Conventional Bio-Transportation Fuels

An update

Report 2GAVE-03.10

GAVE schakelt door

Colophon

Projectnumber: 6247-02-02-01-1009/4700003399

This project is carried out as commissioned by The Netherlands Agency for Energy and Environment (Novem) in the framework of the so-called "GAVE" programme (inventory of new gaseous and fluid energy carriers for a sustainable energy supply). Novem is carrying out the GAVE-programme on behalf of the Ministry of Housing, Spatial Planning, and Environment, the Ministry of Economic Affairs and the Ministry of Transport and Water.

Management and co-ordination by:

NOVEM
Netherlands Agency for Energy and Environment
Catharijnesingel 59
PO box 8242
3503 RE UTRECHT
telephone: +31-30-2393493
Contact person: ir. E.J.M.T. van den Heuvel
e-mail: e.van.den.heuvel@novem.nl

The project is carried out by:

Energy research Centre of the Netherlands (ECN)
PO box 1
1755 ZG PETTEN
telephone: +31-22-4564949
Authors:
H. den Uil
R.R. Bakker
E.P. Deurwaarder
H.W. Elbersen
M. Weismann

Date: May 2003

More copies of this report can be acquired against payment of € 10,= (excl. of mailing costs) at NOVEM 's Publication Centre, by mentioning the title and number of this report (publicatiecentrum@novem.nl, telephone +31-55-5348199). The report is also available for downloading on http://gave.novem.nl.

Acknowledgement

The study described in this report has been performed by the Energy research Centre of the Netherlands (ECN), the Agrotechnological Research Institute (ATO) and Royal Nedalco. The Product Board Margarine Fats Oils (MVO) was so kind to supply statistical information. This study has been performed within the GAVE programme of the Dutch Agency for Energy and the Environment (Novem) (Novem project nr.: 6247-02-02-01-1009/4700003399). The study is registered at ECN under project number 8.20273.

Abstract

Up to now renewable energy sources are primarily used in the Netherlands for electricity production. At the end of the past decade Novem started the GAVE programme on behalf of the ministries of Housing, Spatial Planning and Environment and of Economic Affairs to facilitate the introduction gaseous and liquid fuels in the post-Kyoto period (after 2010), with the potential of more than 80% CO2 reduction as compared to its fossil alternative. In the first phase of the GAVE programme a large number of options for the production of climate neutral gaseous and liquid fuels were evaluated in a comprehensive study by ADL (Arthur D. Little International, Inc.). During the GAVE/ADL study, the conventional bio-transportation fuels (bio-ethanol from sugars and starch and bio-diesel from vegetable oils) were not included in the detailed analyses given their prospects for reduction of Greenhouse gas emissions (less than 50% CO2 reduction) and/or because of their costs of reduction of Greenhouse gas emissions as compared to improved options (e.g. cellulosic based ethanol vs. sugarbased ethanol)

The objective of this study is to update the knowledge on the conventional bio-transportation fuels. The data on costs and environmental performance of conventional bio-transportation fuels in recent studies analysed and compared with the GAVE/ADL study. Developments with respect to feedstock and conversion processes are described and reviewed. Current commercial activities in different countries are summarised. Finally, the prospects for reduction of Greenhouse gas emissions in the Netherlands by conventional-bio transportation fuels are determined and socio-economic issues relevant for these fuels are described.

Keywords

Bio-ethanol, bio-diesel, sugars, starch, vegetable oils, rapeseed, soybeans, animal fats, fatty acids, used cooking oil, waste vegetable oil, Greenhouse gas emissions, costs, commercial activities, socio-economic factors

Contents

Summary

In 1998 Novem started the GAVE programme on behalf of the Ministry of Housing, Spatial Planning and the Environment and the Ministry of Economic Affairs. The objective of the GAVE programme is to stimulate and speed up the market introduction of climate neutral gaseous and liquid fuels. In the first phase of the GAVE programme a large number of options for the production of gaseous and liquid fuels have been evaluated in a comprehensive study by ADL (Arthur D. Little International, Inc.). During the GAVE/ADL study the conventional bio-transportation fuels, bio-ethanol from starch and sugars and bio-diesel from vegetable oils, were not included in the detailed analysis. Bio-diesel from vegetable oils because of relative low reductions in Greenhouse gas emissions and corn-ethanol because of relative high cost of reduction of Greenhouse gas emissions. The objective of this study is to update the status of the conventional bio-transportation fuels.

For bio-diesel from rapeseed and soybeans the average price in recent studies are 0.56 €/litre (=17 €/GJ) respectively 0.76 €/litre (=23 €/GJ). For ethanol from sugar and starch crops the average price in recent studies is 0.50 €/litre (=23 €GJ). Use of the conventional bio-transportation fuels results in a considerable reduction of Greenhouse gas emissions, but they do not meet the criterion of a 80% reduction of Greenhouse gas emissions currently used in the GAVE programme. Bio-diesel from rapeseed results in a 52-61% reduction of Greenhouse gas emissions and for bio-diesel from soybeans and ethanol from wheat these ranges are 65-78% respectively 41-61%. Use of pure plant oil results in a somewhat higher reduction of Greenhouse gas emissions than use of bio-diesel.

For the feedstock for bio-diesel production it is important to consider the prospects of residues. Animal fats released by the food and feed industry and used frying oils are possible feedstocks for bio-diesel production. Due to changes in animal feed legislation the use of animal fats for animal feed production has been limited and the use of used cooking oils from restaurants for animal feed production has been banned. An estimate showed that totally about 210,000 tons of residues are available for bio-diesel production in the Netherlands, this equals about 3% of the current diesel consumption for transport in the Netherlands.

For bio-ethanol a wide range of different feedstocks can be considered. Generally, feedstocks that can be used for food production are not acceptable because of the relatively high costs. Also here the use of residues offer a considerable short-term potential for the production of bio-transportation fuels. Currently Royal Nedalco already uses molasses from the sugar industry and C-starch from the wheat processing industry for ethanol production. Waste streams released by the agro-industry potentially may be used to produce 2.2 million hectolitre ethanol/year, this is about 2.6% of the current gasoline consumption in the Netherlands. In the rest of Europe it is more economically feasible to use wheat, barley and C-sugars (surplus of European sugar production) as the primarily feedstock.

For bio-diesel developments in conversion technology focus on use of waste streams for bio-diesel production and on the use of micro-emulsions of lower alcohols and vegetable oils to reduce feedstock cost respectively conversion costs. It is expected that productions costs for bio-diesel will be reduced in the coming years, with anticipated improvements in conversion technologies, upscaling of present conversion facilities and a more constant fuel quality. Developments in ethanol production show continuous improvements in all parts of the production chain. Increasing yields and decreasing tillage and fertiliser use lower costs and improve environmental performance of crop production. Process development decreases energy use and capital costs of the ethanol production.

Bio-diesel and bio-ethanol are already produced and used in a number of countries within the European Union. In Germany, Austria, France and Italy bio-diesel is used, and in France, Spain and Sweden bio-ethanol (or derivates) are used.

As already noted residues offer considerable potential to fulfil the guidelines drafted by the EU for use of bio-transportation fuels. Using the draft directive for substitution of fossil transportation fuels in the Netherlands, the reduction of Greenhouse gas emissions amount 0.16 Mton CO2 in 2005 to 0.45 Mton CO2 in 2010 for bio-ethanol substituting gasoline en 0.66 Mton CO2 in 2010 for bio-diesel substituting fossil diesel. Complete substitution of all transportation fuels by bio-ethanol or bio-diesel results a reduction of Dutch Greenhouse gas emissions of 24 Mton CO_2 for bio-diesel and 19 Mton CO_2 for ethanol. The costs of reduction of Greenhouse gas emissions by bio-diesel and bio-ethanol are 200-260 €/ton CO_2 for bio-diesel (dependent on the feedstock used) and 305 €/ton CO_2 for bio-ethanol.

Apart from technical, environmental and cost factors other factors influence the implementation of bio-transportation fuels. For the Netherlands limitations on the use of animal fats for animal feed production and the reduction of the number animal farms might influence the discussion.

Although one can argue about the data used for and the results of life-cycle analyses, the general opinion reflected in different studies is that the future production of liquid fuels from woody and herbaceous biomass outperform the conventional bio-transportation fuels considered in this study with respect to costs and environmental benefits. This justifies that the conventional bio-transportation fuels are not considered for demonstration in the GAVE programme, especially considering the experiences that have already been gathered elsewhere.

Nevertheless, it is important to note that the conventional bio-transportation fuels will play a major role in the transition from petroleum based to biomass based transportation fuels. Development of markets and supporting mechanisms will be required before the introduction of the more favourable long-term options is feasible. The European directive on bio-transportation fuels will be the driver behind this development. Furthermore, the conventional bio-transportation fuels represent the only possibility to fulfil the guidelines drafted by the EU.

Even when in the short-term conventional bio-transportation fuels are implemented in the Netherlands, the discussion will arise about the environmental benefits of these fuels. In life-cycle analyses performed for these fuels often input data from different continents are used. It is important to note that the continents differ in type of feedstock used and in the characteristics of the conversion process and end-use. A specific European life-cycle analysis will be required to assess the prospects of conventional bio-transportation fuels.

