50802 Rueil-Malmaison Cedex / France

phone: +33 1 47 14 21 00

fax: +33 1 4714 2500

www.axens.net

michel.bloch@axens.net

History:

Axens was formed on July 1, 2001 through the merger of IFP's technology licensing division with Procatalyse Catalysts & Adsorbents. Axens is a subsidiary of IFP (Institut Français du Pétrole), which is engaged in petroleum related research & development.

Company's scope of work:

Axens is a world leader in several areas, such as:

- petroleum hydrotreating & hydroconversion,
- FCC gasoline desulphurisation,
- catalytic reforming,
- BTX (benzene, toluene, xylenes) production & purification,
- selective hydrogenation,
- Claus and Tail Gas Treatment (TGT).

Development steps of IFP/Axens biodiesel process technology:

1984: Lab research initiated

1989: Pilot operations for homogeneous Esterfip process process

1992: First Esterfip plant started up for Sofiproteol (now Diester) near Compiègne - France with 20.000 t/yr capacity

1997: Debottlenecking of Compiègne plant (present capacity: 100.000 t/yr)

2002: Development of an heterogeneous (solid catalyst) process: Esterfip-H

2004: Selection of Esterfip-H process by Diester for its new plant in Sète / France

2006: Successful start-up of Sète plant.

Suitable feedstock:

Virgin vegetable oils;

Semi-refined vegetable oils (degummed, neutralized)

Main required specifications:

Phosphorus content:	10 ppm wt max.
Acid value:	0,25 % FFA max.

Process type and process steps applied:

The process applied is a continuous process.

The catalyst section includes two fixed-bed reactors which are fed by oil and methanol. Excess methanol is removed after each of the two reactors by a partial flash vaporization. Esters and glycerin are then separated in a settler. Glycerin phases from each reactor are combined and the last traces of methanol are removed by vaporization. Biodiesel is produced after final recovery of methanol by vaporization under vacuum.

The catalyst used in the Esterfip-H process is a non-noble metal solid catalyst supplied by Axens.

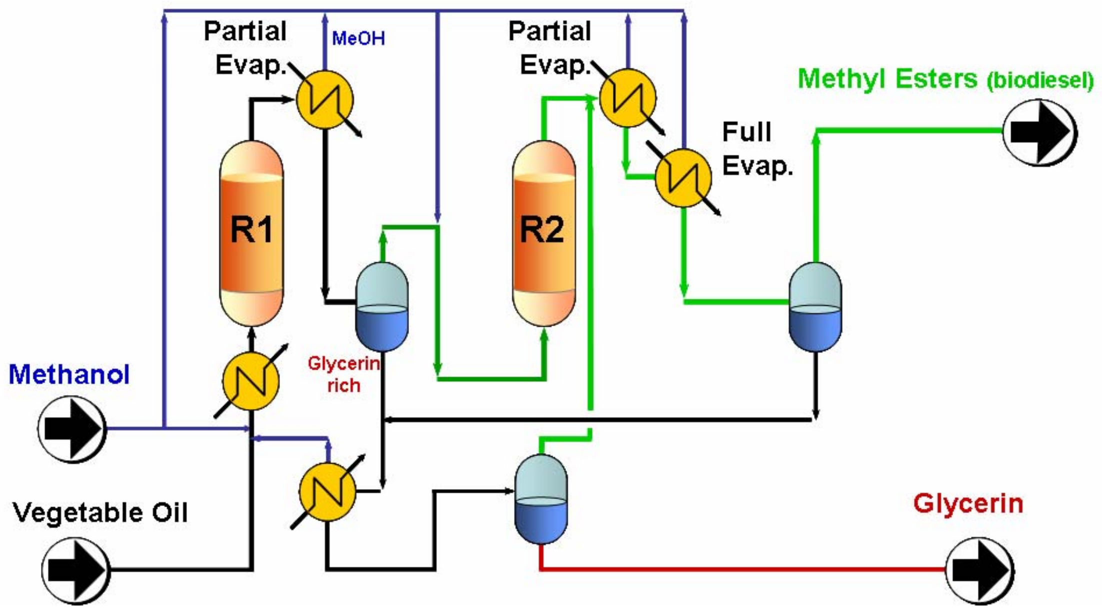


Figure 8: Esterfip –H Simplified Process Flow Diagram

Biodiesel quality:

EN 14214 compliant.

By-products:

An exceptional salt-free glycerin with purity above 98% is produced without the need for further purification.

No soap formation or waste production of low-value fatty acids occur. Consequently, the yield in biodiesel is close to the theoretical yield (i.e. > 100% in weight).

There is no handling of hazardous acid and base chemicals.

The catalytic cost is much lower as compared to other processes.

Plant sizes offered:

Esterfip-H can be designed for a wide range of capacities. However solid catalyst technology is best suited for large biodiesel plants (100.000 t/a and above).

References:

Year	Company	Location/ Country	Capacity t/a	Status
2006	Diester	Sète, France	160.000	In operation
2007	Perstorp Oxo	Stenungssund, Sweden	160.000	In operation
2007	Confidential	Southern Europe	50.000	Ordered
2007	Beatrice Biodiesel, LLC	Beatrice, NE, USA	165.000	Ordered
2008	NaturOil	Ourhinos SP, Brazil	200.000	Under engineering
2009	Confidential	Canada	100.000	Under engineering

Table 5: Axens Biodiesel References

Axens – Reference 1:

Diester Industrie

Sète, France

The first Esterfip-H plant went on-stream at the beginning of March 2006 for Diester Industrie.

Company:

Diester Industrie, created in 1993, is Europe's foremost biodiesel producer. Owned by Sofiproteol (66.66%) and a group of farm cooperatives (33.34%), Diester Industrie commercializes and distributes Diester™ (FAME) in France. The decision by Diester Industrie confirms its pioneering role in the area of biodiesel. Already in 1992, and in partnership with IFP, the company built its first Esterfip unit in Venette (near Compiègne, France).

Feedstock and Capacity:

The plant has a name plate capacity of 160.000 t/a and processes various feeds such as rapeseed, soybean and sunflower oils.

Figure 9: Diester Biodiesel Production Facility

BDI - BioDiesel International AG

CEO Wilhelm Hammer

Parkring 18
A-8074 Grambach/Graz / Austria

phone: +43 316 4009 100

fax: +43 316 4009 110

http://www.biodiesel-intl.com

bdi@bdi-biodiesel.com

History:

The company emerged as a result of a management buyout of a subdivision of Vogel&Noot Industrieanlagenbau Gesellschaft m.b.H. in 1996, which was transferred to BDI-Anlagenbau Ges.m.b.H., founded on 12 September 1996, as legal predecessor of the company. By resolution of the general shareholders' meeting of BDI Ges.m.b.H. in 2006, the company was transformed into a joint stock corporation BDI-BioDiesel International AG, listed on the stock prime market in Frankfurt.

Vogel & Noot had been active since 1982 in developing technologies to produce BioDiesel from plant and animal oils and fats. They have installed the first biodiesel plant for rape seed oil in Asperhofen, Lower Austria, in the year 1989, followed by the first industrial biodiesel plant in Mureck in the year 1991. They have focused on the use of alternative feedstock for biodiesel production like waste oils and animal fats very early. In 1994 the first biodiesel plant for the processing of recycled frying oil in Mureck, owned by SEEG, was opened. In 1992 the industrial scale plant in Bruck was put into operation. This plant was dedicated for the use of rape seed oil, and also for the first time pharmaceutical grade glycerol was produced.

1994 the first industrial scale plant outside Austria was installed in Olomouc in Czech Republic, followed by a biodiesel plant for animal fat in Kentucky, USA, in the year 1998. Since then BDI has gained reputation in the field of so-called Multi-feedstock-technology.

From the very first beginning of its biodiesel activities BDI has established close cooperation with research institutions, like the Karl-Franzens-University Graz and the Graz University of Technology. There is also a close co-operation with VTU-Engineering (http://www.vtu.com), Graz, in the field of basic engineering, and with M&R Automation (http://www.mr-automation.at), Graz, in the field of automation and process control systems.

Company's scope of work:

BDI is a globally operating provider of complete customized industrial plants for the production of biodiesel. The services it provides comprise the planning and design of the plant, its construction and commissioning, together with the subsequent technical consulting that accompanies production. BDI procures the necessary plant components from suppliers and awards subcontracts for the construction and installation services necessary for the erection of the plant.

Number of employees: 80 (October 2006)

Suitable feedstock:

Virgin vegetable oils, used oil, rendered fats; pure or in blends of any ratio.

For single feedstock plants fresh, degummed vegetable oils are required, for Multi-feedstock plants almost no limitations of the feedstock quality are necessary (free fatty acids up to 100 %); however, depending on the quality, special pre- or post-purification steps may be applied.

Process type and process steps applied:

The process is described as fully automated, semi-continuous process using 2-step transesterification and recycling of fatty acids, formed as side products during the reactions, with a patented process. Depending on the amount of free fatty acids in the raw material, also a pre-esterification step may be necessary. Homogenous alkaline catalysts are used for the transesterification, and acids are used for the esterification step.

The yield in single feedstock plants is around 100 %, as all fatty acids are converted in fatty acid methyl esters. In Multi-feedstock plants the yield depends on the quality of the feedstock, but up to 100 % is also possible in that case.

There is no solid or liquid waste accumulating from biodiesel production. The catalyst is converted into metal salts which can be used as fertilizer.

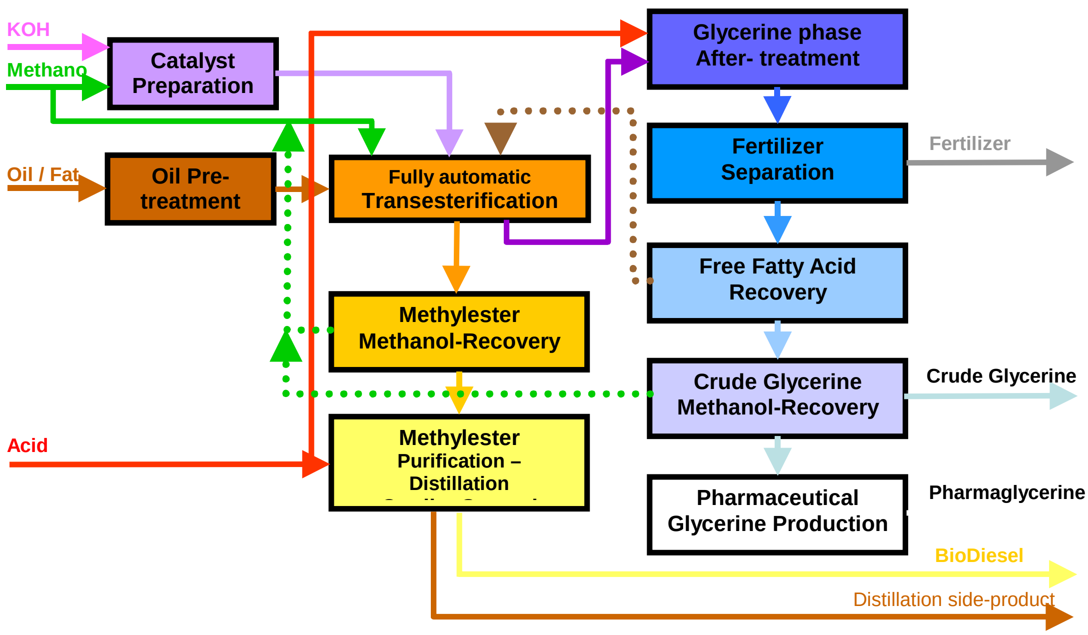


Figure 10: BDI Multi-feedstock production scheme

Patents:

US 5.399.731

PCT/AT94/00088

AT 406.871

PCT/AT/00320

AT 412.280 B

PCT/AT2004/000214

Biodiesel quality:

Biodiesel produced meets EN 14214.

By-products:

Glycerol can be produced in different qualities, depending on the customers' demands, starting from 80 % up to pharmaceutical grade glycerol.

Plant sizes offered:

Biodiesel plants are offered within a capacity range of 6.000 t/a to 250.000 t/a biodiesel.

References:

Today 14 biodiesel plants are in operation with a total capacity of 452.000 t/a, and further 12 biodiesel plants are under construction with an additional capacity of 936.000 t/a.

	Location	Technology	Established by	Capacity
1.	Mureck, Austria	multi-	1991	9.000 t/a
2.	Güssing*	single-	1991	(1.000 t/a)
3.	Bruck/Leitha, Austria	single-	1992	20.000 t/a
4.	Olomouc, Czech Republic	single	1994	30.000 t/a
5.	Butler, USA	multi-	1998	5.000 t/a
6.	Malchin, Germany	multi-	2001	12.000 t/a
7.	Cavisa, Spain	multi-	2002	6.000 t/a
8.	Niederpöllnitz, Germany	single-	2002	50.000 t/a
9.	Arnoldstein, Austria	multi-	2003	25.000 t/a
10.	Motherwell, Great Britain	multi-	2004	50.000 t/a
11.	Vienna, Austria		2006	95.000 t/a
12.	Huesca, Spain	multi-	2006	25.000 t/a
13.	Cavisa 2, Spain	multi-	2006	25.000 t/a
14.	Lünen, Germany	multi-	2006	50.000 t/a
15.	Lünen 2, Germany	single-	2007	50.000 t/a
	Total capacity			**452.000 t/a**

*) After 13 years of successful operation, the plant was dismantled and sold 2004.