1. Introduction

1.1. Background

In the past decade the Dutch government has set targets on improving energy efficiency and on the use of renewable energy sources. Furthermore, the Dutch government has committed itself, by signing the Kyoto resolutions, to reduce Greenhouse gas emissions. Up to now only the improvement of energy efficiency and the production of electricity from renewable energy sources have been implemented.

The use of gaseous and liquid fuels account for more than 50% of energy consumption and for more than 50% of the CO_2 emissions in the Netherlands. Use of climate neutral or renewable gaseous and liquid fuels will be required to enable a further increase in the use of renewables and to enable a further decrease of Greenhouse gas emissions.

To facilitate the implementation of climate neutral gaseous and liquid fuels, Novem[1] started the GAVE programme in 1998, on behalf of the Ministry of Housing, Spatial Planning and the Environment and the Ministry of Economic Affairs. The objective of the GAVE programme is to stimulate and speed up the market introduction of climate neutral gaseous and liquid fuels. The GAVE programme aims for the development of options that enable a further reduction of Greenhouse gas emissions in the post-Kyoto period.

1.2. Problem definition

In the first phase of the GAVE programme an inventory has been made of possible chains for the production and use of climate neutral gaseous and liquid fuels. In a first evaluation all chains have been assessed by Arthur D. Little International (ADL) on technical feasibility and impact, costs and environmental performance (esp. reduction of Greenhouse gas emissions). Existing chains, e.g. bio-diesel from rapeseed, as well as chains that have to be developed, e.g. ethanol from ligno-cellulosic biomass have been considered in this evaluation.

Conventional bio-transportation fuels[2], bio-diesel from fatty acids and ethanol from sugars and starch, have been rejected in the first evaluation, either because the reduction of Greenhouse gas emissions was not high enough or because the cost of reduction of Greenhouse gas emissions was relative high compared to competing options.

The most promising options have subsequently been subjected to a more extensive analysis in a second evaluation. Finally, ethanol, DME[3] and Fischer-Tropsch diesel from ligno-cellulosic biomass have been identified as the most attractive chains for substitution of petroleum based transportation fuels. It should be noted that the options that have been finally selected all require considerable development before market introduction is possible.

---

[1] Novem = Netherlands agency for energy and the environment
[2] For the existing chains for the production of liquid fuels from biomass (bio-diesel from fatty acids and ethanol from sugars and starch) the generic term conventional bio-transportation fuels is used in this report.
[3] DME=dimethylether

Meanwhile, the European Union has drafted directives on the use of biofuels for transport. Member states have to set targets for the minimum amount of biofuels for transport in their markets. Reference values for these targets are 2% substitution in 2005 and 5.75% substitution in 2010 (EU, 2002). The directives of the European Union necessitate a reconsideration of the prospects of conventional bio-transportation fuels.

1.3. Objective

The objective of this study is to reassess the status and developments for the production of conventional bio-transportation fuels. The following subjects will be considered in this study:

- Check whether for conventional bio-transportation fuels the results of the evaluation in the first phase of the GAVE programme are in line with recent data.
- Review the developments in the production and use of conventional bio-transportation fuels over the last 5 years.
- Provide an overview of commercial activities on conventional bio-transportation fuels in European countries.
- Estimate the potential of reduction of Greenhouse gas emissions by using conventional bio-transportation fuels in the Netherlands.
- List socio-economic factors relevant for the implementation of bio-transportation fuels

1.4. Report outline

The chains for the production of conventional bio-transportation fuels considered in the first phase of the GAVE programme will be described and analysed in chapter 2. In chapter 2 the results of the GAVE/ADL study for the conventional bio-transportation fuels will be compared with more recent studies. The developments in the production and use of bio-diesel will be reviewed in chapter 3. In chapter 4 the developments in the production and use of ethanol from sugars and starch will be presented. Commercial activities on conventional bio-transportation fuels in European countries will be reviewed in chapter 5. Based on the new data for the chains for conventional bio-transportation fuels the CO_2 reduction potential for the Netherlands will be estimated in chapter 6. Apart from the technical factors and costs, social and macro-economic issues might influence the policy on the use of conventional bio-transportation fuels. These issues are discussed in chapter 7. Finally, conclusions are given in chapter 8 and a discussion and recommendations in chapter 9.

2. Comparison of data from GAVE/ADL study with recent studies

2.1. Introduction

In this chapter for the conventional bio-transportation fuels the results of the evaluation in the first phase of the GAVE programme by ADL are described, analysed and compared with recent studies. The methodology and the input data used and the results of the study by ADL[4] have been described in a set of three reports (Novem, 1999a; Novem 1999b and Novem, 1999c). This chapter starts with a short description of the methodology used in the GAVE/ADL study. Subsequently the results for bio-diesel and conventional bio-ethanol are described, analysed and reviewed.

The GAVE/ADL study started with an inventory of options for the production of climate-neutral gaseous and liquid energy carriers. This resulted in a long-list with about thirty options. All options have been categorised in six distinct groups based on end-use and the type of final energy carrier produced. For each group a reference fuel chain based on fossil fuels was included in the analysis.

The long-list of options was subjected to a first evaluation by applying three filters, see Figure 1. In the technology filter options that will not be feasible within the next 20 years and options that will have little impact, i.e. a negligible potential for CO_2 reduction, were rejected. For the last two filters (fuel chain emissions and cost filter) integrated chains of feedstock exploration/production up to end-use have been analysed in the GAVE/ADL study. The steps considered in the integrated chains are:

Exploration & Production; of the feedstock.

Transport; of the feedstock to the fuel processing plant.

Fuel processing; to convert the feedstock into a transportation fuel.

Distribution; transport of the transportation fuel to a local market.

Marketing; to provide the transportation fuel to the end user.

End use of the transportation fuel.

Because of the relatively limited potential of waste streams and of biomass cultivation in the Netherlands import of biomass has been assumed for all fuel chains. In the second filter chains that resulted in relatively low reductions of CO_2 emissions (less than 50%) were rejected. Finally, the costs of the remaining options were compared. Options with cost above 1000 NLG/ton CO_2 (454 €/ton CO_2) were rejected and options that have competitors (within the

[4] In this report the study performed by ADL in the first phase of the GAVE programme is called the GAVE/ADL study

same group) with much lower costs of CO_2 reduction were also rejected. After the last filter fuel chains that were rejected were reassessed to ensure that no fuel chain was inappropriately discarded.

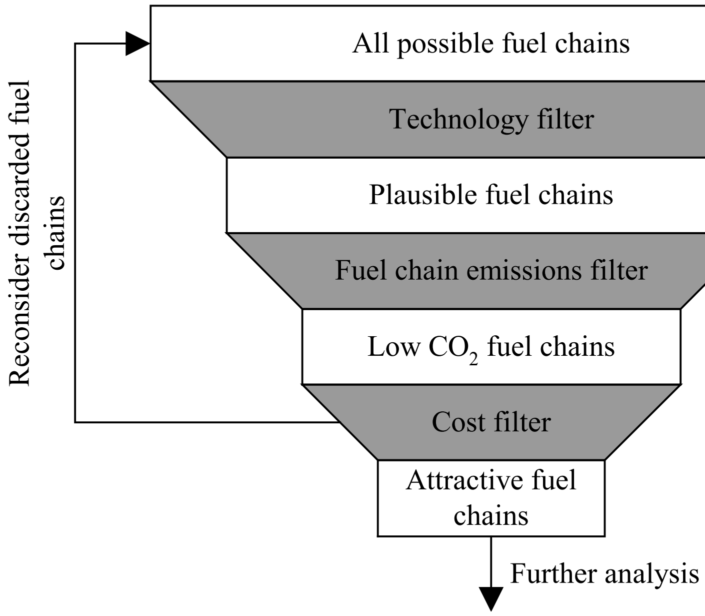

Figure 1: Filters used to reduce long-list of options

The conventional bio-transportation fuels considered in this report were discarded in this first evaluation phase of the GAVE/ADL study:

Bio-diesel from rapeseed was rejected because the complete chain resulted in less than 50% reduction of CO_2 emissions.

Bio-diesel from soybeans was rejected because the costs of avoiding CO_2 emissions were above 1000 NLG/ton CO_2.

Ethanol from corn was rejected because the costs of avoiding CO_2 emissions for ethanol from cellulosic biomass were much lower than for corn ethanol.

Twenty fuel chains survived the three filters in the first evaluation phase. This short-list of options was subjected to a second more thorough evaluation phase. Subjects covered in the second evaluation phase were a macro- and socio-economic analysis, a stakeholder support analysis and a replication potential analysis. Based on the results of these analyses, the most promising options were identified. For climate-neutral transportation fuels, ethanol, DME and Fischer-Tropsch diesel from ligno-cellulosic biomass were identified as the most promising options. For climate-neutral substitutes for natural gas, hydrogen with CO_2 sequestration, hydrogen from renewable electricity and synthetic natural gas (SNG) from biomass were identified as the most promising options.

It should be noted that all options selected after the second evaluation phase still require a considerable amount of research, development and demonstration before implementation is possible. With regard to the directives of the European Union it is worthwhile to reconsider the options that are already available and implemented elsewhere, i.e. the conventional bio-transportation fuels.