Table 6: BDI References in Operation

	Location	Technology	Start up by	Capacity
16.	Ventspils, Latvia	single-	2007	100.000 t/a
17.	Barnawartha, Australia	multi-	2007	50.000 t/a
18.	Klaipeda, Lithuania	single-	2007	100.000 t/a
19.	Sevilla, Spain	single-	2007	50.000 t/a
20.	Almeria, Spain	multi-	2007	6.000 t/a
21.	Arnoldstein 2, Austria	multi-	2007	25.000 t/a
22.	Sines, Portugal	multi-	2007	25.000 t/a
23.	Losning, Danmark	multi-	2008	50.000 t/a
24.	Ferrol, Spain	single-	2008	200.000 t/a
25.	Bilbao, Spain	single-	2008	200.000 t/a
26.	Altorricon, Spain	multi-	2008	100.000 t/a
27.	Wexford, Ireland	multi-	2008	30.000 t/a
	Total capacity			**936.000 t/a**

Table 7: BDI References under Construction

BDI – Reference 1:

BioDiesel Vienna (BDV) GmbH

CEO Ewald-Marco Münzer

Ölhafen Lobau – Uferstraße 12,
A-1220 Wien
Austria

phone: +43 (3112) 6969
fax: +43 3112 6969-4

http://www.biodiesel-vienna.at

ewald-marco.muenzer@biodiesel-vienna.com

Ownership:

Münzer Holding GmbH

Feedstock:

Virgin oils: rapeseed oil, sunflower oil, soy bean oil, palm oil;

Used oils: with FFA content 2 – 20 %.

Products:

Biodiesel according to EN14214;

Pharmaceutical glycerol and metal salts.

Capacity:

The nominal capacity is 95.000 t/a biodiesel in the 1st stage; extension to 400.000 t/a is planned. The start-up was in June 2006. The plant is running on full capacity.

Site parameters and space requirements:

The actual biodiesel production unit occupies 30m*20m*10m.
Energy and water supply assured from on-site utility plants.
Located at harbor at river Danube.
Located nearby and connected via pipeline with the Austrian mineral oil refinery OMV.

Figure 11: BDV Vienna/Austria

BDI – Reference 2:

Argent Energy

Andrew Hunter, Joint managing Director

The Rural Centre, West Mains, Ingliston, Newbridge, Midlothian

EH28 8LT
UK

phone: +44 131 472 4131
fax: +44 131 472 4139

http://www.argentenergy.com

info@argentenergy.com

Ownership:

Argent Group Europe

Feedstock:

Virgin oils: rapeseed oil, sunflower oil, soy bean oil, palm oil, jatropha oil;

Rendered fats;

Used oils.

FFA content up to 20%

Products:

Biodiesel according to EN14214;

Crude glycerol (80 %) and metal salts

Capacity:

The nominal capacity is 50.000 t/a biodiesel; the start-up was in July 2005; the actual production was 25.000 t in 2005.

Site parameters and space requirements:

The actual biodiesel production unit occupies 27m*17m*14m.

Energy and water supply assured from on-site utility plants.

Located near rendering plant.

Figure 12: Argent Energy, Motherwell/Scotland

BDI – Reference 3:

BioDiesel Kärnten (BDK) GmbH

Werner Stulier

Industriestrasse 29

A9601 Arnoldstein
AUSTRIA

phone: +43 (0) 4255 / 90812-0
fax: +43 (0) 4255 / 90812-12

http://www.biodiesel-kaernten.com

Werner.stulier@biodiesel-kaernten.at

Ownership:

Rudolf - Münzer Bioenergie GmbH

Feedstock:

Virgin oils: rapeseed oil, sunflower oil, soy bean oil, palm oil, jatropha oil;

Rendered fats;

Used oils.

FFA content up to 20% is suitable

Products:

Biodiesel according to EN14214;

Crude glycerol (80 %) and metal salts.

Capacity:

The nominal capacity is 25.000 t/a biodiesel; the start-up was in June 2003; the facility produced nameplate capacity in 2004 and 2005.

Site parameters and space requirements:

The actual biodiesel production unit occupies 24m*14m*10m.

Energy and water supply assured from on-site utility plants

Located in industrial area

Figure 13: BDK Arnoldstein/Austria

CD-Process Technology

Contact person:

Dr.–Ing. Joosten Connemann

Sägemühlenstraße 49
D-26762 Leer, Germany

+49 (491) 92900

jc@conne.net, info@hammerlit.de

Licensees:

Westfalia Separator Food Tec GmbH

Klaus-Peter Eickhoff

Werner Habig Straße 1
D-59302 Oelde, Germany

phone: +49 2522 77 2384

fax: +49 2522 77 1794

Eickhoff.klaus-peter@gea-westfalia.de

http://www.westfalia-separator.com

CIMBRIA SKET GmbH

Bernd Emersleben

Schilfbreite 2
D-39120 Magdeburg, Germany

phone: +49 2631977110

fax: +49 2631 977 120

bem@cimbria-sket-bon.de

http://www.cimbria.com

History:

The CD-process technology was developed by Dr.-Ing. Joosten Connemann, the former owner of the Ölmühle Leer in Germany, whose crushing facility was sold in 1987 to Oelmühle Hamburg AG, now owned by ADM (Archer Daniels Midlands in Decatur, Illinois, USA). His so-called CD PROCESS system ("continuous deglycerolisation") was the first and continuously operating biodiesel process used in industrial scale in Europe.

In 1991 the low-pressure transesterification process, put into effect by reaction columns and centrifugal separators, was realized in Leer, Germany. The first plant produced 1 t/day, a technical pilot plant for 20 t/day followed in 1993, producing 8.000 t/a. In 1995 the industrial demonstration plant for the production of Biodiesel with a capacity of 80.000 t/a was opened in Leer/Germany, close to the existing oil crushing facility for rapeseed and sunflower seeds.

A second industrial scale plant with the same technology was erected by Oelmühle Hamburg AG in Hamburg and put into operation in 2002 with a capacity of 140.000 t/a, was upscaled in 2005 to 200.000 t/a, which was followed by a third plant for 300.000 t/a later on.

Company´s scope of work:

Licenses of the Connemann-ADM technology have been provided to other companies like GEA-Westfalia Separator Food Tec in Oelde and MAN-Ferrostaal AG in Essen, both located in Germany; Cimbria-Sket in Magdeburg, Germany, is a case to case sub-licensee of Westafila Separator.

Suitable feedstock:

The CD-process requires neutralized and degummed oil. This can be done, depending on the kind of oil and the quality, by different pre-treatment processes, which are integrated into the plant concept. For seed oil Westfalia Separator can offer a degumming combined with an alcohol neutralization to reduce the consumption of energy and utilities. For higher FFA content in the crude oil, physical refining is useful.

Process type and process steps applied:

The process is described as an automated, fully continuous process using 2-step transesterification (with reaction plus separation at the same time) and continuous separation (plus extraction) of the glycerol phase by centrifuges. Simultaneously these centrifuges carry out a countercurrent water washing, followed by a final drying of the ester under vacuum. By means of modification of the second wash centrifuge the separation of sterol glycoacids from processing soy bean oil or palmoil is possible as well. Stable and uniform production in up to 360 days/a.

Additionally this process can be combined with the so-called “Alcoholic Neutralization” (GEA patent), an “Acid Esterification” (ADM application), or a physical refining (CIMBRIA SKET-Technology) in order to handle feedstock with higher contents of free fatty acids.

The catalysts used are heterogeneous, either sodium hydroxide or sodium methylate.

The amount of steam which has to be used is stated to be 200-400 kg/t, the amount of electricity is 20-30 kWh/t of biodiesel. The total yield of the process is 98 – 100 %, depending on the quality of feedstock.

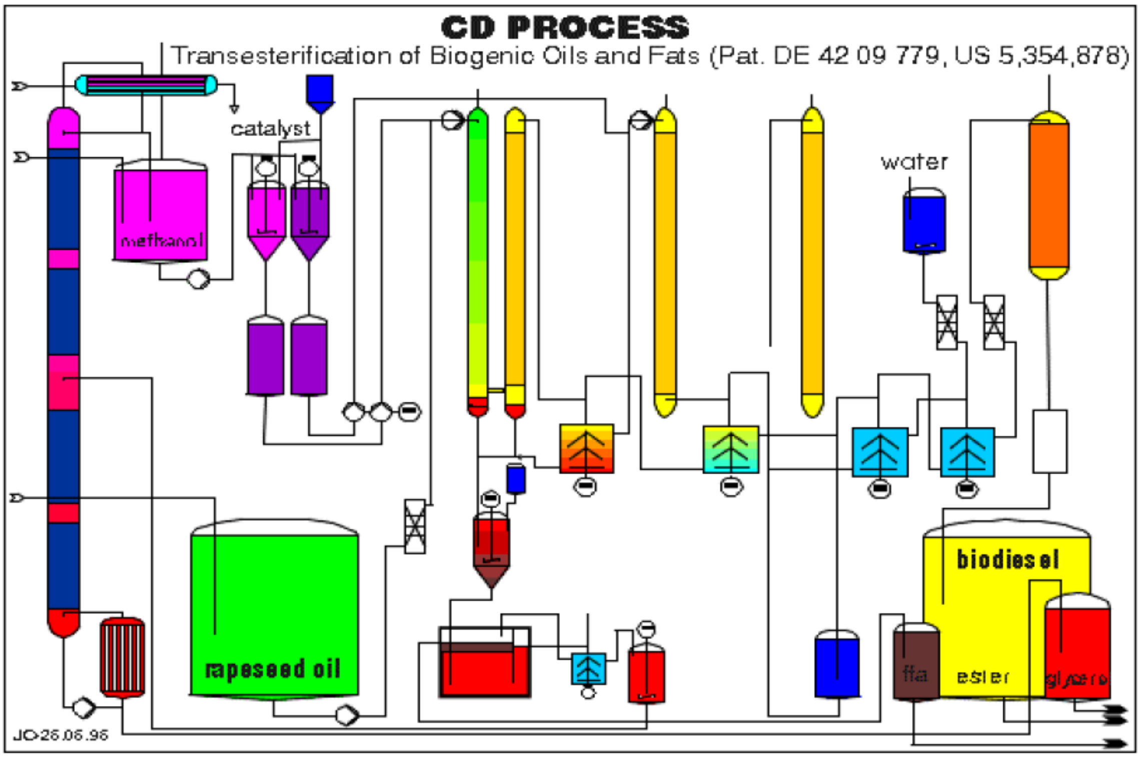


Figure 14: Connemann-ADM Process Flow Chart

Patents:

EP 0 562 504, 1992

US 5,354,878, 1993:

Offenlegungsschrift DE 102 43 700 A1 2004.04.01

EP 1 542 960 A1

WO 20/04029016 (08.04.2004 Gazette 2004/15)

Biodiesel quality:

Biodiesel produced meets EN 14214, shows extremely low Acid Value, Free Glycerol Content, Alkali Metals Content.

By-products:

Glycerol can be produced in different qualities, depending on the customers' demands, starting from 80 % up to 88 % (Westfalia Separator) or 99.8 % (Cimbria-Sket).

Free fatty acids (Westfalia Separator)

As solid by-products NaCl is formed as an output from glycerine distillation. (Cimbria Sket)

Plant sizes offered:

Biodiesel plants are offered within a capacity range of 35.000 t/a to 500.000 t/a biodiesel in one line.

References:

Today 13 plants are in operation with a total capacity of 1,605.000 t/a, and further 16 biodiesel plants are under construction with an additional capacity of **3.415.000** t/a.