2.2. Bio-diesel

For bio-diesel two chains were considered in the GAVE/ADL study, see Figure 2. Bio-diesel is produced either from soybeans or from rapeseed. The bio-diesel is assumed to be imported from the Baltic States. After harvesting the feedstock is transported by truck to a transesterification plant. The bio-diesel produced is transported by a tanker to the Netherlands were it is marketed and used in internal combustion engines. It should be noted that at this moment most of the oilseeds are transported to the Netherlands, where the seeds are processed into meal and oil. This is due to the fact that the Netherlands has a relatively big animal feed industry.

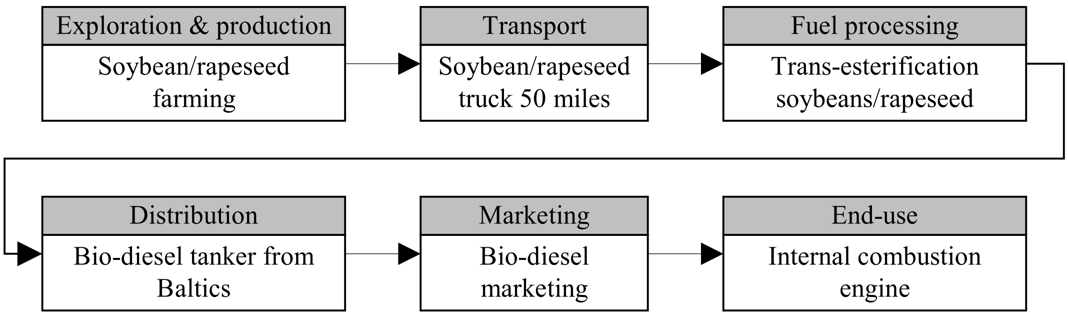

Figure 2: Fuel chain for bio-diesel from either soybeans or rapeseed

Based on the characteristics for each step in the fuel chain the costs and Greenhouse gas emissions have been calculated for the complete chain. Results of this evaluation are summarised in Table 1. The results show why rapeseed and soybeans based bio-diesel were rejected in the first phase of the evaluation: rapeseed based bio-diesel resulted only in 38% emission reduction (less than the 50% reduction required), whereas the costs of CO_2 reduction were too high for soybeans based bio-diesel (higher than the maximum of 454 €/ton CO_2 required).

	Rapeseed		Soybeans	
	GAVE/ADL study	GAVE/ADL study With correction	GAVE/ADL study	GAVE/ADL study With correction
Costs (€/litre)				
Bio-diesel				
• Exploration & production	0.46	0.00	1.25	0.00
• Transport	0.01	0.01	0.01	0.01
• Fuel processing	0.36	0.36	0.83	0.83
• Distribution	0.01	0.01	0.01	0.01
• Marketing	0.00	0.00	0.00	0.00
• End use	0.00	0.00	0.00	0.00
• **Total**	0.84	0.38	2.10	0.85
Diesel from petroleum		0.23		
CO_2 emissions (g/km)				
Bio-diesel				
• Exploration & production	99.49		29.19	
• Transport	1.14		1.45	
• Fuel processing	22.07		62.53	
• Distribution	0.64		0.64	
• Marketing	0.15		0.15	
• End use	0.00		0.00	
• **Total**	123.49		93.96	
Diesel from petroleum		198.17		
Reduction CO_2 emissions (%)	38		53	
Costs CO_2 reduction (€/ton CO_2)	575	144	1255	418

Table 1: Costs and CO_2-emissions for bio-diesel in the GAVE/ADL study

A closer look at the data of the GAVE/ADL study reveals that costs for exploration and production of feedstock are taken into account as well as the costs for the vegetable oil in the fuel processing step. This means that costs for feedstock are charged twice[5]. Therefore, in Table 1 also the costs of bio-diesel are given when feedstock costs are charged only once. Since it is assumed that there is paid for the rapeseed or soybean oil at the gate of the transesterification plant, costs for exploration & production are set at zero. The effect of this correction on the price of bio-diesel is rather large, costs for bio-diesel are reduced with 55% for rapeseed and with 59% for soybeans.

A number of studies are available on costs and reduction of Greenhouse gas emissions of bio-diesel. Not all these studies consider the complete fuel chain of bio-diesel in the same detail as in the GAVE/ADL study. However, the GAVE/ADL study showed that the costs of bio-diesel as produced equals about the cost price of the complete fuel chain. For Greenhouse gas

[5] This error has also been made for other fuel chains

emissions an assessment of the complete chain is required. The data given in different studies are summarised Table 2.

The price of bio-diesel from rapeseed given by different studies is within a relatively narrow range, 0.49-0.62 €/litre. The original value from the GAVE/ADL study is considerably higher, 0.84 €/litre, whereas the price of bio-diesel from rapeseed after correction is considerably lower, 0.38 €/litre. For bio-diesel from soybeans the price given in different studies shows a somewhat wider range, 0.63-0.98 €/litre. Clearly, the price given originally in the GAVE/ADL study is much higher. After the correction for charging feedstock twice the price of the GAVE/ADL study is within the range given by other studies.

With respect to reduction of CO_2 emissions a wide range of figures can be found in literature. A number of these figures are based on LCA studies in the period 1990-1995. Recent studies regularly only consider blends of fossil diesel fuels with bio-diesel (GM Europe, 2002; Davis 2002). Only three recent studies have been found that consider pure bio-diesel. The average value of CO_2 emission reduction from these studies is much higher than the value given in the GAVE/ADL study. For bio-diesel from rapeseed the emissions reduction is 57% (versus 38% in the GAVE/ADL study) and for bio-diesel from soybeans the value is 72% (versus 53% in the GAVE/ADL study). The reason for the much higher reduction of Greenhouse gas emissions is likely the differences in the oil yield assumed. For rapeseed an oil yield of 2.2 ton/ha/year was assumed in the GAVE/ADL study. Oil yields depend on farming practices and type of rapeseed, winter or spring rapeseed but higher yields seems to be possible. The Austrian Biofuels Institute (2001) reported a yield of 3.9 ton/ha/year in Schleswig-Holstein (Germany).

Reference	Rapeseed		Soybeans	
	Costs (€/litre)	CO_2 emission reduction (%)	Costs (€/litre)	CO_2 emission reduction (%)
Data based on review of previous studies				
De Jager, 1998	0.49	32		
Van Walwijk, 1998 (short term)			0.63	
Van Walwijk, 1998 (medium term)			0.76	50-80
Van Walwijk, 1998 (long term)			0.98	
Stevens, 2001 (USA)			0.67	
Stevens, 2001 (Austria)	0.52	25-80		25-80
Stevens, 2001 (Sweden)	0.60			
Enguidanos, 2002a (2000/2001)	0.56			
Enguidanos, 2002a (2007/2008)	0.62			
Armstrong, 2002		53		
Data based on new LCA studies				
Sheehan, 1998				78
Beer, 2000		52		65
Reinhardt, 2001		61		
Average	0.56	57[6]	0.76	72[6]
Range	0.49-0.62	52-61[6]	0.63-0.98	65-78[6]
GAVE/ADL, 1999	0.84	38	2.10	53
GAVE/ADL, 1999, with correction	0.38		0.85	

Table 2: Comparison of the results for bio-diesel of the GAVE/ADL study with different studies

Part of the Greenhouse gas emissions released in the bio-diesel chain are a result of the transesterification process. Use of pure plant oil, instead of bio-diesel, results in a further reduction of Greenhouse gas emissions.. The emission analysis in the GAVE/ADL study, see Table 1, show that the contribution of transesterification process to the Greenhouse gas emissions of the complete chain differs from feedstock to feedstock. For rapeseed 18% of the Greenhouse gas emissions are released in the transesterification/fuel processing step and for soybeans about 68% of the Greenhouse gas emissions. Ecobilan/PWC (2002) gives for the use of rapeseed oil 17.8 g $CO_{2,eq}/MJ_{fuel}$ and for the methylester of rapeseed 23.7 $CO_{2,eq}/MJ_{fuel}$, so Greenhouse gas emissions for use of pure rapeseed oil are 25% lower than for the methylester of rapeseed. So use of pure plant oils give lower emissions for Greenhouse gasses than methylesters of plant oil. However, use of pure plant oils is not possible in conventional diesel engines and requires the use of dedicated engines.

The Greenhouse gas emissions released in the fuel chains of bio-transportation fuels are a result of direct or indirect use of fossil fuels (fertiliser, fuels used for harvesting and conversion etc.). Replacing the use of these fossil fuels by renewable fuels offers an opportunity for a further reduction of Greenhouse gas emissions of the complete chain. Life cycle analyses on chains that use renewable inputs for harvesting and conversion have not been found in literature.

[6] Only data of new LCA studies are included

2.3. Ethanol from starch and sugars

The fuel chain for 'conventional' ethanol studied in the GAVE/ADL study is the production of ethanol from corn in the USA. Corn is grown in the USA and transported by truck to an ethanol production plant. The ethanol product is transported by tankers to the Netherlands, marketed and used as a substitute for gasoline. The results for corn ethanol are summarised Table 3.