Company Name	Country	Capacity in t/a	Start-up	Supplied by
ADM Oelmühle Leer	Germany	120.000	1996	ADM
Palma Tumys	Slovakia	35.000	2001	Westfalia Separator
ADM Oelmühle Hamburg I	Germany	150.000	2001	ADM
Bioölwerke Magdeburg	Germany	75.000	2003	Cimbria Sket with Westfalia Separator
ADM Oelmühle Hamburg II	Germany	200.000	2005	ADM
Iberol	Portugal	100.000	2006	Cimbria Sket with Westfalia Separator
RVM Vorpommern	Germany	100.000	2006	Cimbria Sket with Westfalia Separator
Ecanol	Germany	65.000	2007	Cimbria Sket with Westfalia Separator
Bio-Carburantes CLM.SL.	Spain	100.000	2007	Westfalia Separator with Cimbria Sket
EOP Falkenhagen	Germany	100.000	2007	Cimbria Sket with Westfalia Separator
Dansuk	Korea	35.000	2007	Westfalia Separator
ADM Oelmühle Mainz	Germany	275.000	2006	ADM
ADM	USA	250.000	2006	ADM
Total capacity		**1,605.000**		

Table 8: CD-process based biodiesel plants in operation

Plants under construction are listed in table 9:

Company Name	Country	Capacity in t/a	Start-up	Supplied by
Biocom Energia	Spain	75.000	2007	Westfalia Separator with Cimbria Sket
Dreyfus	USA	300.000	2007	Westfalia Separator
3 X ADM Wilma	Indonesia	1*250.000 2*300.000	2007	ADM
Biovegetal	Portugal	100.000	2007	Cimbria Sket with Westfalia Separator
Granol	Brasil	120.000	2007	Westfalia Separator
Fiagril	Brasil	120.000	2007	Westfalia Separator
Bioölwerke Magdeburg II	Germany	200.000	2007	Cimbria Sket with Westfalia Separator
Biolux	China	275.000	2008	Westfalia Separator / Cimbria Sket
Coansa /Koipe	Spain	200.000	2008	Westfalia Separator with Cimbria Sket
Korean National Energy	Korea	100.000	2008	Westfalia Separator with Cimbria Sket
ADM	Brazil	150.000	2008	ADM
Initiativas Bioenergeticas	Spain	250.000	2008	Westfalia Separator with Cimbria Sket
Greenfuel Estramadura	Spain	100.000	2009	Westfalia Separator with Cimbria Sket
Lotos	Poland	100.000	2009	Ferrostaal
Dreyfus	Argentina	275.000	2009	Westfalia Separator
Mercuria Energy BV	Nether-lands	200.000	2009	Ferrostaal
Total capacity		**3,415.000**		

Table 9: CD-process based biodiesel plants under construction

CD-Process – Reference 1:

Bio-Ölwerk Magdeburg GmbH

MD Mr. Reinhard Kluge

Am Hansehafen 8

D-39126 Magdeburg

Germany

phone: +49 (0)391 8381 - 0
fax: +49 (0)391 8381-333/444

http://www.bio-oelwerk-md.de/

kluge@bio-oelwerk-md.de

Bio-Ölwerk Magdeburg I was erected for the production of 65.000 t/a biodiesel from rapeseed. Its capacity was extended to 80.000 t/a in 2005. A second plant with a capacity of 200.000 t/a Biodiesel is currently under erection, and will be commissioned in the third quarter of 2007.

Feedstock:

Rape seed, rapeseed oil, soy bean oil, palm oil;

Products:

Biodiesel according to standard EN14214;

Pharma glycerine

Process:

Feedstock preparation: full press, acid degumming, physical refining;

Biodiesel process: transesterification

Glycerine treatment up to 99,5%

Capacity:

80.000 t/a; second plant with 200.000 t/a under construction

Site parameters:

The Magdeburg plant is located in the Elbe river harbour of Magdeburg, has access to the highway A2 and a train connection under construction.

Figure 15: Production Facility in Magdeburg, Germany

CD-Process – Reference 2:

Bio-Carburantes Castilla La Mancha SL

MD. Mrs.Ana Gabaldon Garcia

Ctra. Ocana y Yepes km 2,700

E- Ocana Toledo

Spain

phone: +34 915044085
f

http://www.biocarborantes.es

rim@bioarburantesclm.es

The Bio-Carburantes Castilla La Mancha has just recently been commissioned. The plant is located close to Madrid (70 km) at the highway A 4/R4

Feedstock:

Rapeseed oil, soy bean oil, palm oil;

Products:

Biodiesel according to standard EN14214.

Crude glycerine of 80 % purity.

Process:

Feedstock preparation: acid degumming, alcohol neutralization;

Biodiesel process: transesterification

Glycerine treatment up to 80%

Capacity:

100.000 t/a Biodiesel

Figure 16: Production Facility in Ocana, Spain

Christof Group
Maschinenbau & Handels GmbH

Helmut Winterleitner

Concept Str. 1

A-8101 Gratkorn / Austria

phone: +43 3124 22150 0

fax: +43 3124 22150 210

http://christof-group.at/cmb

cmb@christof-group.at

History:

The CMB Christof Group is a cluster of family-owned companies, which are among Austria´s leading internationally active industries with several specific branches in the metal working industry: e.g. industrial plant & pipe construction, apparatus construction & engineering, electrical installation & control and environmental engineering, representing a work force of over 1.200 employees.

With the takeover of the company ENA-Technik GmbH, which had a licensed process technology, CMB became intensively engaged with Biodiesel process technology from 1995 onwards, utilizing the synergy factors of the newly formed team.

The first large-scale commercial Biodiesel plant outside Austria was established for the company EOP ElbeOel Prignitz AG in Falkenhagen, Germany, in May 2003 with a capacity of 30.000 t/a Biodiesel, including an oil mill as well.

Company's scope of work:

- Process technology development
- Project planning; basic and detailed engineering of Biodiesel plants
- Consulting, feasibility and business plan
- Authority engineering for Biodiesel plants
- Manufacturing of main-equipment and installation of the plant, also including the infrastructure
- Start-up management of Biodiesel plants, commissioning
- General contractor for Biodiesel plants
- Technical operation management

Employees: 40 in the Biodiesel sector; this workforce can be increased from other sectors within the several CMB-company branches in a flexible way.

Suitable feedstock:

Virgin vegetable oils, used oil, rendered fats.

These raw materials can be used either straight or in blends.

Untreated (oil from the oilseed crushing plant without any further preparation) up to fully refined vegetable oils can be processed.

Used oils with an upper limit of FFA (Free Fatty Acid) of max. 20,0 % can be processed.

Plants with a process suitable for oils with a content of higher than 20 % FFA (Free Fatty Acid) can be built on request.

Process type and process steps applied:

The process applied is a continuous process. Depending on feedstock properties the Biodiesel production process operates optionally with

- pre-cleaning
- pre-esterification
- trans-esterification

and is using KOH as a homogenous catalysts in the process.

The “Best Yield Technology” applied allows the processing of non-degummed raw oils. Conventional degumming processes entail up to 4% loss of the raw oil material that usually is eliminated from the production process with the oil cake during pressing. These valuable resources are optimally used by CMB’s process technology. Thus, biodiesel plants by CMB reach yield levels up to 4% higher than plants with degumming and neutralization.

There is practically no solid or liquid waste accumulating from the Biodiesel production.

Biodiesel quality:

Biodiesel is produced according to the European Biodiesel standard EN 14214 and is superior in certain parameters (consult Annex B for further details).

It meets all criteria of the US Biodiesel standard ASTM-D 6751-02 as well. Further improvements can be ordered and installed upon specific request.

The process technology appears to be well suited for expected increased challenges to improve further the quality of Fatty-acid-methylester.

By-products:

By-products of the Biodiesel production are:

Crude glycerin, approx. 80 - 90% – raw material for industry, etc., which can be refined up to 99,7 % pharmaceutical grade quality, if requested.

Potassium fertilizer which can be used as spread fertilizer in agriculture.

Patents:

AT 397.510,

AT 410.443,

EP 658.183.

Plant sizes offered:

Biodiesel plants are offered within a capacity range of 30.000 t/a to 300.000 t/a biodiesel.

References:

ENA-Technik started very early in the days of small scale farmers' cooperative Biodiesel plants.

With the takeover by CMB Christof Group GmbH the Biodiesel plants got increasingly larger with an activity scope from basic and detailed engineering to complete construction, including the oilseed crushing part as well (e.g. Falkenhagen, Eemshaven).

Year	Location	Country	Type of feedstock	feedstock	Type of process	Capacity t/a	Status
1998	Henningsleben	DE	RS	SFS	batch[1)]	6.200	in production
2003	Falkenhagen	DE	RS	SFS	continuous	30.000	in production
2007	Eemshaven	NL	RS	SFS	continuous	66.000	under construction
2007	Valdetorres	ES	-	MFS	continuous	250.000	under construction
2008	Gaishorn	AT		MFS	continuous	60.000	under construction
	Lendava	SL	-	MFS	continuous	66.000	under construction
						478.200	**total capacity**

RS = rapeseed; SF = sunflower; SFS = single-feedstock; MFS = multi-feedstock;

Table 10: CMB References

CMB – Reference 1:

LPV - Landwirtschaftliche Produkt Verarbeitungs- Ges.m.b.H. / ADIB

General manager Ralf Bergholz

Hauptstrasse 98

D-99958 Henningsleben

Germany

phone: +49 (0) 3603 3908 0
fax: +49 (0) 3603 3908 28

http://www.lpv-biodiesel.de

lpv-kvg@adib.de

LPV is a member of ADIB (Agrar-, Dienstleistungs-, Industrie- und Baugesellschaft GmbH), http://www.adib.de

Feedstock:

Cold pressed rapeseed oil from seed grown in this area;

FFA content of max. 1 %.

Products:

Biodiesel according to standard EN14214 (and ASTM-D 6751-02), with additives as antioxidants and as CFPP-depressant in winter time.

Crude glycerine of 45 % purity.

Process:

Transesterification only.

Capacity:

The nominal capacity is 5.000 t/a Biodiesel, but has reached now 6.200 t/a after overall optimization.

The start-up took place in March 1998.

Site parameters:

Located in the middle of a productive rapeseed area in Eastern Germany.

Background information:

Member of “Arbeitsgemeinschaft für Qualitätsmanagement” (AGQM), the German Biodiesel quality circle, and of “Union zur Förderung von Öl- und Proteinpflanzen”, (UFOP - the German Union for the Promotion of Oilseed and Protein plants).

Figure 17: Production Facility in Henningsleben, Germany

CMB – Reference 2:

EOP ElbeOel Prignitz AG

CEO Sven Schön

Am Hünengrab 9

D-16928 Falkenhagen
Germany

phone: +49 (0) 33 986 / 505-0
fax: +49 (0) 33 986 / 505-99

http://www.eopbiodieselag.de

vorstand@eopbiodieselag.de

History:

The company was founded in 2000 and commenced production in 2004. At present it has 35 employees. In the financial year 2005/06 ending on June 30, EOP Biodiesel AG expects sales to have exceeded € 30 million and a € 1 million net profit for the year despite the cost of becoming a listed company.

It has been listed on the stock market since 14 September 2005 and has been traded in the Entry Standard segment on the Frankfurt Stock Exchange since the standard was launched on 25 October 2005.

Figure 18: General view of the oil mill and Biodiesel plant in Falkenhagen

Feedstock:

Virgin oils: rapeseed oil from rapeseed grown in this area, but recently also importing 4.500 t from the Baltic Holding Company in Latvia.

Products:

Biodiesel according to standard EN14214.

Crude glycerin according to the specifications of BS 2621 (80 % purity).

Process:

Continuous pre- and transesterification

Capacity:

The nominal capacity is 32.500 t/a Biodiesel with the start-up in May 2003; the plant capacity is going to be increased to 132.500 t/a by beginning of 2007.

Site parameters:

The plant is strategically positioned in the middle of a productive rapeseed area in Eastern Germany.

CMB – Reference 3:

Biovalue Nederland B.V.

Managing director Nico Vost
Westlob 6
NL – 9979 XG Eemshaven
The Netherlands

phone: +31 596-51 68 56

www.biovalue.eu

info@biovalue.eu

History:

Biovalue was established in 2004 and aims to set up international and national biodiesel plants using both pure plant oils and animal fats. Biovalue has a patent for the production process to convert glycerin into a fuel and additive. The company works in cooperation with partners in Austria, Germany and the Netherlands.

Plant description:

Oilseed crushing facility with a capacity of 165.000 t/a of rapeseed.

Trans- and Esterification unit.

Storage capacity for 2 weeks.

Products:

Biodiesel according to standard EN14214 (and ASTM-D 6751-02), with additives as antioxidants and as CFPP-depressant in winter time.

Technical glycerine of 80 % purity.

Capacity:

The designed capacity is 66.000 t/a biodiesel

Figure 19: Biovalue Nederland B.V.

Site parameters:

Located at a deep sea harbor and connected via pipeline for vegetable oil import.

Located at and connected via pipeline with a petrol oil refinery.

Energy and water supply assured from within the networks of this industrialized site.

Desmet Ballestra Oleo S.p.a

Contactperson: Francesco Soragna
Product manager

Via dei Castelli Romani, 2L
Pomezia
I-00040 Rome / Italy

Phone: +39 06 911 821

fax : +39 06 91 06 762

General E-Mail :
info@desmetballestraoleo.com

www.desmetballestraoleo.com

info@desmetballestraoleo.com

History:

De Smet Ballestra is known as one of the world leaders in engineering of oils & fats, oleochemical technologies, detergent and surfactant technologies and soap technologies.

De Smet was founded in 1946, when Mr Jean-Albert De Smet developed the first horizontal process for the continuous extraction of oilseeds. The company rapidly extended its range of products to supply the entire oil mill processing equipment, from seed intake to the bottled salad oil, i.e. seed preparation, pressing and extraction, oil refining and modification.

In about the same period, Ballestra, founded by an engineer in Milan, Mr. Ballestra, ventured into oleo chemicals and detergents. Through various technology alliances, combined with a strong product development, Ballestra achieved major references in this field. In more than 40 years, Ballestra have installed more than 220 oleo-chemical processes worldwide. Ballestra is also active in other fields of chemical processing.

In 1993 the first industrial biodiesel plant was established by Ballestra in Italy under EU demonstration program. The second one was built in the harbor of Livorno close to an oil mill for the company Novaol of the Ferruzzi Montedison Group with a capacity of 100.000 t, (which was purchased by the Bunge Group later on).

Since early December 2004, De Smet Ballestra is operating as one integrated group and on the 1st of December 2006 Barclays Private Equity, supporting this three years old strategy, acquired a majority stake in De Smet Ballestra enabling it to take full advantage of the expected growth of the oils and fats, chemicals and biodiesel markets.

Employees: approx. 200 in the biodiesel sector; worldwide over 800 people cumulative.

Company's scope of work:

- Fatty acid processes and fatty alcohol processes
- Glycerine processes for sweetwater, spent lyes and methylesters.
- Biodiesel & methylesters processes
- Plus the portfolio covering oilseed crushing, seed preparation, pressing and extraction, oil refining and modification

Suitable feedstock:

Virgin vegetable oils, used oil, rendered fats;

These raw materials can be used in varying blends of oils in a multi-feedstock approach.

Any type of feedstock can be accommodated by designing proper pretreatment, e.g.

- fully refined oil with <0,1 % FFA content,
- degummed vegetable oil with <0,1 % FFA content,
- recycled oils with >0,1 % - 10 % FFA content,
- oils and fats beyond 10 % FFA.

Process type and process steps applied:

The Ballestra Technology is based on a 3-step continuous transesterification unit that allows to operate under mild operating conditions with constant quality and minimized specific consumption of raw materials and energy.

The plant design is targeted also to reduce to a negligible extent the process effluents with consequent virtual elimination of pollutant and process wastes.

The Biodiesel production section, namely the transesterification of oils and the biodiesel purification step are characterized by unique features that with reference to the illustrated process block diagram (see next page), are here below described:

The transesterification reaction is accomplished in 3 steps with a methanol surplus with respect to the stoichiometric quantity, using an alkali methylate in anhydrous methanol solution as a catalyst.

Methanol and catalyst are dosed and recycled to the 3 reaction steps within prefixed rates. Reaction temperatures are lower than 60°C and pressure is max 0,5 bar(g). Overall residence time of the whole plant is 2 hours approx.

The yield of the continuous transesterification is 99,8% calculated as ratio of Neutral / Refined Oil fed to the transesterification versus the produced Biodiesel.

At the end of the transesterification process, two phases are accurately separated. Purification of the upper methylester phase involves separation of unreacted methanol, washing with water solutions and final drying.

Purification of the lower glycerine phase involves: neutralization, separation of unreacted methanol, dilution with wash liquid stream coming from methylester washing, splitting of soaps and final concentration up to 88 - 90%.

Partially refined glycerine can be delivered as such or sent to the upgrading-distillation section up to pharmaceutical grade meeting the most stringent pharmaceutical specifications.

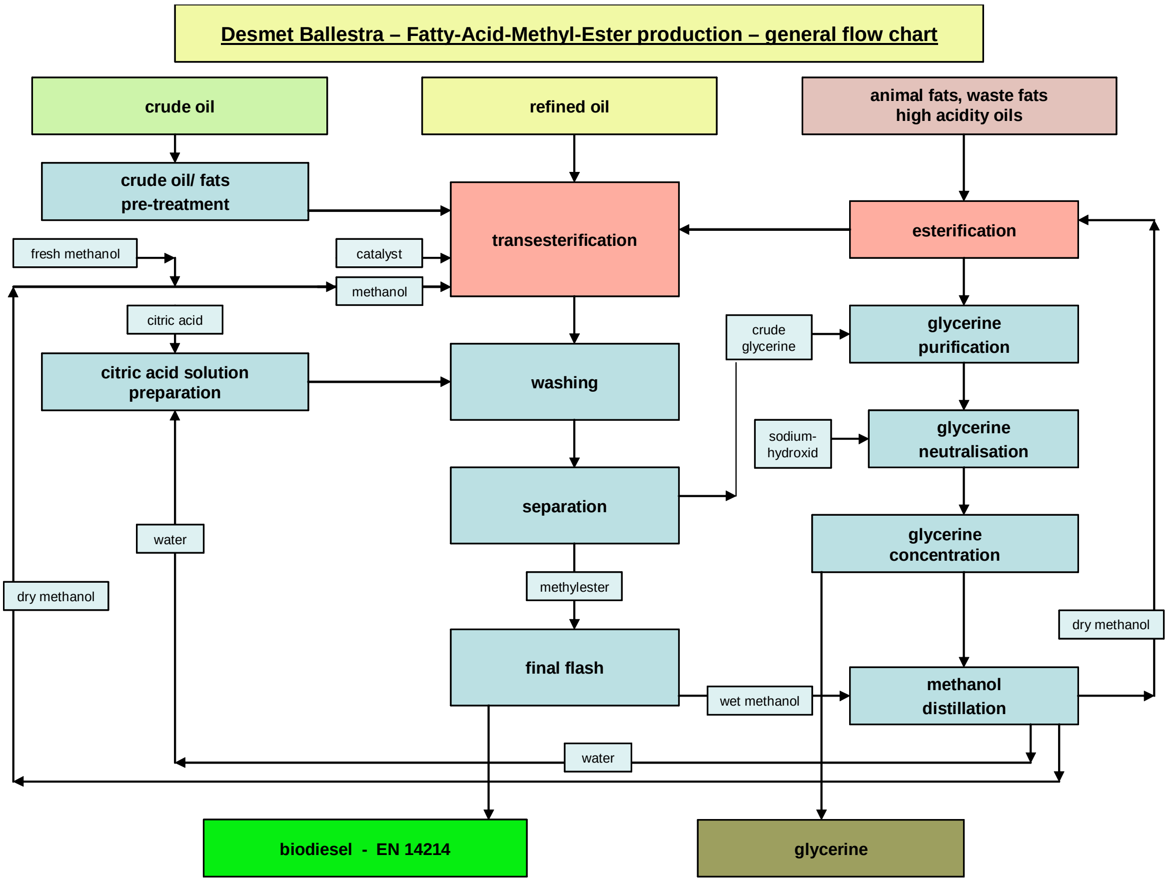


Figure 20: DeSmet Ballestra Biodiesel Production Flow Chart

Fatty-acid-ethylester (FAEE): production has been proven on small scale; a large industrial plant is under execution presently in Brazil and will be in operation beginning of 2007.

Biodiesel quality:

According to the European standard EN 14214 as well as to the US-standard ASTM-6751-03. Some improvements can be achieved on request:

By-products:

Glycerol, % according to costumers' needs, between 82 – 85 %;

Free fatty acids, (which can be fully converted to fatty-acid-methylester in an acid esterification)

Plant sizes offered:

Biodiesel plants are offered within a capacity range of 40.000 t/a to 400.000 t/a biodiesel.

References:

Desmet Ballestra has built 16 biodiesel plants that are currently in operation:

Company name	Location	Established in	Capacity t/a	Feedstock
Novaol	Greece	2005	100.000	rape/soy/cotton
Elvi S.A.	Greece	2005	40.000	rape/soy/cotton
Fábrica Torrejana	Portugal	2005	40.000	rape/soy/palm
Vance	Malaysia	2006	50.000	RBD* palm oil
Mid-Atlantic	USA	2006	20.000	soy/UFO**
Biopaliwa	Poland	2006	100.000	rape/soy/palm
Barralcool	Brazil	2006	50.000	soy RBD*/tallow
Granol	Brazil	2006	100.000	soy RBD*
Confidential	Malaysia	2006	100.000	RBD* palm oil
Zoop	Malaysia	2006	100.000	RBD* palm oil
Greenergy 1	UK	2007	100.000	rape/soy/palm
Martifer	Romania	2007	100.000	rape/soy/palm
Vance	Malaysia	2007	100.000	RBD* palm oil
Bertin	Brazil	2007	100.000	tallow
Caramaru	Brazil	2007	100.000	soy RBD*
Chemoproject 1	Czech Republic	2007	100.000	rape/soy/palm
Torrejana 2	Portugal	2007	40.000	rape/soy/palm
Total capacity:			**1 280.000**	

* RBD = refined bleached deodorized; ** UFO = used frying oil

Table 11: DeSmet Ballestra References in Operation

The portfolio of firm contracts comprises the following:

Company name	Location	Established in	Capacity t/a	Feedstock
Linares	Spain	2007	100.000	rape/soy/palm
Slunchevi	Bulgaria	2007	100.000	rape/soy/sunflower
Naturol	India	2007	100.000	crude palm oil
Kulim	Malaysia	2007	100.000	RBD* palm oil
Emami	India	2007	100.000	crude palm oil
Wratislawia	Poland	2007	150.000	rape/soy/palm
Peter Cremer	Singapore	2007	100.000	RBD* palm oil
Universal Biofuels	India	2007	150.000	crude palm oil and palm fatty acid distillates
Ruchi	India	2007	150.000	crude palm oil
Clean Cities	India	2007	250.000	crude palm oil
Darmex	Indonesia	2007	150.000	RBD* palm oil
SPC	Malaysia	2007	100.000	crude palm oil
Renewable Sources	USA	2007	33.000	soy/UFO**

Lake Erie	USA	2007	150.000	soy/palm/UFO**
Owensboro	USA	2007	150.000	soy
Tagol	Portugal	2007	100.000	rape/soy/palm
PT Ciliandra Perkasa	Indonesia	2007	250.000	crude palm oil
Palma Espino	Peru	2007	50.000	RBD* palm oil
Daabon	Colombia	2007	100.000	crude palm oil
Valouro	Portugal	2007	100.000	rape/soy/palm
Acor	Spain	2007	100.000	rape/soy/palm
Seabord	USA	2007	100.000	tallow/soy
Gebiosa	Spain	2007	200.000	rape/soy/palm
Greenenergy 2	UK	2007	100.000	rape/soy/palm
Biodiesel	Estonia	2007	100.000	rape/soy/palm
GF Energy	Greece	2007	100.000	rape/soy/palm
European Biofuels	Netherlands	2008	200.000	rape/soy/palm
Biofuel Company/Bunge	USA	2008	150.000	soy
Saras	Spain	2008	200.000	rape/soy/palm
Abener	Spain	2008	200.000	rape/soy/palm
Meroco	Slovakia	2008	100.000	rape/soy/palm
Expur	Romania	2008	100.000	rape/soy/palm
Ecosolution	South Korea	2008	200.000	RBD palm oil and palm fatty acid distillates
Dutch Biofuels	Netherlands	2008	250.000	rape/soy/palm
Rosendaal	Netherlands	2008	250.000	rape/soy/palm
Biodiesel SP	Malaysia	2008	100.000	RBD* palm oil
Confidential	Austria		100.000	rape/soy/palm
Confidential	Indonesia		250.000	crude palm oil
INEOS	France		100.000	rape/soy/palm
EBIRO	Netherlands		200.000	rape
INEOS	UK		500.000	rape/soy/palm
Bakrie	Indonesia		100.000	crude palm oil
Confidential	Italy		250.000	rape/soy/palm
Infinita-Isolux	Spain		600.000	rape/soy/palm
Infinita-Isolux	Spain		300.000	rape/soy/palm
Biooil	Spain		250.000	rape/soy/palm
Agrenco	Brazil		200.000	soy
Agrenco	Brazil		100.000	soy
Agrenco	Brazil		100.000	soy
Manuelita	Colombia		100.000	crude palm oil
Plant Biofuel Co.	Malaysia		100.000	crude palm oil
Patagonia	Argentina		250.000	soy
Dosbio	Spain		200.000	rape/soy/palm

Caffaro	Italy		100.000	rape/soy/palm
Oxen	Italy		200.000	rape/soy/palm
Irish Food Proces.	UK		100.000	UFO**/tallow
Global Biodiesel	Malaysia		300.000	jatropha/crude palm oil
Confidential	Indonesia		200.000	RBD* palm oil
Confidential	Indonesia		200.000	RBD* palm oil
Gomedic Sdn Bhd.	Malaysia		100.000	RBD* palm oil
Biodiesel LD Snd Bhd.	Malaysia		300.000	RBD* palm oil
Pure Biodiesel Co. Ltd.	Thailand		100.000	crude palm oil
Total capacity:			**10 233.000**	

* RBD = refined bleached deodorized; ** UFO = used frying oil

Table 12: DeSmet Ballestra References under Construction

DSB – Reference 1:

Novaol, Livorno, Italy

Via Leonardo da Vinci, 35 a

IT – 37100 Livorno
Italy

Company data:

The Novaol Company, originally part of Ferruzzi-Montedison Group, was acquired by Bunge in 2001. In October 2005 Bunge and the French Diester Industries formed a Joint Venture (40/60%) called Diester Industries International (DII).