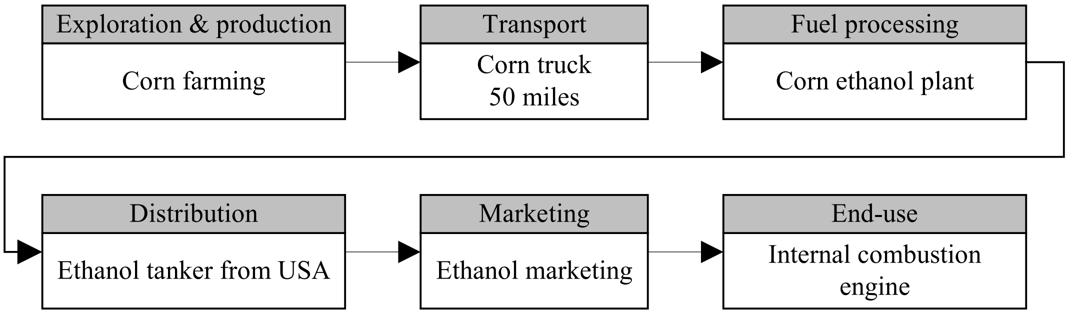

Figure 3: Fuel chain for corn ethanol

	GAVE/ADL study	GAVE/ADL study with correction
Costs (€/litre)		
Corn ethanol		
• Exploration & production	0.04	0.00
• Transport	0.01	0.01
• Fuel processing	0.45	0.45
• Distribution	0.00	0.00
• Marketing	0.00	0.00
• End use	0.00	0.00
• **Total**	0.50	0.45
Gasoline from petroleum	0.21	
CO_2 emissions (g/km)		
Corn ethanol		
• Exploration & production	45.38	
• Transport	1.65	
• Fuel processing	17.52	
• Distribution	0.00	
• Marketing	0.10	
• End use	0.00	
• **Total**	64.65	
Gasoline from petroleum	230.71	
Reduction CO_2 emissions (%)	72	
Costs CO_2 reduction (€/ton CO_2)	214	186

Table 3: Costs and CO_2 emissions for corn ethanol

Just like for bio-diesel, the feedstock for ethanol production has been charged twice in the GAVE/ADL study. In the second column the costs of ethanol are given when the feedstock is only taken into account once. Contrary to bio-diesel this results in only slightly lower ethanol costs.

The results of the GAVE/ADL study are compared with other studies in Table 5. The costs of corn-ethanol in the GAVE/ADL study are well in agreement with the data from other studies. Van Walwijk (1998) gives an increase in ethanol costs because an increase in feedstock costs is assumed

Concerning the data on reduction of Greenhouse gas emissions, it is important to note that these data are dependent on:

1. Type of feedstock used: corn, corn, wheat, rye, sugar beets, etc.
2. Local conditions; type of fossil energy used in the production process: coal or natural gas
3. Accounting of co-products.

The effect of the type of fuel, coal or natural gas, used in the ethanol production process is illustrated in Table 4. In the United States coal is use as primary fuel in ethanol production plants and in Canada natural gas (S&T Consultants, 2000).

	United States	**Canada**
85% ethanol	13.7 –18.8	37.1 – 44.5

Table 4: Reduction of Greenhouse gas emissions by ethanol use in the U.S. and Canada (in %).

Just like for bio-diesel figures on reduction of Greenhouse gas emissions found in litreature are often based on LCA studies in the period 1990-1995. For the more recent LCA studies, a distinction has been made between European and non-European studies. The GAVE/ADL study assumes import of corn-ethanol from the United States. Therefore, the results of the GAVE/ADL study have to be compared with studies on ethanol production in the USA. Based on the data listed in Table 5, the 72% reduction of Greenhouse gas emissions given in the GAVE/ADL study seems to be quite high. In recent studies this ranges from 19-32%.

For the European studies the reduction of Greenhouse gas emissions ranges from 41-61%, with an average of 51%. The uncertainties in the data are probably best reflected by the range given in GM Europe (2002) study (13-80% reduction in Greenhouse gas emissions). For the GM Europe (2002) study it should be noted that current ethanol production is compared with production of fossil fuel based transportation fuels in 2010.

Reference	**Costs (€/litre)**	**Emission reduction (%)**
Data based on review of studies		
Van Walwijk, 1998 (short term)	0.57	-/-30 – 35
Van Walwijk, 1998 (medium term)	0.65	
Van Walwijk, 1998 (long term)	0.80	
Stevens, 2001 (Canada)	0.33	
Stevens, 2001 (USA)	0.30	
Stevens, 2001 (France)	0.44	
Stevens, 2001 (Spain)	0.45	
Stevens, 2001 (Sweden)	0.50	
Enguidanos, 2002b (2000/2001)	0.42	
Armstrong, 2002		37

Data based on new LCA studies, for USA		
Wang, 1999 (current, corn, USA, E95)		19-25
Wang, 1999 (near-future, corn, USA, E95)		30-32
Davis, 2002 (corn, USA E90)		31
Data based on new LCA studies, for Europe		
Ecobilan/PWC 2002 (wheat)		61%
Ecobilan/PWC, 2002 (sugar beets)		60%
Röder, 2001 (wheat)		43%
Röder, 2001 (sugar beets)		49%
GM Europe, 2002 (sugar beet, Europe, fuel cell car)		41 (13-80)[7]
Average	0.50	51[8]
Range	0.30-0.80	41-61[8]
GAVE/ADL, 1999	0.50	72
GAVE/ADL, 1999, with correction	0.45	72

Table 5: Comparison of the results for conventional bio-ethanol of the GAVE/ADL study with other studies

[7] For ethanol from sugar beets and use in a fuel processor + fuel cell
[8] Only new LCA studies for Europe are included

3. New developments for bio-diesel

3.1. Feedstocks

Resources for bio-diesel production can be locally grown rapeseed or by-products of the food and feed industry in general and the oil seed processing industry in particular. The national oilseed production of The Netherlands is low due to its small size. Soybeans are not grown in the Netherlands but imported mainly form South America. Rapeseed is imported mainly from Eastern Europe.

	2001	**2000**	**1999**	**1998**
Rapeseed	2.4	2.9	4.5	2.7
Linseed	4.2	4.0	4.6	3.2
Poppy seed	0.9	0.8	2.1	1.7
Caraway seed	0.2	0.2	0.2	0.2
Total production	7.8	7.9	11.2	7.6

Table 6: Production of oilseeds, in 1000 tons, in the Netherlands (CBS, 2002)

The size of the oil seed processing industry in the Netherlands is mainly based on the size of the national animal feed industry and that of surrounding countries.

	2001	**2000**	**1999**	**1998**
Soy beans	4237	4075	4117	4103
Sunflower	636	640	472	516
Rapeseed	-	135	220	216
Linseed	59	102	129	137
Other seeds	10	22	26	24
Total processing	4942	4974	4963	4996

Table 7: Processing (in 1000 tons) by the Dutch oil seed processors

Soybeans and rapeseed as well as the oils are traded as commodities with a fluctuating price which depends on influences like weather conditions and demand. The connection of the prices between rapeseed and soybeans is less strong than the connection between the refined oils. This is due to the influence of the meal market.

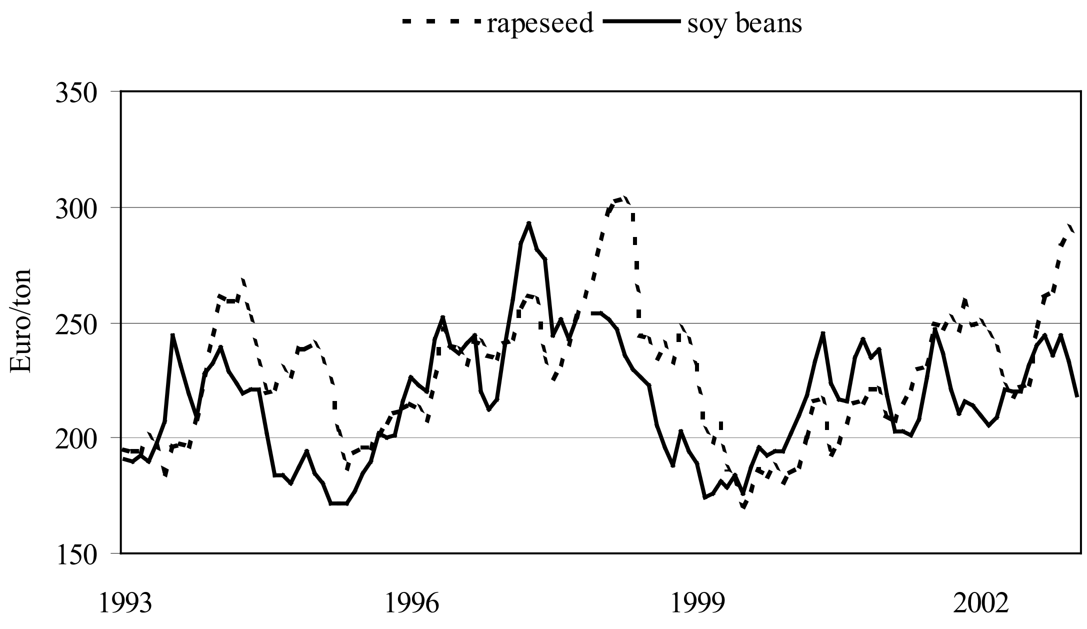

Figure 4 : Prices of soybeans (ex South America, CIF Rotterdam) and rapeseed (lower Rhine) (MVO, 2003)