Feedstock:

Virgin oils: rapeseed, sunflower, soy bean, palm oil

Used oils

Products:

Biodiesel according to EN14214;

Crude glycerol (80 %)

Capacity:

The Livorno plant was originally built in 1992 as the first industrial plant in Europe with 60.000 t/a capacity, later expanded to 100.000 t/a. A second 100.000 t/a line has been built in 2004.

Site parameters:

Located at a deep sea harbor and connected via pipeline for vegetable oil import.

Located very close to a petrol oil refinery.

Methanol supply and water treatment assured from adjacent companies in this industrialized site.

Figure 21: Biodiesel plant in Livorno, Italy

DSB – Reference 2:

Fábrica Torrejana de Biocombustíveis SA, Torres Novas, Portugal

Casal da Amendoeira – Apartado 2

PT – 2354-908 Riachos (Torres Novas)
Portugal

Company data:

The investors, originally a large transport company, were the first ones to see the opportunity in the Portuguese market. First step 50.000 t has started up early 2006 and intends to complete a second phase of construction within 2007 in order to expand the capacity to 100.000 t/a.

Feedstock:

Multiple type.

Foresees future usage of Jatropha (pinhão-manso).

Products:

Biodiesel according to EN14214, sold to the Portuguese petrol company GALP.

Crude glycerol (80 %).

Capacity:

The nominal capacity of the plant after completion of plant revamping in 2007 is 100.000 t/a biodiesel.

Figure 22: Biodiesel Production Facility on Torrejana, Portugal

DSB – Reference 3:

Vance Bioenergy, Pasir Gudang, Malaysia

PLO 668, Jalan Keluli 5, Kaw. Perindustrian www.vancebioenergy.com

Pasir Gudang
Malaysia

Company data:

Founded in September 2005. Start-up in July 2006.

Feedstock:

Refined Palm oil and olein

Products:

Biodiesel according to EN14214;

Crude glycerol (80 %).

Capacity:

The plant has a capacity of 50,000 t/a. Capacity shall be expanded to 150,000 t/a during 2007.

Site parameters:

Located in Pasir Gudang, industrial park close to Johor Bahru; nearby there are large palm oil refineries and it is close to an oil terminal.

Figure 23: View of the biodiesel plantin Pasir Gudang, Malaysia

DSB – FAEE Production Facility:

Usina Barralcool, Brazil

Barra do Bugres - MT

Brazil

Company data:

The country's first integrated biodiesel and ethanol plant in Barra do Bugres in the state of Mato Grosso for the production of ethylester. The President Lula has inaugurated the plant, the first of this kind in the world, in November 2006.

Feedstock:

Soy oil and Ethanol to produce FAEE

Products:

Biodiesel according to ASTM specifications

Crude glycerol

Capacity:

50.000 t/a

Site parameters:

Located in the state of Mato Grosso, in the center of Brazil, 2000 km from the sea. Mato Grosso is one of the biggest states of Brazil and agriculture is one of the principal activities.

Figure 24: View of the biodiesel plant in Barro do Bugres, Brazil

Energea Umwelttechnologie GmbH

CEO Nurhan Erguen

Inkustrasse 1-7/3
A-3400 Klosterneuburg / Austria

phone: +43 2243 26960

fax: +43 2243 26960 40

http://www.energea.at

mail@energea.at

History:

The company was founded in 1997 following the development of the basic continuous process technology by Mr. Ergün in a pilot plant in Schönkirchen / Austria. The process technology was implemented in a commercial-size Biodiesel plant in Zistersdorf in the year 2001. R&D-support was provided by the Technical University in Vienna. The actual R&D partners are the Austrian Research Center Seibersdorf and the IUCT (Chemical Institute of Barcelona University), Spain.

The first commercial Biodiesel plant outside Austria was established for Australian Renewable Fuels Limited in Adelaide, Australia in September 2004 with a capacity of 40,000 t/a followed by other plants (see below).

Since 2006 Energea cooperates amongst others with Chemie Anlagenbau Chemnitz (www.cac-chem.de) as partner for the general and detailed engineering world-wide.

Company's scope of work:

- Process technology development
- Project development and business plan for biodiesel plants
- Basic and detailed engineering of biodiesel plants
- Authority engineering for biodiesel plants

Employees: 15 in the biodiesel sector

Suitable feedstock:

Virgin vegetable oils, used oil, rendered fats;

These feedstock sources can be used straight or in blends at any ratio.

Free fatty acid content up to 100% can be processed.

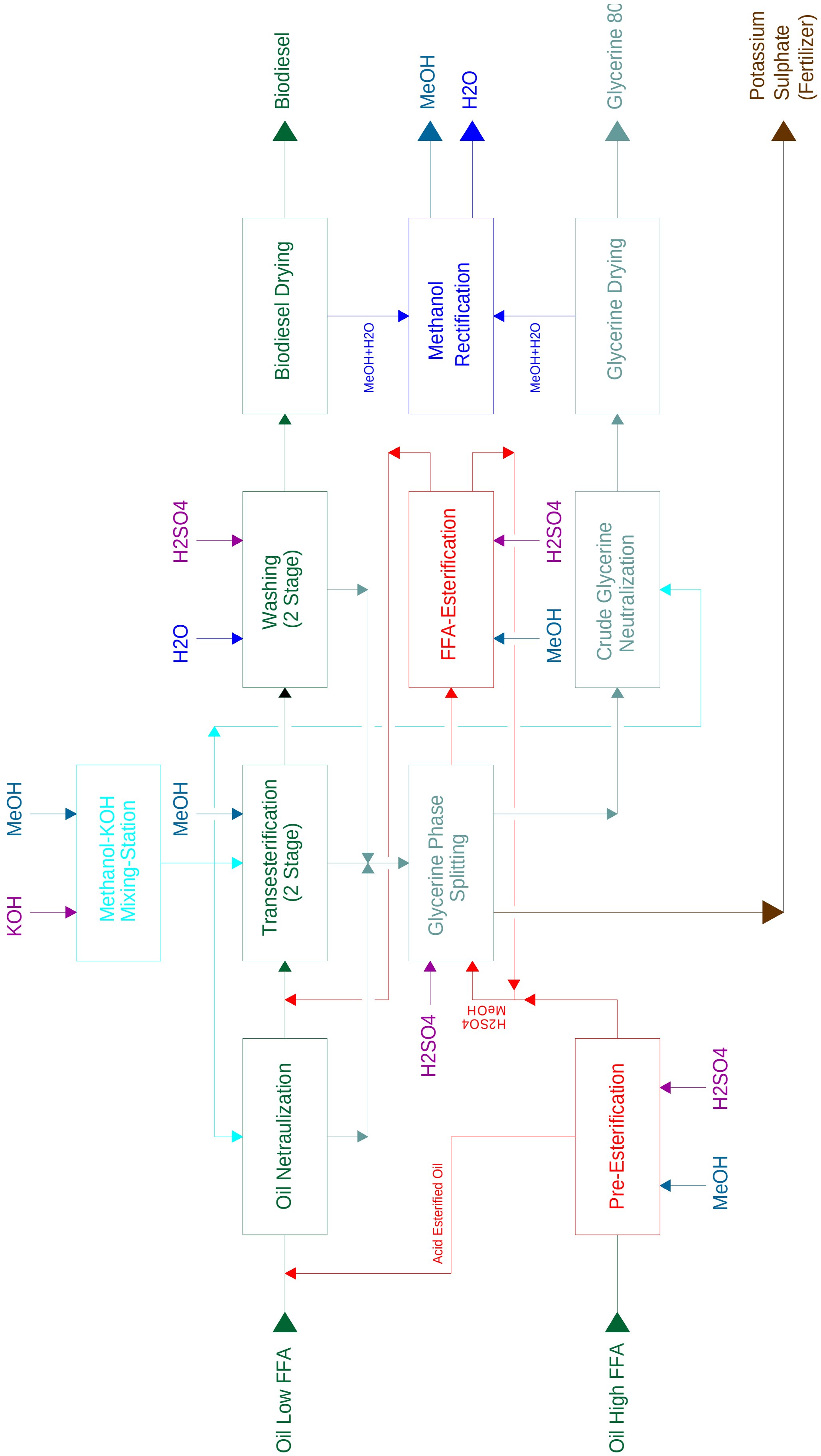


Figure 25: Energea Biodiesel Process Flow Sheet

Process type and process steps applied:

The conversion process takes place in the CTER-Reactor (Continuous Trans Esterification Reactor).

Depending on feedstock properties the biodiesel production process operates optionally with

- pre-esterification,
- trans-esterification and
- post-esterification

using homogenous catalysts in the process.

The process yield is at a level of approx. 100 % for fully refined vegetable oil as well as for oils with high FFA contents.

The process requires 330 – 400 kg steam and 28 kW electric energy per ton of produced Biodiesel for 250.000 tones Biodiesel per year.

There is no solid or liquid waste accumulating from biodiesel production.

Patents:

PCT AT 98/00284

PCT AT 03/00101

Biodiesel quality:

According to EN 14214

By-products:

Glycerol, in concentrations according to costumers' needs, usually 80%;

Metal salts.

Plant sizes offered:

Biodiesel plants are offered within a capacity range of 40.000 t/a to 300.000 t/a biodiesel according to EN14214.

References:

Energea Environmental Technology GmbH has so far established 4 dedicated biodiesel plants, with a total capacity of 370.000 t/a. These reference plants are:

Company	Location	established by	Capacity
Donauwind Erneuerbare Energie-gewinnung und Beteiligungs GmbH & Co. KG	Zistersdorf, Austria	November 2001	40.000 t/a
Australian Renewable Fuels Ltd.	Adelaide, Australia	March 2006	40.000 t/a
Biofuels Corporation PLC	Teesside, United Kingdom	April 2006	250.000 t/a
Australian Renewable Fuels Ltd.	Picton, Australia	June 2006	40.000 t/a

Table 13: Energea References

Energea – Reference 1:

DonauWind GmbH & Co. KG

Hartäckerstrasse 19/1

A-1190 Wien
Austria

phone: +43 (0)1 890 18 03
fax: +43 (0)1 890 20 87

http://www.donauwind.at

office@donauwind.at

Feedstock:

virgin oils: rapeseed oil, soy bean oil, palm oil

used oils: with FFA content < 4.5%

Products:

Biodiesel according to EN14214;

Crude glycerol (80 %) and metal salts

Capacity:

The nominal capacity is 40.000 t/a biodiesel; the start-up was established in November 2001.

Site parameters and space requirements:

Approx. 4.000 m^2, of which the actual processing plant occupies 250 m^2

Energy and water supply assured from within the networks of this industrialized site.

Figure 26: Delivery Unit, Tank Farm, Processing Unit

Energea – Reference 2:

Biofuels Corporation PLC

CEO Sean Sutcliffe

16 Earls Nook,
Belasis Hall Technology Park,
Billingham, Teesside,

TS23 4EF
UK

phone: +44 (0) 1642 371 600

http://www.biofuelscorp.com

mail@biofuelscorp.com

Feedstock:

Virgin oils: rapeseed oil, soy bean oil, palm oil

Used oils: with FFA content <4.5%

Products:

Biodiesel according to EN14214;

Crude glycerol (80 %) and metal salts

Capacity:

The nominal capacity is 250.000 t/a biodiesel; the start-up was in April 2006; the plant had reached 95 % capacity by August 2006.

Site parameters and space requirements:

Located at a deep sea harbor and connected via pipeline for vegetable oil import; pipeline connection to petrol oil refinery.

Energy and water supply assured from within the networks of this industrialized site.

57.955 x 35.036 m = 2.030 m^2 for the actual processing plant including pharmaceutical glycerol production, of which the processing unit occupies less than 1.000 m^2:

Figure 27: View of Biodiesel Production Plant in Teesside, UK

Energea – Reference 3:

Australian Renewable Fuels Ltd – “arfuels”

CEO Darryl Butcher

P.O.Box 837

South Perth WA 6951
Australia

phone: +61 (8) 9363 3500

http://www.arfuels.com.au

info@arfuels.com.au

Ownership:

The Australian Renewable Fuels Limited is the parent entity and owns:

1. Australian Renewable Fuels Adelaide Pty Ltd. (100%), in Adelaide, South Australia: The nominal capacity is 40.000 t/a biodiesel.
2. Australian Renewable Fuels Picton Pty Ltd. (100%), in Picton, Western Australia: The nominal capacity is 40.000 t/a biodiesel.
3. ASG Analytik Pty Ltd. (50%), biodiesel quality assurance laboratory. (Joint venture with the German company ASG)

Feedstock:

Unrefined canola oil

Tallow blended 80/20 with unrefined canola

Used cooking oil blended 30/70 with unrefined canola.

Products:

Biodiesel according to the established Australian National Standard for Biodiesel (Environment Australia, 2003), as developed and established in cooperation with the NBB / USA and the Austrian Biofuels Institute / Austria.

Site parameters and space requirements (for each of the two plants):

The actual processing plant occupies approx. only 350 m^2.

It is located at a deep sea harbor and connected via pipeline for vegetable oil import.

It is also located at and connected via pipeline with a petrol oil refinery.

Energy and water supply is assured from within the networks of this industrialized site.