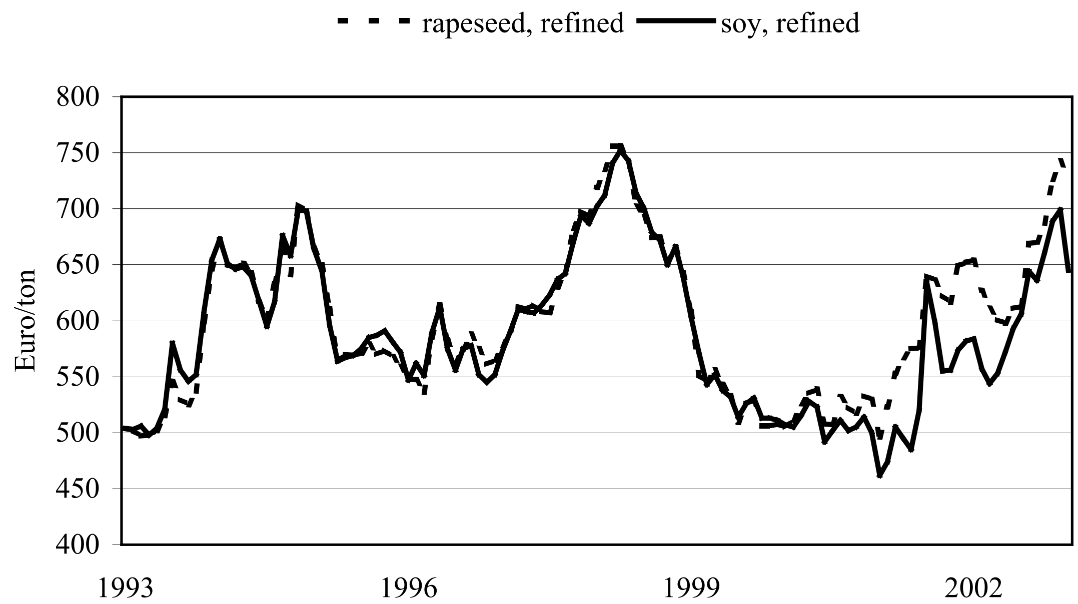

Figure 5: Price of rapeseed and soybean oil at factory gate (MVO, 2003)

Estimations by agricultural organisations show that in the northern provinces 12,500 hectares are available on a yearly base.

Another readily available feedstock is the by-products of the food and feed industry. Used frying oil from restaurants (also known as WVO=waste vegetable oil or UCO=used cooking oil) and animal fats can be used to produce bio-diesel. Until recent years most of this products were being used in the animal feed industry. While animal feed legislation became stricter the quantities of by-products available for fuel production grew. The use of used frying oil from restaurants in animal feed was banned in November 2002. Table 8 gives an estimation of the available quantities.

	2001
WVO Netherlands	60,000 ton
WVO import	50,000 ton
Production animal fat	70,000 ton
Production fatty acids	30,000 ton
Total 2001	210,000 ton

Table 8: Amount of residue streams that are suitable for technical uses including bio-diesel production in the Netherlands (MVO, 2003)

By-products and animal fats need more care during the conversion process because these products tend to have a higher fatty acid content. Commercial production of bio-diesel from used frying oil in Austria, where several locations are up and running, show however that this is a feasible option. Most of them blend the used frying oil derived bio-diesel with RME. Besides the use of used frying oil from restaurants some local Austrian initiatives have put up an effective system to collect used frying oil from households. In the Netherlands the maximum yield from households can be approximately 20,000 tons/year.

3.2. Conversion

High costs for production of alcohol esters from crops has generated considerable efforts to develop conversion processes for vegetable oils based on waste-fats and greases, or application of microemulsions of vegetable oils with lower alcohols. Vegetable oils and their methyl esters need to undergo additional processing for use in cold climates, a process also referred to as winterisation. To obtain bio-diesels with acceptable fuel properties by dry winterisation/fractionation increases the costs of bio-diesel with about 16% (Lee, 1996; Dunn, 1996). Micro-emulsions of oil/alcohols can be blended with petroleum diesels and offer the advantage that chemical modification costs of the oil are avoided to obtain the desired physico-chemical parameters, as will be noted later. Nevertheless, the temperature stability of the emulsion systems still causes some problems. Table 9 presents an overview of feedstocks used in recent studies.

Feedstock	Reference
Winterised Methyl Soyate	Lee et al. (1996)
Beef Tallow Ethyl esters	Wu et al. (1998)
EE Recycled Restaurant Grease	
IPA tallowate	
IPA greasate	
Soybean Oil/Ethanol emulsions	Dunn et al. (2000)
Soapstock	Haas et al. (2000)
Beef tallow ME	Muniyappa et al. (1996)

Table 9: Overview of feedstocks used for bio-diesel in recent studies

Conversion processes

The general process to produce fatty acid esters is transesterifaction in alcohol using a base (NaOH, KOH) as the catalyst. Reactions are carried out at atmospheric pressure, 68-70°C and conversion up to 90-99% occurs in about 1.5-2 hrs. Use of methanol and NaOH has the advantage of low costs, which is a requirement for low-cost bio-diesel production. Plant layouts have been published in litreature and semi-automated units are commercially available up to 130 tons per year. The esterification can be a one or two step process, depending on the required purity of the methyl esters. Process conditions must be carefully controlled to obtain maximum yields. An additional effect to be notified is the formation of a gel-like material in case the feedstock is highly saturated, such as beef tallow.

Base catalysts are faster than acid catalysts. Acid catalysts, such as p-toluenesulfonic acid or sulfuric acid, have the advantage that free fatty acids (FFA) are also transesterified, so these catalysts are only used when oils with high FFA are to be transesterified. The disadvantage of using acid catalysts is that they require higher temperatures and pressure thus leading to increased processing costs. Additionally, investment costs are higher due to corrosion problems. Production of higher alcohol esters, ethyl, n-propyl, I-propyl, n-butyl, I-butyl, requires increasing temperatures and reaction times. In addition, for the production of propyl and butyl esters it is necessary to use acid catalysts. Tert-butyl ester production has been unsuccessful so far. ABE fermentation mixtures have also been used in the preparation of esters for bio-diesel, but need long reaction times and suffer from incomplete conversion due to the presence of higher alcohols. Using enzymatic transesterification to produce methylesters from tallow and restaurant greases has been reported in litreature as well. Production of ethyl esters results in higher amounts of partial glycerides.

Glycerol is an economically important by-product and can be obtained from the aqueous phase after the conversion into methyl esters. However, increased production quantities of bio-diesel might cause market instability of the glycerol market. An alternative process that was suggested in litreature is direct conversion of the unpurified glycerol phase directly into monoglycerides. These monoglycerides can be used as emulsifiers in edible products.

It is also possible to process glycerol after thermal cracking in a fermentor, together with organic waste and use the biogas as fuel.

Fuel properties

High viscosity, low volatility and poor cold flow properties of vegetable oils result in severe engine deposits, injector cooking and piston-ring sticking. The Cloud Point (CP) or crystallisation onset temperature (TCO) is an important parameter for cold flow properties. It can be reduced by winterisation or fractionation of the raw material source. Generally TCO and CP correspond via the melting curve. Cold flow properties are also indicated by the kinematic viscosity, referenced at 40°C.

Unsaponifiables increase the crystallisation behaviour. However, CP and pour point (PP) can be adjusted by commercially available cold-flow additives, usually mixtures of ethylene vinyl acetate copolymers and naphtenic distillates. Furthermore, the cetane number is important. The cetane number indicates ignition delay time. It decreases by increasing content of branched molecules, e.g. replacing methyl esters by isopropyl or increasing IV. A normal diesel has a cetane number of about 40. Generally, fatty acid alcohol esters have a much higher cetane number. Correlations have been developed to predict the cetane number based on the molecular structure and physico-chemical parameters.

It is known that vegetable oils and their methyl esters deteriorate over time, which has been demonstrated in reported research. Although oil quality parameters showed a substantial quality deterioration over a two-year period, the combustion efficiency was only slightly affected. In a storage stability study the type of packaging containing the bio-diesel had no significant effect, but ethyl esters seemed to be more stable than methyl esters.

Engine performance

Fuel consumption with 20%-blends of esters in diesel fuel is somewhat higher which is directly related to lower caloric value of the esters: the energy content of esters is about 12% lower. Using pure methyl esters will undesirably dilute the engine lubrication system. In field trials with direct-injected (DI) diesel engines fueled by vegetable oils instead of esters, the three main problems indicated were: (1) injector coking, i.e. deposit built-up on the nozzles, causing dropping instead of spraying of fuel, (2) deposits on all parts of the engine, and (3) polymerisation of the oil. These problems became manifest already after a few hours of operation. The use of methyl esters prevents these problems, however compatibility of the rubbers, coatings and polymers with the esters should be observed.

Environmental impact

Direct environmental impact is measured in emissions, such as particulate(s), CO, unburned hydrocarbons (HC) and oxides of nitrogen (NOx). It should be noted that emissions are sensitive to environmental conditions, so reported data are not fully comparable. It should be noted that HC emissions decrease but this may be due to condensation of methyl esters in the exhaust system, making measuring difficult. Lower caloric value of esters might result in lower flame temperatures which explains the reduction in HC and CO. Generally, NOx is found to decrease at low concentrations of bio-diesels but increase with increasing ester content, usually >30%. NOx goes up probably as a result of higher cetane number and hence shorter ignition delay. This may cause ignition already at lower amounts of premixed air/fuel, but the cause is still not fully understood. Precombustion, however, is a complex process involving many reactive intermediates and is up till now poorly understood. Also, cetane number improving additives reduce NOx emissions. Generally, the observed emission effects are independent of the type of bio-diesel. Reduction of particulate emissions is generally attributed to the absence of aromatics and sulphur in the ester fuels and the increased oxygen content.

4. New developments for ethanol from starch and sugars

4.1. Feedstocks

Several feedstocks can be used for bio-ethanol production. Although availability and climate characteristics generally determine feedstock production, there are also some political policy based reasons to opt for a specific feedstock. Europe, United States and Brazil all promote domestic production and protect these products from imports (mainly with tariff barriers at the border). So the choice of feedstock for ethanol production (and their market prices) is also influenced by regional production policy and trade issues.

Sugar beet

Sugar beet is one of the feedstocks used for bio-ethanol production in Europe (only). A number of sugar producing plants in France are owned by farmer unions and produce also bio-ethanol. These production facilities are able to switch between two possible products: white sugar and ethanol. The construction of the factory is very different from most sugar factories. One pulps the sugar beet into a sugar syrup, from there one can produce white sugar or side stream the syrup for fermenting to ethanol. When, for example, sugar beet yields are too high, the national A- and B-quota for white sugar are easily met, which results in overproduction of sugar (so called C-sugar). The sugar companies can decide two things; export C-sugar syrup to the world market (at world market prices) or use the sugar for fermentation to ethanol. This economical decision depends on world market prices. Last years there is always been C-sugar production which was partially used for the (always stable) production demand for 1.2 million hectolitre bio-ethanol.

In the Netherlands sugar facilities are designed very differently. The sugar beets are solved into sugar syrup. Sugar companies extract from the syrup as much as sugar as possible. At some point it is not economical sound to keep on extracting. This side stream (molasses) still contains 45% sugars. There are two major sugar companies in the Netherlands, CSM and COSUN, with production share of 39% and 61%. Both companies sell their molasses to Royal Nedalco (which is a joint venture of both sugar companies). The molasses can be used for fermentation into ethanol. Most of the energy is already been used for sugar extraction, which leaves it for Nedalco very energy-efficient to ferment the molasses.

Sugar cane

Sugar cane grows in tropical and sub-tropical areas. It is for example the main source for bio-ethanol production in Brazil. Bio-ethanol from sugar cane can be produced in Brazil at a low level price and (over-)flows world market from time to time. Parallel with the sugar production process, sugar cane molasses can be produced as a side stream from sugar (cane) production. In the Netherlands (and Europe) sugar cane molasses are in very limited amounts being used as a (additional) feedstock for ethanol production (for food and industrial usage). Cane molasses are not able to compete with beet molasses on the European market. It is not likely that new WTO round will lower the import levy on sugar cane with such amounts that this will equal the price of beet molasses-delete

Grain

Several sorts of grains can be used for fermentation. For example wheat, barley, rye and corn. Which of the grains will be used for ethanol productions depends on:

Local circumstances; in areas with unfertile soils barley (Spain, France) and rye (East Germany) are produced in significant amounts.

European Common Agricultural Policy (CAP). Production of corn is not supported under the European CAP. It is not economical feasible to use corn for ethanol production in the European Union.

In the European Union there exists an intervention price for grain (except for corn). The European Commission guarantees this intervention price. When prices will fall below intervention price, the European Commission has the obligation to buy this grain. In the past this has happened frequently. But after the Mac Sherry reforms, intervention prices have been gradually lowered in the direction of the world market price. So less intervention was needed. In the proposals to review the CAP for 2006, the European Commission has proposed to reduce intervention price with another 5%. Besides the last 10 years quality demands for intervention have been increased. Nowadays only middle and high quality grains qualify for intervention.

Wheat, barley and rye (temporally) are expected to become the most competitive feedstock for bio-ethanol production (at large scale) in the European Union. Grain for bio-ethanol production will compete with the grains farmers use for their cattle feed. High quality wheat, barley (brewers) and rye are considered as feedstock for food production, and not for bio-ethanol production because prices are too high.

Side streams agri-processing industry

Side-streams of agri-processing industry contain valuable sugars, which can be used as a feedstock for bio-ethanol production. Several studies have indicated that this industry sector is highly represented in the Netherlands. Historically, the port of Rotterdam has been a gateway for all kind of agri-feedstock from around the world. Logically agri- and food processing industry has settled near water infrastructure in the Netherlands. Secondly, valuable outlet of side streams to the animal feed sector always had a positive economical impact on settlement of this industry in the Netherlands.

Last year the Rabobank studied the agri-processing (potato, grain, sugar) industry and its side-streams. Figures from this study show that there is potential ethanol production of 2.18 million hectolitre from side-streams alone. Prices of these side-streams are under pressure because of a declining animal (especially pig) sector. It is expected that this decline will continue coming years. Side-streams are therefore considered to be an interesting feedstock for bio-ethanol production in the Netherlands.

Royal Nedalco produces at this moment only ethanol from two side streams. The first side stream is molasses which is a sugar rich side stream from the sugar industry (see sugar beet). For the sugar industry it is not economically possible to extract all sugars from the sugar beet, but this is still a very interesting fermentation feedstock for ethanol production. The second side stream is so called C-starch which is supplied by Cargill. For milling of wheat huge quantities of wheat are being processed. Cargill's "A-stream" of starch is used for food purposes. Cargill's B-stream is also a side stream and is sold to animal feed sector. The C-stream of starch is a feedstock for the ethanol production.

Agriculture and trade politics

The agricultural feedstock prices heavily depend on Common Agriculture policy. For the coming years reforms of this historical long evolved policy could be crucial to this aspect. Compared with the United States we still have relatively expensive feedstock (see Table 5). Also the WTO round which will conclude in 2004 will have an impact on possible feedstock prices. How will European prices of grain develop? How will the sugar regime continue? Or do we end up importing bio-ethanol from Brazil because of lowering import duties? All of these issues heavily depend on political decisions.

Generally expected changes will develop very slowly. Till 2006 no major changes are expected for the biomass feedstock market for bio-ethanol. Technology developments, like technology for cellulose ethanol production, could speed up this transition process, but this is not yet an economical certainty.

4.2. Conversion

There are a wide variety of technologies used for producing fuel-ethanol from starch and sugars, and the vast majority is based on fermentation with the yeast *Saccharomyces cerevisiae*. Ethanol from sugar cane is produced by extraction (crushing) of sugar cane juice from the cane, after which the sugar concentration is increased through centrifugation and/or evaporation. Ethanol from corn (corn) is produced either through wet milling (grain is steeped in water followed by grinding, by-product separation, cooking, addition of enzymes to break down starch, final saccharification, and fermentation) or dry milling (entire grain is milled before adding water and enzymes, subsequent process is similar to wet milling).

In Brazil, 70% of the sugar-cane fermentation plants employ a batch process with separation of yeasts from the fermentation medium by centrifugation, and reuse of the yeasts. In North America, most older corn-fermentation plants are based on batch-culture technology that does not re-use the yeasts. In more modern plants, continuous input and output processes are used together with simultaneous saccharification with fermentation (SSF), which can be combined with yeast propagation. These plants are having computer-controlled process control, which reduces labour costs on a per unit basis.

Over the last two to three decades, a great deal of effort has gone into improving ethanol yields and reducing production costs, and these efforts are continuing in the near future. In Brazil for instance, ethanol production costs have reduced by 3% per year owing to a combination of new high-yielding sugar-cane varieties, improved cultivation practices and improvements in the extraction, fermentation and distillation processes.

In the USA, costs of producing ethanol have reduced by two-thirds since the early 1980's due to a 22% increase in ethanol yield and a 50% reduction in energy requirements. Moreover, the capital costs to erect a modern corn-to-ethanol facility has decreased from approximately 0.52 to 0.40 $/litre.

Table 10 presents an overview of recent technological developments in the production of fuel ethanol from starch and sugars, including changes to the production of raw materials (e.g. corn yields, fertilisation, establishment), fermentation, and distillation. Besides improvements to the ethanol production process itself, changes in the use of by-products (bagasse for electricity; corn stillage as fertiliser or bio-gasification) have increased the energy efficiency of the operation and reduced production costs.