Figure 28: Adelaide biodiesel plant

Analytical lab (ASG analytical lab)

Lurgi AG

Contactperson: Manfred HOFFMANN
Director Technology Oleochemicals

Lurgiallee 5

D-60295 Frankfurt/Main / Germany

phone: +49 (5808) 2717

fax: +49 69 5808 2766

http://www.lurgi.de

Manfred.Hoffmann@lurgi.de

History:

On 5 February 1897 the „Metallurgische Gesellschaft" was founded under "Metallgesellschaft AG". Its middle letters "…lurgi…" were used then as the cable address for the newly founded company. The word of "Lurgi" was taken to all countries and became an internationally renowned synonym for top-quality technological performance.

In order to meet the requirements of the international markets, Lurgi constituted itself as a German stock corporation in 1990. For establishing an efficient and future-oriented project execution structure the operating business units Lurgi Oel • Gas • Chemie GmbH and Lurgi Life Science GmbH, Frankfurt were merged to Lurgi AG, which now operates under the name of "GEA Group AG".

Lurgi AG no longer takes the function of a holding but is active on the market as an operating company. Lurgi focuses on proprietary technologies and exclusively licensed technologies in the product areas gas-to-petrochemical products via synthesis gas or methanol and synthetic fuels, gas generation and treatment, petrochemical intermediates and end products, biofuels as well as food and oleo chemicals.

Company's scope of work:

With the inauguration of its first biodiesel production plant for NEW GmbH in Marl/Germany, on 17 July 2002, Lurgi has made a successful start into the new biodiesel plant construction market, thus expanding from the existing segment of oleo chemical processes for food into the promising and fast growing non-food market segment.

Lurgi offers today biodiesel plants in a volume range from 40.000 to 250.000 t/a including esterification as well as transesterification process design.

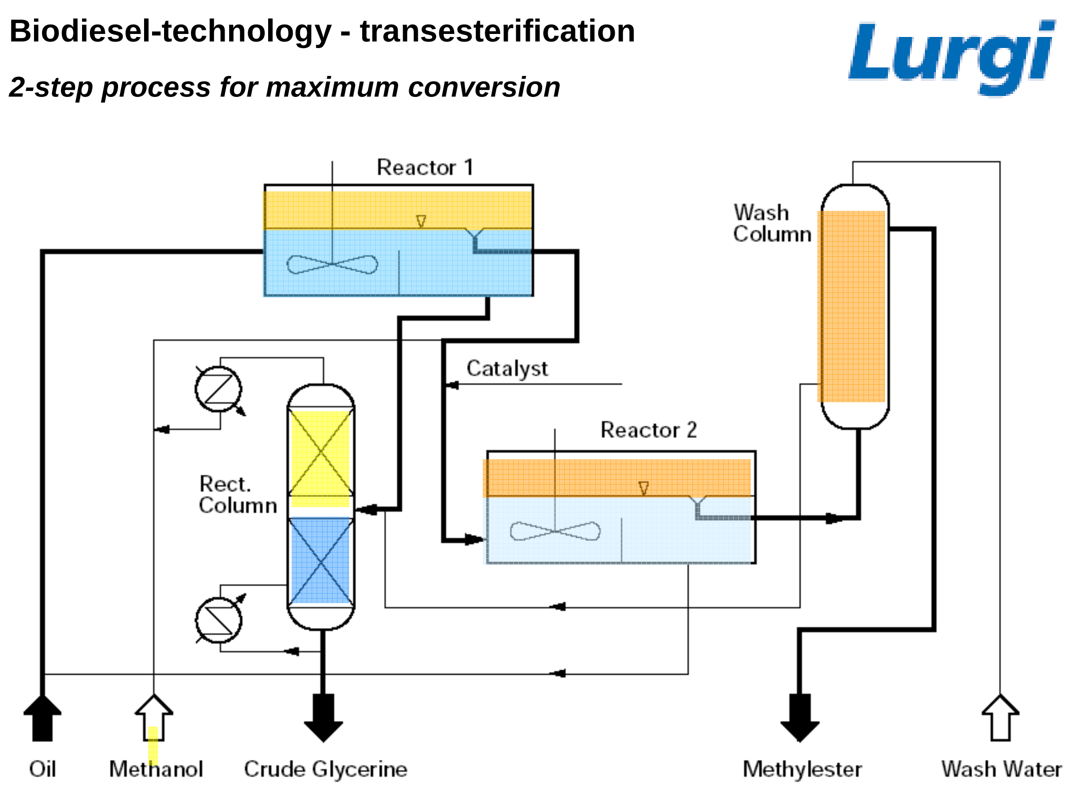
Lurgi's expertise covers basic and detailed engineering, procurement and supply, construction and construction supervision, commissioning and start-up.

Suitable feedstock:

- Vegetable oils derived from a variety of different oil producing plants (e.g. rapeseed, sunflower, soybean, palm, jatropha); degummed or higher quality level.
- Recycled oils and fats after pretreatment (removal of impurities), high FFA content possible.
- Rendering fats after pretreatment (removal of impurities), high FFA content possible.

Process type and process steps applied:

The reaction is effected in a two-stage mixer-settler unit. In a continuous process transesterification and - where applicable - acid esterification is taking place at atmospheric pressure and approx. 60°C, using sodium-methylate ($NaOCH_3$ – 29,5 %) as a homogenous catalyst for both esterification and transesterification. A subsequent countercurrent washing step for the methylester removes by-product components and produces a Biodiesel "ready for use" after a final drying step. The surplus methanol contained in the glycerine water is removed in a rectification column. The separation process does not require centrifuges.



More information: http://www.lurgi.de/website/fileadmin/pdfs/brochures/Biodiesel.pdf

Figure 29: Lurgi Biodiesel Process Flow Sheet

Yield measured as percentage of total triglyceride and free-fatty-acid in the feedstock material turned into fatty-acid-methyl-ester is nearly 100 %.

The process requires approx. 320 kg steam, 25 m^3 cooling water, 12 kW electrical energy, 96 kg methanol, 5 kg catalyst (Na-Methylate 100 %),10 kg hydrochloric acid (37 %), 1,5 kg caustic soda (50%), 1 Nm^3 nitrogen and 20 kg process water per t of produced biodiesel.

There is no solid waste accumulating from biodiesel production; concerning liquid waste only minimal volumes are produced.

Fatty-acid-ethylester (FAEE): production has been proven in lab scale; a pilot plant is under execution presently in Brazil.

Biodiesel quality:

According to the European standard EN 14214 as well as to the US-standard ASTM-6751-03. Improvements of several parameters can be achieved on request.

By-products:

Glycerol: crude glycerine according to British Standard 2621, pharmaceutical-grade glycerine according to EU Pharmacopoeia 99.5% on request.

Free fatty acids, (which are fully converted to fatty-acid-methylester in an acid esterification on request).

Plant sizes offered:

Biodiesel plants are offered within a capacity range of 40.000 t/a to 250.000 t/a biodiesel according to EN14214 or better as lump sum turnkey projects with single-line responsibility.

References:

Lurgi has so far established 7 dedicated biodiesel plants in production, with a total capacity of 790.000 t/a. These reference plants are:

Company	Location	Established in	Capacity t/a	Type of Feedstock
Natural Energy West/NEW	Marl, Germany	2002	100.000	RS
	Malchin, Germany	200x	40.000	n.a.
NEW, (extension)	Marl, Germany	2004	100.000	RS
EHN	Pamplona, Spain	2004	100.000	RS, SF, SB, POI
Biopetrol,	Rostock, Germany	2006	150.000	n.a.
	Frankfurt, Germany	2006	200.000	n.a.
Neckermann	Mannheim, Germany	2006	100.000	n.a.
Total capacity			**790.000**	

RS = rapeseed SF = sunflower SB = soybean POI = palm olein

Table 14: Lurgi References in Operation

Under construction:

Company	Location	Established in	Capacity t/a	Type of Feedstock
	Lülsdorf, Germany	2006	125.000	n.a.
	Cargill, USA	2006	100.000	n.a.
	Schrobenhausen, Germany	2006	100.000	n.a.
	Neubrandenburg, Germany	2006	40.000	n.a.
	Darwin, Australia	2006	150.000	n.a.
Neckermann	Piesteritz, Germany	2006	200.000	RS
	Cuenca, Spain	2006	35.000	n.a.
	USA	2006	15.000	n.a.
	USA	2006	100.000	n.a.
	Ettvelde, Belgium	2007	95.000	n.a.
Victoria	Novi Sad, Serbia	2007	100.000	RS, SF, SB
Neckermann	Enns, Austria	2007	100.000	RS
Biopetrol	Rotterdam, Netherlands	2007	200.000	n.a.
Total capacity			**1.560.000**	

RS = rapeseed SF = sunflower SB = soybean

Table 15: Lurgi References under Construction

Lurgi – Reference 1:

NEW- Natural Energy West GmbH

Manager: Mr. Bernhard Muke phone: +49 2131 2604 1

Chemiepark Marl;
Paul-Baumannstrasse 1

D-4576 Marl
Germany Bernhard.muke@natural-energy-west.de

Company data:

The total investment reached a volume of Euro 12 mill. The financial foundation was established by the 4 owners holding a 25 % share each.

Name of owners	Location	Business	Function
Bunge	New York / Hamburg	Agrotrade	International risk management for feedstock supply
Diester	Paris	Biodiesel-production	Marketing of glycerine
RCG Nordwest	Münster	Agro-cooperative	Marketing of Biodiesel
C.Thywissen	Neuss	Oil mill	Supply of semi refined rapeseed oil

Capacity:

The initial nominal capacity of the Marl plant was 100.000 t/a biodiesel in 2002 and has been expanded to 200.000 t/a in 2004.

Feedstock:

Virgin oils: refined rapeseed oil with < 0,05 % FFA supplied by pipeline from the oil mill in Neuss. Basically the use of other vegetable oils is possible.

Products:

Biodiesel is produced according to the EN14214 standard;

The crude glycerine is being purified to a concentration of 85,2 % purity.

Process:

Continuous transesterification.

Site parameters:

Located at a river harbor and connected via pipeline for vegetable oil import.

Supply of steam, electricity and waste management is provided by the existing chemical industry park installations.

Figure 30: Tank farm of the NEW biodiesel production plant

Lurgi – Reference 2:

EHN Combustibles Renovables

Manager: Mr. Alfonso Ezquerro phone: +34 948 22 94 22

Yanguas y Miranda 1, 5°

E-31002 Pamplona
Spain aezquerro@ehn.es

Company data:

The investor company is EHN (Energia Hidroelectrica de Navarra, S.A.), a company owned 100% by Acciona Energia S.A., and heading the Energy Division of Acciona.

This project has created 33 direct and 100 indirect jobs.

Investment cost worked out at 532 €/t, i.e. approx. 16 mill €.

Feedstock:

Virgin oils, such as sunflower, rapeseed, soybean, palm-olein.

Products:

Biodiesel according to EN14214;

Crude glycerol.

Capacity:

The nominal capacity of the plant is 30.000 t/a biodiesel and the start-up took place in 2004, producing now 35.000 t/a of biodiesel. The running cost were evaluated with 750 €/t biodiesel.

Site parameters:

The biodiesel production unit requires approx. 15 m x 30 m floor area and approx. 15 m building height. Additionally there are tank farm, utility sections and off-sites as well as infrastructure; approx. 2 hectares are required for the complete Biodiesel plant.

Figure 31: Overall View of the Biodiesel Processing Unit

4 Future Trends

Presently a very fast and accelerating development of Biodiesel production capacities can be observed on any continent and in nearly any country of this world with intensive investment activities in a kind of gold rush mentality.

This strongly accelerated development was certainly further supported by a rather unexpected rise of the crude oil price up to 78 USD/barrel in August 2006, (which has declined however to a level of just below 50 USD/barrel by mid January 2007,) triggering an increased willingness of governments to establish favorable national frame conditions for investors. In this macro-economically interesting situation the following trends can be observed:

4.1 Legislation

The quite successful and well founded biofuels legislation of the European Union (Directive 2003/30/EC) in supporting the development of renewable and carbon emission saving transport fuels has triggered a rather unexpected fast development of investment in biodiesel production capacities within the European Union. This development was undoubtedly faster in member states with an already established biodiesel industry like Austria, France and Germany, where a basic legislation (e.g. mineral oil tax exemption) did already exist and an understanding and acceptance – much broader than in other member states – had grown over the years for this new industry.

At present the European Commission is preparing the further expansion of market shares and to rise the obligatory consumption levels from 5,75 % market share in 2010 to 10 % by 2020 with a vision of 20 % market share later on.