Area	Developments
Crop production	High yielding varieties; reduced tillage; decline in fertilisation
Starch hydrolysis	Improved enzyme technology; On-site enzyme propagation
Fermentation	High-concentration wort; CO2 ethanol stripping: continuous membrane-bioreactor (removes ethanol but not yeast); yeast strain selection; continuous fermentation units: yeast immobilisation
Distillation	Pressure-swing adsorption; dehydration with molsieves
Process control	System Automation; integrated thermal engineering (capture and re-use of process heat
Co-product use	bagasse gasification; corn stillage refinery; corn-fibre oil and gum

Table 10: Recent (and near future) technological innovations in the fuel-ethanol production chain

Following the publication of the negative energy value (NEV) of ethanol from corn in the 1980's by David Pimentel, a number of recent studies have been carried out to develop new estimates for the NEV based on the technological improvements outlined above. In general, these studies conclude that the NEV of corn ethanol is positive and has been rising over the years due to technological advances in ethanol conversion and increased efficiency in farm production. The most recent study by the United Stated Dept of Agriculture (2002) states that:

- There has been a steady increase in annual corn yields since 1975, even with low annual yields due to drought in 1983, 1987 and 1993.
- The higher corn yields are shown without corresponding increases in energy use at the farm level, indicating that farm resources are used more efficiently.
- The use of both nitrogen and phosphate use (two major fertilisers that are derived from fossil fuels) has started to decline in the 1980's and manufacture of agricultural chemicals has become more energy efficient.
- A shift in ethanol production to larger plants and adoption of energy-saving innovations has reduced processing energy by 64% in the 1981-1991 period.
- Overall, the NEV of corn ethanol in the United States is 5978 kJ/litre for dry milling and 5089 kJ/litre for wet milling, taking into account a conservative energy replacement value for the co-products. These NEV's correspond to an overall energy ratio (output: input) of 1.37 and 1.30 respectively.

There is less information available on the learning curve for producing bio-ethanol in Europe because of the limited experience in bio-ethanol production so far. There are three potentially differences compared with the USA to produce bio-ethanol in Europe in the midterm more efficiently (at a higher overall energy ratio):

- Wheat, barley and molasses can be processed more efficient compared with corn (which is not an economical feedstock for Europe).
- Energy efficiency in production process is higher (driven by environmental concerns and high energy prices).
- Electricity for processing energy during production process is partially still based on coal in the USA, where natural gas or crude oil has a larger market share in Europe.

In the explanatory statement of the European Commission on the directive for promotion of biofuels is referred to the Ecobilan study which was produced in request of the French renewable energy agency ADEME. The NEV in this updated study (2002) corresponds with 2,05 for wheat and sugar beet including co-product outlet. There is no public information available on NEV based on side streams.

The advantage of an efficient production process is the European experience with rather large (beverage) alcohol production capacity. The principals for beverage alcohol production process can roughly be adapted to future bio-ethanol production on large scale.

Recent R&D developments

R&D efforts within the production process for conventional bio-ethanol is focused on improving production yields and lowering energy use. As explained above significant improvements have been made the last decades.

For the future (from 2008 onwards) major stakeholders, like enzyme companies, ethanol producers, Shell etc, are interested and involved in ethanol production with (ligno-)cellulose as a feedstock. The current available technology follows largely the same path as the technology for producing bio-ethanol from sugar beet, or other starch rich feedstocks. The major differences between ethanol production from conventional feedstock and ligno-cellulosic feedstock are 1) pre-treatment of the feedstock (liberation of glucose and xylose from the biomass fibres), and 2) the xylose fermentation to ethanol. Improvements in pre-treatment technology and xylose fermentation are foreseen in 2008, such improvements will result in rapid introduction of bio-ethanol produced from ligno-cellulose.

Successful pre-treatment and fermentation of cellulose would create a wide range of new potential feedstocks. Besides, yields of currently used feedstock could increase significantly because not only glucose but also cellulose derived sugars could be used. This will further increase NEV performance (more sustainable biomass could be used and energy efficiency from feedstock will increase) and reducing costs of producing ethanol (because higher yield from the same feedstock and because the increase of biomass availability). Moreover, bio-ethanol produced from this type of feedstock is identified as a highly cost effective option for CO2 emission reduction in the transportation sector. The cost of CO2 emission reduction using current technology will be between 73-108 € /ton. The cost of CO2 emission reduction in the future (2010) will be between 27 – 38 €/ton.

Although there is nowhere around the world a commercial plant producing bio-ethanol from ligno-cellulose two serious initiatives are on their way to commercialisation: a pilot plant build by ETEK (Sweden, ethanol production capacity 400 l/day), and a demonstration plant build by Iogen (Canada, ethanol production capacity 880 l/day).

The path for production of this “climate neutral” bio-ethanol has been drawn by the GAVE/ADL study (1999). Cellulose ethanol has been considered as one of the three most promising climate neutral liquid biofuels. More information on this R&D path can be found in the study “Cellulosic-Ethanol, a second opinion, which is produced upon request of Novem/GAVE, parallel to this report.

5. Analysis of commercial activities

5.1. Bio-diesel

The policy of the European Union with respect to bio-diesel in general, is to promote their production and use, mainly for the transport purposes. To encourage the use of bio-diesel for transport the European Union has recently accepted a proposal from a designated commission (July 2002), to apply a differentiated rate of excise duty to fuels containing bio-diesel. Finland, France Germany, Italy and the United Kingdom have already applied for this tax differentiation.

The motivations of different EU countries whether or not to use bio-diesel are various. Germany considers bio-diesel an effective measure to reduce greenhouse gases and only uses it 100% neat to create a positive bio-diesel image. France is mainly concerned with opportunities for farmers to produce the oil seeds and uses bio-diesel blends. The Danish government is completely against the use of bio-diesel due to a, in their vision, too expensive alternative of reducing the CO_2 emissions. They see EU initiatives only as support for the agricultural sector. The UK also does not want to use bio-diesel to support their agricultural sector and does only give tax exemption for bio-diesel production from waste oils. Austria is concerned with both reducing emissions and using waste streams and actively promotes bio-diesel production from both rapeseed oil and waste oils. The Dutch government doesn't want to support foreign agricultural sectors and does only give tax exemption on a project base (Financiën, 2001). Although some companies successfully applied for their project for exemption none of them has capacity readily available at this moment.

The main feedstock for bio-diesel in Europe is rapeseed oil. Almost all of the rapeseed used for the production of bio-diesel is currently grown on 'set-aside' land. This is land that only may be used for the production of non-food crops as decided in the Common Agricultural Policy of the European Community in 1988, because of the costly overproduction of agricultural crops. The set-aside policy prescribes a compulsory set-aside percentage of 10% agricultural land to remain fallow or to be used for non-food production (years 2000 to 2007). The rapeseed meal obtained as by-product may not be used for food products like animal food, except for a maximum of one million tonne soymeal equivalent per year, an amount that will soon be reached. This is agreed in a bilateral agreement between the European Union and the United States called the Blair House Agreement (1992) in order to protect the United States' export of soymeal (and effectively also Brazils) to the EU. It is not yet foreseen what the impact will be of the enlargement of the European Union in the coming years with respect to the set-aside policy or the Blair House Agreement. Therefore, the long-term feedstock availability is unsecure and this is an important barrier for large new bio-diesel initiatives. The meal can also be used to produce energy.

The cost of bio-diesel depends largely on the feedstock costs. In a report made for decision-makers in the European Union (Enguidanos, 2002a) the costs of bio-diesel from rapeseed were estimated at € 0.56 per litre, of which € 0.48 are rapeseed costs. Processing costs for bio-diesel production at different scales are given in Table 12. According to Connemann (1998) bio-diesel conversion costs for large-scale bio-diesel production are 0.14 €/litre. The feedstock costs of waste oils are considered to be much lower. In 1998, waste oils used for tests in an Irish bio-diesel pilot plant (Rice, 1998) were purchased at € 0.28 and € 0.21 per litre bio-diesel for respectively waste cooking oil and tallow. These prices could drop further, because of recently approved EU legislation restricting the use of waste oils for food purposes. The best example of real production cost can be found in the bio-diesel production in Germany. In general the price of feedstock from by-products like used frying oil ranges between 0.20 and 0.30 €/litre.

	Rapeseed (Enguidanos, 2002a)	**Waste Cooking Oil (Rice, 1998)**	**Tallow (Rice, 1998)**
Oil costs	0.48	0.28	0.21
Production costs	0.16	0.16	0.16
By-products income	(0.08)	(0.03)	(0.03)
Total	0.56	0.41	0.34

Table 11: Bio-diesel costs in €/litre

Process type		**batch**	**Batch**	**batch**	**Cont.**	**Cont.**
Investment	(Million €)	1.5	10.2	12.8	25.6	10.2
Capacity	(Ton/year)	2,000	15,000	75,000	125,000	80,000
Oil quality		ref.deg.	ref.deg.	ref.deg.	ref.deg.	crude/ref.
Glyc.prep. cont.%	(cont. %)	60	80/99.5	90	92	80/99.7
Personel		3	8	15	20	12
Deprec.(10yr)	(€/ton)	77	68	17	20	14
Interest 6.0%(1/2)	(€/ton)	23	20	5	6	4
Personnel	(€/ton)	61	22	8	7	6
Methanol	(€/ton)	24	18	16	15	15
Energy+Chem	(€/ton)	48	41	21	29	16
Maint.3%	(€/ton)	23	20	5	6	5
Overheads	(€/ton)	38	10	5	5	5
Total operating costs Euro/t	(€/ton)	294	200	78	89	65
-Glycerol, 125/60	(€/ton)	0-	55-	30-	31-	56-
-F.acids, 55	(€/ton)	11-	9-	7-	11-	6-
+Loss of oil, 90	(€/ton)	23	18	14	23	13
Surcharge on oil basis Euro/t	(€/ton)	306	155	55	70	17

Table 12: Operating costs for bio-diesel plants at different scales (Connemann, 1998)

The quality of the bio-diesel produced from waste oils that contain mostly vegetable oils, such as waste cooking oil, can meet the current quality standards that exist for bio-diesel (Rice, 1998). If the standards are not met, it can always be blended with bio-diesel from rapeseed to meet the specifications. For waste oils that are mainly animal oils, it is much more difficult to convert them into bio-diesel meeting the quality standards, but blending with a larger amount of bio-diesel from rapeseed may solve this problem. Currently, bio-diesel quality standards exist in Austria, France, Germany, Italy and Sweden. The European Union has prepared its own standard (prEN 14214) and is awaiting approval from the member states.