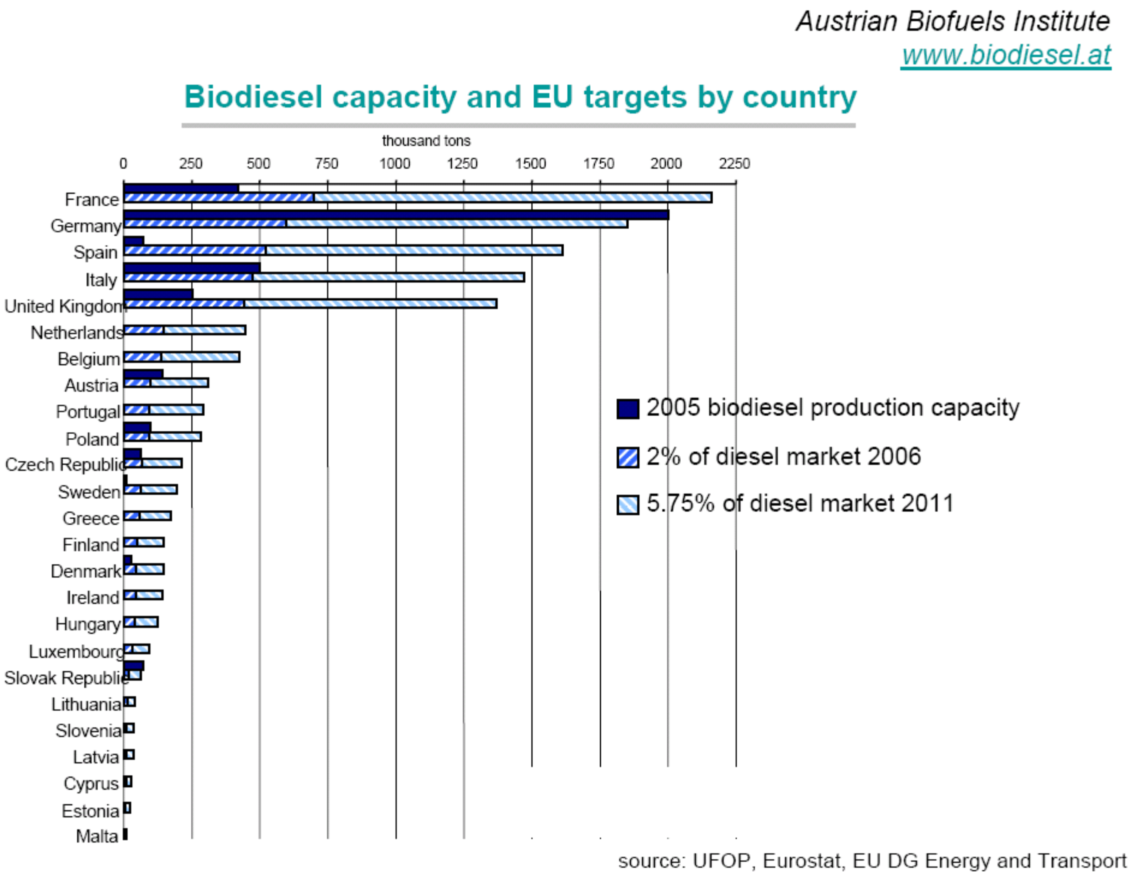


Figure 32: Biodiesel Production Capacity and EU Targets by Country

This legislation has also set the pace for other non-EU countries and continents to follow with similar initiatives. It can be observed that new national legislations may define new energy supply objectives measured by required market shares (like in the European Union) or by minimum blending requirements of e.g. up to 5 – 10 % biodiesel.

Other states support and encourage the development of a biodiesel industry by a number of different measure options such as fuel tax reductions or tax exemption for biofuels, subsidies to feedstock producers and to farmers growing established food crops as well as new non-food oilseed crops, investment incentives or other measures.

In a few countries financial support is provided by the state to initiate new oilseed plantations e.g. the non-food oilseed crop Jatropha curcas in India, China and Brazil with the motivation to increase the living standard of small local farmers.

Summarizing the applied legislative motives, three main objectives can be identified as the key driving forces for the expansion of biodiesel production: the reduction of greenhouse gas emissions, the reduction of dependency on fossil and non-renewable energy sources and the creation of additional income sources to the farming community and of new jobs.

4.2 Feedstock

Feedstock Supply and Flexibility

As a usual pattern, in a first step existing and nationally already produced oilseeds and oil bearing plants (such as rapeseed, palm, soybean and sunflower as the world-wide leading oilseeds) are used as the major source of feedstock for biodiesel production plants.

It can be observed that the world-wide production, processing and trade of oilseeds and vegetable oils is going to be increased substantially, hereby triggering expansion of required oilseed acreage as well as transport facilities for road, rail and waterways and related oilseed processing capacities.

In a second step the rather large family of non-food oilseed plants (e.g. Jatropha curcas as the lead plant) can develop over the years to a substantial supplier of oil, but these activities will need further R&D in professional breeding and cropping technology over the next 10 years.

This expansion potential is in so far interesting as those non-food oilseed plants will not compete for land against food oil seeds as they will be grown on so far not utilized land on marginal soils and in rather semi-arid climatic zones creating new sources for income there.

Additionally animal fats and low quality recycled oils from restaurants can be used as a low cost feedstock, however with a rather limited volume potential.

In a few countries the production of oils in algae is investigated, which looks quite interesting but is however in an early R&D-stage.

Observing the ups and downs of oilseed supply situations world-wide and related price variations over the years it can be assumed that a biodiesel production plant with a multi-feedstock supply strategy and a process technology, which can process low quality oils and fats, will be better off, as it offers more options in choosing the lowest cost feedstock mix at a specific point of time.

Sustainability Issues

Sustainability issues have been recently discussed and will become a major area of dispute as e.g. the expansion of soybean fields (e.g. in Brazil) or oil palm plantations (e.g. in Indonesia) may cause the destruction of natural forests and of rich biodiversity regions there. In order to meet this new challenge in a professional way Malaysia has already established a “Roundtable on Sustainable Palm Oil” - http://www.rspo.org/ - in order to develop guidelines for sustainable and world-wide acceptable palm oil production.

These and other activities may lead to a certification procedure, by which the overall production process is evaluated along sustainability criteria. It cannot be excluded that such criteria are going to be applied to the quite intensive and high-input European rapeseed production as well.

4.3 Production

Capacity Development

While the first biodiesel production plants were built with a capacity range of 5.000 to 15.000 t per year in the early 90ies, a clear trend towards much larger plants developed in the late 90ies with plant sizes of 100.000 to 150.000 t biodiesel.

This clear and strong trend towards even larger units is continued as we can see expansions of existing plants from 250.000 t being enlarged to 500.000 tons biodiesel production capacity per year (e.g. ADM in Hamburg, Germany and Diester Industries in Rouen, France).

New investments are starting with such capacity targets from the very beginning.

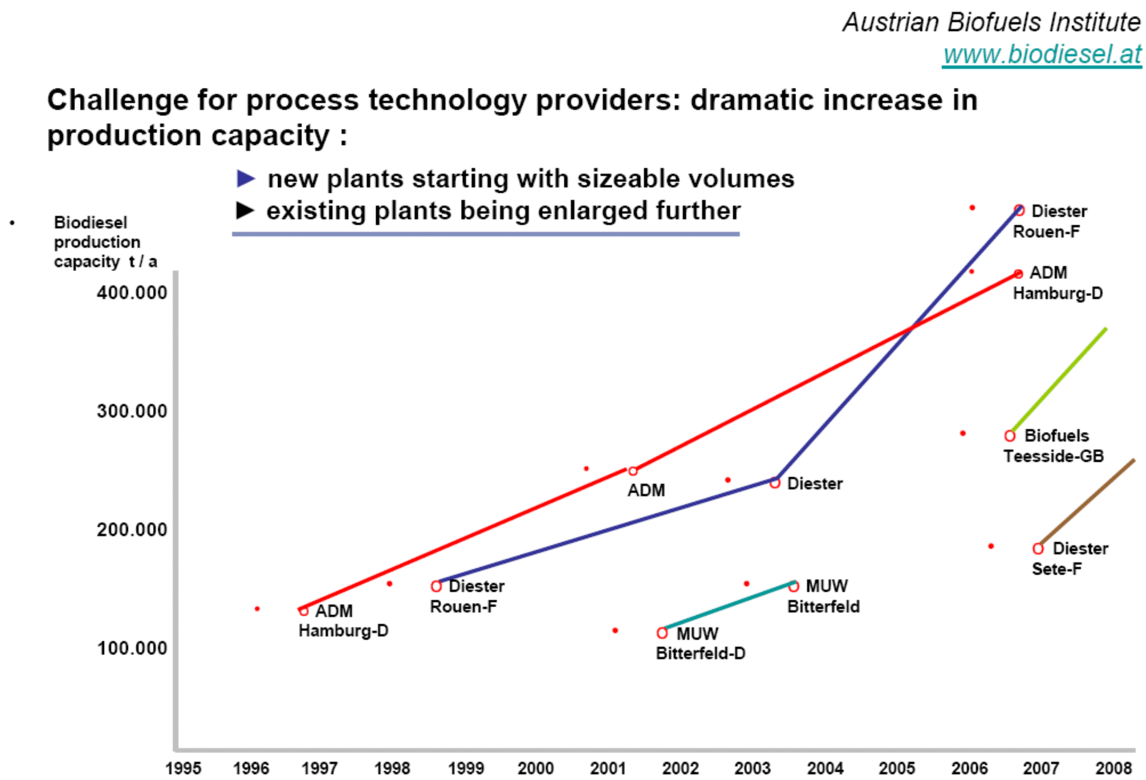


Figure 33: Biodiesel Plant Capacity Range Development

Site and Logistics

The selection of an appropriate site with optimal economy factors is seen as crucial as managing transport cost of low value goods is a key task.

Biodiesel production plants located at deep sea harbors have a clear advantage over river harbors or only railway connected plants as such a site offers more options for low-cost feedstock supply from various regions of the world and for shipment of biodiesel to any destination. Transport by truck is obviously the most expensive option.

Ideally such a biodiesel plant is located at an oilseed crushing plant for the processing of oilseeds including the degumming of the oil and connected by a biodiesel pipeline to a nearby fossil oil refinery as customer with lowest possible transport cost.

The following graph illustrates the various options of transport and related cost:

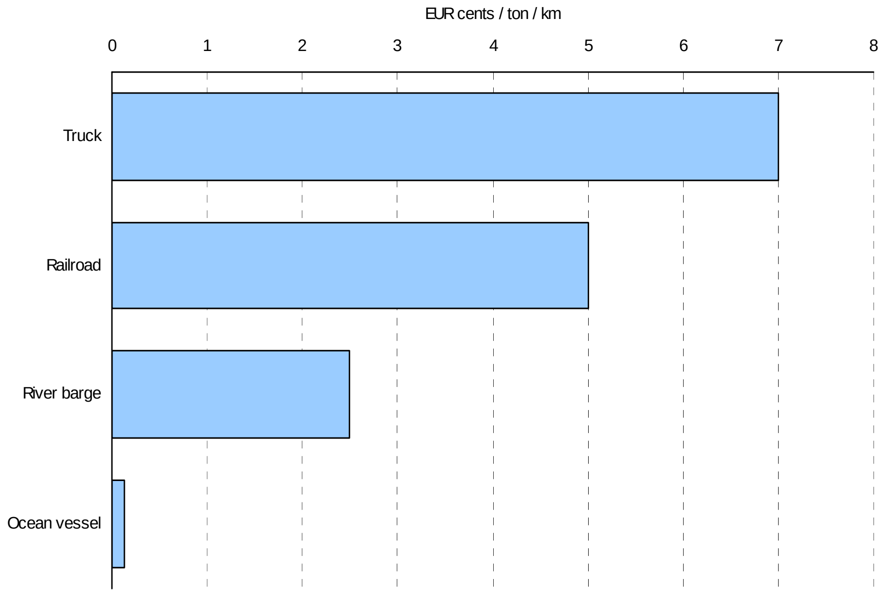


Figure 34: Cost of various Transport Options

4.4 Biodiesel Fuel Quality

Since the first definition of a biodiesel fuel standard in 1991 in Austria as a pacesetting measure for quality assurance, and the first European biodiesel standard EN 14214 in 2003, new and more challenging fuel quality requirements have been developed for both fossil diesel and biodiesel, which were triggered by the ongoing and further increasing demands to lower harmful engine exhaust emissions.

Both engine and fuel injection equipment design as well as fuel quality had to be improved accordingly, which required even cleaner production of any combustion fuel.

The European Commission has initiated the further development of the European standard EN 14214. Within the EU funded project “BIOSCOPES” further developments of the analytic methods for the ester content, free glycerol and glycerides as well as for polyunsaturated fatty acids have been carried out. Especially an adaptation of these methods to new feedstock like palmoil and coconut oil proved necessary. Furthermore a literature study has been carried out in order to evaluate engine performance with feedstock with higher Iodine Number like soybean oil and sunflower oil. This study should be the basis for the decision, if the parameter “Iodine Number” is still necessary or if the limit could be increased. Additionally, within CEN a standard for fatty acid ethyl esters will be developed, and the adaptation of the mineral oil standard EN 590 to allow biodiesel blends up to B10 is in preparation.

The parameters which are under discussion for further change of limits are the water content, the phosphorus content and the sulphated ash. Also the Rancimat method for the determination of oxidation stability will be adopted in order to use it also for biodiesel blends with mineral diesel.

4.5 Process Technology

The principles of most of the different process technologies today have become quite similar: transesterification of triglycerides as well as pre-esterification of free fatty acids have become state of the art and the required biodiesel fuel quality and high yield levels are achieved by all technologies.

Increasing requirements for further improvement of biodiesel fuel quality can be managed too, as a few process technology companies are already able to offer ways and means to improve fuel quality significantly.

Overall processing costs are relatively low and it appears challenging to improve this level of efficiency further.

Most of the biodiesel technologies today still use traditional catalysts like sodium methoxide or potassium hydroxide. However, some technologies will enter the market with heterogenous catalysts which could be reused and which lead to an easier purification of glycerol. A series of new developments like use of enzymes as catalysts or reaction under supercritical conditions have been published, but it is unlikely that those technologies will be used in industrial scale within the next years.

4.6 Glycerine

With the quickly developing capacities of Biodiesel production quite a dramatic increase of glycerine production was triggered, which will continue to grow further.

Simultaneously the overall price levels declined significantly from 900 US$ / metric ton in 1995 to approx. 100 US$ / metric ton in 2007. This dramatic decline triggered however new ideas of alternative usages of glycerine, e.g. to produce dibutoxy-glycerol as oxygen containing fuel additive (as proposed by Procter & Gamble) or to use it in the animal feed industry.

4.7 Information Availability

While information and literature availability was rather limited in the very beginning of the “Biodiesel age” in the late 80ies, there is now plenty available, with the challenge however to sort out the really valuable and well founded information from superficial and showy promotion as distributed by the home-brewer league.

It can be observed that information is still traveling at low speed and the “wheel” is reinvented in many countries, but with quite limited success however in this very beginning.

The authors’ team is confident that with this study a useful and instructive tool can be provided to the seriously interested biodiesel investor and that further success stories can be written in the near future.

5 Annex

Questionnaire

Questionnaire

Report „Process Developers Catalogue"

Commissioned by IEA Bioenergy Task 39

1. General Data

Name of company Owner

Does your company work in the field of:

☐ chemical engineering
☐ fuel production technology
☐ fuel production
☐ fuel transport and logistics
☐ trade of agricultural products
☐ waste collection

Contact person: First Name Last Name Position

Headquarters´ address Post Code City Country

Other offices´ address Post Code City
Country

E-mail address URL

	http://

Phone Fax

The evaluation of this questionnaire will be integrated into the report on "European Biodiesel Production Technologies", as commissioned by IEA Bioenergy Task 39. If you want us to include up to three pictures in our report, you can send them to pdc@biodiesel.at. Additionally please cite the corresponding captions below:

1
2
3

2. Process Technology

1. Detailed description of company´s work scope: since:

	since:
☐ project development and business plan for biodiesel plants	
☐ engineering and design of biodiesel plants	
☐ authority engineering for biodiesel plants	
☐ start up management of biodiesel plants	
☐ general contractor for biodiesel plants	
☐ any other (please specify)	

2. Number of employees in the biodiesel sector

3. Annual turnover in the biodiesel sector [EUR] (optional)

as in 2001	2002	2003	2004	2005

4. Your company offers its services in relation to a biodiesel plant that operates under the following conditions:

a) Suitable feedstock:

vegetable oils	**rendered fats**	**used oil**
☐ rapeseed oil (canola)	☐ tallow	☐ individual homes
☐ sunflower oil	☐ lard	☐ restaurants
☐ soy bean oil	☐ poultry fats	☐ food industry
☐ palm oil		☐ yellow grease
☐ jatropha oil		☐ trap/brown grease
☐ other vegetable oil, please specify**:**		
☐ **other feedstock, please specify:**		

b) These feedstock sources will be used:

☐ straight
☐ in blends of (please specify blending recipes):
e.g.: rapeseed oil 50-80% palm oil 10-40% lard 10-20%

c) The feedstock quality should be:

☐ fully refined vegetable oil
☐ degummed vegetable oil

d) The maximum fatty acid content of the feedstock should not exceed (please specify): [%]

Process Technology continued (1)

e) The biodiesel production process operates with:

☐ transesterification only
☐ pre-esterification and transesterification
☐ transesterification and post-esterification
☐ simultaneous esterification and transesterification
☐ others, please describe:
Please add appropriate process flow diagram(s)

f) Do you hold any patents or patent applications (registered or granted) related to biodiesel production?
If so, please specify:

1.
2.
3.

g) The catalysts used for the biodiesel production process are (specify, if you like):

esterification	**transesterification**
☐ homogenous	☐ homogenous
☐ heterogenous	☐ heterogenous

h) By-products of biodiesel production are:

☐ glycerol
☐ please specify % of glycerol:
☐ % of glycerol according to customer
☐ free fatty acids
☐ metal salts (fertilizer etc.)
☐ others, please specify:

i) Please specify the yield of your biodiesel production process for at least one of the following quality grades of feedstock:

Feedstock quality:	Yield [%]
☐ fully refined vegetable oil	
☐ <1% FFA	
☐ <2% FFA	
☐ <5% FFA	
☐ <10% FFA	
☐ >10% FFA	

j) Please specify the average required steam and electricity quantities per tonne of produced biodiesel: J/t

☐ steam:
☐ electricity:

Process Technology continued (2)

k) Please describe the waste accumulating from the biodiesel production and your waste management:

	Amount [kg/kg biodiesel]	risk category	treatment/disposal
solid waste:			
liquid waste:			

l) Biodiesel plants offered are within a capacity range of: [t/a FAME]

☐ Larger capacities can be offered upon request.

m) Biodiesel will be produced according to:

☐ EN14214
☐ ASTM-D 6751-02
☐ others, please specify:

5. Possible production of fatty acid ethyl esters (FAEE) using bioethanol

The European Commission is interested whether FAEE might be an option in the biofuels for transport sector. We are therefore trying to gather information on FAEE production technologies and its possible implementation. Most companies might not have any experience on FAEE; nevertheless, any information given will be highly appreciated.

a) Is your process technology capable to produce FAEE?:

☐ yes : proven in pilot scale
☐ yes : proven in existing plant
☐ after minor technical modification possible
☐ no experience available

b) How much FAEE have been produced with your process technology so far?:

☐ none
☐ lab scale, several kg
☐ up to 1t
☐ 1 to 10t
☐ > 10t

c) What do you think are the main barriers for FAEE production (multiple answers possible)?

☐ no interest from customers
☐ price of ethanol too high
☐ no specifications for FAEE available
☐ change of technology too costly
☐ others, please specify

d) What is your opinion on the production and use of FAEE? Please describe:

3. References

In the following section you can describe up to three references. Any plant cited has to be dedicated to biodiesel production. Plants can either be actually operating ones, or projects with a legally binding contract (reference date April 30th 2006).

The total number of dedicated biodiesel plants in operation that your company has contributed to is:

Their total capacity is:

Optional:
Name, location and capacity of all the above plants:

Reference 1

Name of the company	Owner

Contact person: First Name	Last Name	Position

Address	Post Code	City	Country

E-mail address	URL
	http://

Phone	Fax

Date of start-up

Feedstock in use:

vegetable oils	**rendered fats**	**used oil**
☐ rapeseed oil (canola)	☐ tallow	☐ individual homes
☐ sunflower oil	☐ lard	☐ restaurants
☐ soy bean oil	☐ poultry fats	☐ food industry
☐ palm oil		☐ yellow grease
☐ jatropha oil		☐ trap/brown grease
☐ other vegetable oil, please specify**:**		
☐ **other feedstock, please specify:**		

These feedstock sources are used:

☐ straight			
☐ in blends of (please specify blending recipes):			
e.g.:	rapeseed oil 50-80%	palm oil 10-40%	lard 10-20%

The fatty acid content of the feedstock is in the range of (please specify): [%]

Reference 1 continued

The biodiesel production process operates with:

☐ transesterification only
☐ pre-esterification and transesterification
☐ transesterification and post-esterification
☐ simultaneous esterification and transesterification
☐ others, please describe:

The catalysts used for the biodiesel production process are (specify, if you like):

esterification	**transesterification**
☐ homogenous	☐ homogenous
☐ heterogenous	☐ heterogenous

By-products of biodiesel production are: please specify % of glycerol

☐ pharmaceutical glycerol (USP/PHEUR)
☐ technical grade glycerol
☐ crude glycerol
☐ free fatty acids
☐ metal salts (fertilizer etc.)
☐ others, please specify:

The nominal capacity of this plant is (please specify): [FAME t/a]

The size of the biodiesel production unit of this plant is (please specify): [m*m*m]

The actual production of this plant was [FAME t/a]: in

	2004
	2005

The total required steam and electricity quantities were [J/t]: in 2004 in 2005

☐ steam:		
☐ electricity:		

Biodiesel is produced according to:

☐ EN14214
☐ ASTM-D 6751-02
☐ others, please specify:

Reference 2

Name of the company	Owner

Contact person: First Name	Last Name	Position

Address	Post Code	City	Country

E-mail address	URL
	http://

Phone	Fax

Date of start-up

Feedstock in use:

vegetable oils	**rendered fats**	**used oil**
☐ rapeseed oil (canola)	☐ tallow	☐ individual homes
☐ sunflower oil	☐ lard	☐ restaurants
☐ soy bean oil	☐ poultry fats	☐ food industry
☐ palm oil		☐ yellow grease
☐ jatropha oil		☐ trap/brown grease
☐ other vegetable oil, please specify**:**		
☐ **other feedstock, please specify:**		

These feedstock sources are used:

☐ straight			
☐ in blends of (please specify blending recipes):			
e.g.:	rapeseed oil 50-80%	palm oil 10-40%	lard 10-20%

The fatty acid content of the feedstock is in the range of (please specify): [%]

Reference 2 continued

The biodiesel production process operates with:

☐ transesterification only
☐ pre-esterification and transesterification
☐ transesterification and post-esterification
☐ simultaneous esterification and transesterification
☐ others, please describe:

The catalysts used for the biodiesel production process are (specify, if you like):

pre-esterification	**transesterification**
☐ homogenous	☐ homogenous
☐ heterogenous	☐ heterogenous

By-products of biodiesel production are: please specify % of glycerol

☐ pharmaceutical glycerol (USP/PHEUR)
☐ technical grade glycerol
☐ crude glycerol
☐ free fatty acids
☐ metal salts (fertilizer etc.)
☐ others, please specify:

The nominal capacity of this plant is (please specify): [FAME t/a]

The actual production of this plant was [FAME t/a]: in

	2004
	2005

The total required steam and electricity quantities were [J/t]: in 2004 in 2005

☐ steam:		
☐ electricity:		

Biodiesel is produced according to:

☐ EN14214
☐ ASTM-D 6751-02
☐ others, please specify:

Reference 3

Name of the company	Owner

Contact person: First Name	Last Name	Position

Address	Post Code	City	Country

E-mail address	URL
	http://

Phone	Fax

Date of start-up

Feedstock in use:

vegetable oils	**rendered fats**	**used oil**
☐ rapeseed oil (canola)	☐ tallow	☐ individual homes
☐ sunflower oil	☐ lard	☐ restaurants
☐ soy bean oil	☐ poultry fats	☐ food industry
☐ palm oil		☐ yellow grease
☐ jatropha oil		☐ trap/brown grease
☐ other vegetable oil, please specify**:**		
☐ **other feedstock, please specify:**		

These feedstock sources are used:

☐ straight
☐ in blends of (please specify blending recipes):
e.g.: rapeseed oil 50-80% palm oil 10-40% lard 10-20%

The fatty acid content of the feedstock is in the range of (please specify): [%]

Reference 3 continued

The biodiesel production process operates with:

☐ transesterification only
☐ pre-esterification and transesterification
☐ transesterification and post-esterification
☐ simultaneous esterification and transesterification
☐ others, please describe:

The catalysts used for the biodiesel production process are (specify, if you like):

pre-esterification	**transesterification**
☐ homogenous	☐ homogenous
☐ heterogenous	☐ heterogenous

By-products of biodiesel production are: please specify % of glycerol

☐ pharmaceutical glycerol (USP/PHEUR)
☐ technical grade glycerol
☐ crude glycerol
☐ free fatty acids
☐ metal salts (fertilizer etc.)
☐ others, please specify:

The nominal capacity of this plant is (please specify): [FAME t/a]

The actual production of this plant was [FAME t/a]: in

	2004
	2005

The total required steam and electricity quantities were [J/t]: in 2004 in 2005

☐ steam:		
☐ electricity:		

Biodiesel is produced according to:

☐ EN14214
☐ ASTM-D 6751-02
☐ others, please specify:

We appreciate your cooperation in filling in this questionnaire.

The interpretation of all returned questionnaires will be part of a report for IEA Bioenergy Task 39 “Liquid Biofuels from Biomass” (www.task39.org). The report will be published on a CD-ROM by the end of 2006. We will be glad to send a copy to you as a reward for your efforts.

Please feel free to contact us with any further questions and comments:
Austrian Biofuels Institute: pdc@biodiesel.at