Outside the European Union, bio-diesel production is also rapidly increasing. The Czech Republic and Slovakia, both to be EU member in 2004, have already a considerable production of bio-diesel from rapeseed, although production in Slovakia has recently ceased, because of changed tax policies. The Czech Republic even has its own quality standard and was in 1997 the leading country in the world on the number of production sites (16). Poland (also to be EU member in 2004) and the Ukraine are currently increasing their rapeseed agricultural area aiming on the German bio-diesel market. The United States also have a rapidly growing bio-diesel production and also their own quality standard (ASTM Specification D 6751). Their main motives are to decrease their dependence on foreign energy sources and to reduce particle emissions in urban areas. Other countries with bio-diesel initiatives are Canada, Australia and Thailand.

Country	**Performed production**	**Estimated production capacity**	**Bio-diesel tax policy**	**Usage**
Austria	30,000 t (2001)	45,000 t	100% tax exemption on neat bio-diesel	Vehicles drive on 100% neat bio-diesel
Belgium	20,000 t (2000)	40,000 t	No special tax policy	Produced bio-diesel is for export
Denmark	<unknown>	30,000 t	Tax of € 0.36 per litre, same as fossil diesel	
Finland	-	<unknown>	Subsidies on test projects, no commercial activities.	
France	317,000 t (2000)	<unknown>	Subsidies on request: € 396.64 per tonne for a total max. of 350,000 t	5% blended with normal diesel 30% blended on captive fleets
Germany	140,000 t (1999) 270,000 t (2000) 480,000 t (2001)	900,000 t	100% tax exemption on neat bio-diesel	Vehicles drive on 100% neat bio-diesel
Italy	78,000 t (2000) 125,000 t (2001)	550,000 t	Tax of € 0.362 per litre on 5% blends Tax of € 0.286 per litre on 25% blends	Usage: 5% blended into normal diesel 25% blended into diesel of local buses
Luxembourg	-	-	Tax exemption for special projects on request	Current import of 650.000 l bio-diesel per year
Netherlands	-	-	No special tax policy on bio-diesel; Subsidy on special projects on request	
Spain	0 t	1,000 t	No special tax policy	
Sweden	8,000 t	<unknown>	Subsidy on special projects on request	Vehicles drive on 100% neat bio-diesel
United Kingdom	1,000 t	20,000 t	Tax exemption of €0.41 per litre made out yellow grease	
Total EU-15	700,000 t (2000)	2,000,000 t (2002)	Possibility for tax exemption	

Country	Performed production	Estimated production capacity	Bio-diesel tax policy	Usage
Czech Republic	50,000 t	60,000 t	<unknown>	Vehicles drive on bio-diesel blends
Lithuania	0 t	100,000 t	<unknown>	
Slovakia	0 t	> 60,000 t	Tax exemption recently reduced to replenish treasury	Production (temporarily?) stopped, because of changed tax policy

Table 13: Production capacities for bio-diesel in different countries (MVO, 2003)

Commercial activity in the Netherlands

At this moment the following companies/initiatives have more or less sound plans to start producing plantoil or bio-diesel. Most of the entrepreneurs have other business at this moment and wait for the moment that bio-diesel production becomes economical feasible. The initiatives range from producing pure plant oil from cold pressed rapeseed to a fatty acid methyl ester from used cooking oil. More information van be found at their websites:

www.solaroilsystems.nl

www.opek.nl

www.atep.nl

Up till now bio diesel has only been used in small scale projects in boats and street cleaning cars of the municipality and province and some individuals car. The various potential bio diesel producers claim to have potential customers. Both governmental public services and commercial fleet owners have shown interest to switch to bio diesel.

5.2. Ethanol from starch and sugars

The information in this paragraph is gathered from F.O. Licht's two-monthly report "World ethanol and Biofuels report" Volume 1, No 4-9 (october-januari), Agra Europe, London.

Bio-ethanol is currently made by large-scale yeast fermentation of sugars that are extracted from crops including corn, sugar cane, wheat, barley, and sugar beets. The first large fuel-ethanol program started in Brazil in 1975, followed by the USA in 1978. More recently countries like Canada, China, Australia, China, France, Spain, and Sweden, started to promote the production of bio-ethanol. Figure 6 shows world production of bio-ethanol in 2002. The Americas developed a mature ethanol market. Asia and Europe are only at start of this development.

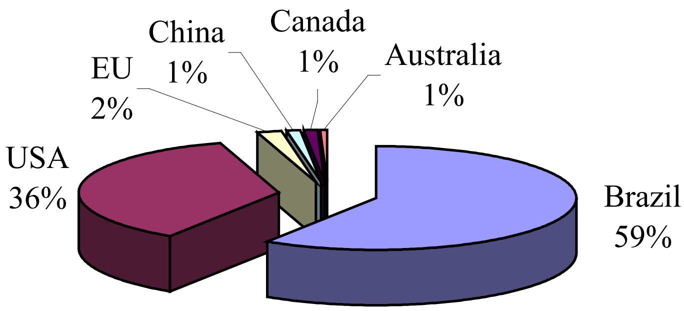

Figure 6: World bio-ethanol production in 2002

In Europe, the largest producer of bio-ethanol is France, which replaces 0.6% of its gasoline consumption by ethanol. The current production in Spain represents 1.0% of gasoline consumption replacement. Today, the major use of ethanol is as an oxygenated fuel additive that reduces emissions of carbon monoxide, oxides of nitrogen (NOx), and unburned hydrocarbons.

Bio-ethanol can be used in two ways, as a mixture in gasoline (at various percentages) and as component in the fuel oxygenates ETBE. As an additive in gasoline, ethanol must compete with methanol (feedstock for production of MTBE, which can be replaced by ETBE) or gasoline (pure ethanol blending replaces gasoline). Replacing methanol with ethanol for oxygenate production is preferred by the petroleum industry. Use of MTBE as a fuel additive is of concern because of its strong odour and bad taste properties when it's contaminated ground water. For these reasons, the state government of California (and 16 other states) has mandated a phase out of the use of MTBE as gasoline additive till 2004. Full oxygenate replacement of MTBE by ethanol in California would require a total ethanol volume of 19 Million hectolitre ethanol per annum. Also Japan has banned the use of MTBE. Table 14 summarises fuel-ethanol types used by country, including the primary feedstock used.

Country	**Volume (million hectolitre)**	**Feedstock**	**Fuel-type with Ethanol % in ()**
Brazil	125	Sugar cane	Hydrous alcohol (95.5%) Anhydrous gasoline (20-25%)
U.S.A.	76	Corn (90%), wheat, side streams food industry	E 10 or Gasohol (10%) Reformulated gasoline (5.7%), E 85 (85%)
China	2.5	Grains	Unknown
Canada	2.35	Wheat, corn	E85, E10 (see above)
Spain	2.26	Wheat, Barley, Wine	ETBE (up to 4%)*[9]
Australia	1.3	Sugar cane, wheat	E10
France	1.19	Sugar beets, wheat	ETBE (3.7%)
Sweden	0.5	Barley	E85, E5 (5%)

Table 14: Fuel ethanol use and fuel type by country in 2002

[9] Note: common ETBE percentage in fuel is 7.6%; ETBE contains 48% ethanol

Recent developments European Union

As shown in Figure 6 bio-ethanol production is dominated by the Americas. A few European countries are producing bio-ethanol: Sweden, Spain and France. In 2001 the European Commission published the "European Directive on the Promotion of Biofuels". Fuels for transport purposes should be substituted with biofuels with 2% in 2005 and at 5.75% in 2010 (each year an additional 0.75%). Since than, current producing countries are planning to expand their production. Spain an additional volume of 2 million hectolitre (in 2004) and France an additional volume of 3.85 million hectolitre. Germany and United Kingdom, which are not producing bio-ethanol at the moment, announced new production facility's (total of 6 mill. Hectolitre by 2005) (FO Licht, 2002). It's generally expected that European production of bio-ethanol will increase significantly in the next decade.

The development of commercial ethanol production in the EU countries is largely driven by the tax exemption of biofuels (in some countries the exemption is 100%) and other policies related to land-use (set-a-side policy of agricultural land which prohibits use for food production) or regional development. According to Enguidanos (2002b) a full implementation of set-a-side land in the EU (10% or 5.5 million ha) to produce raw materials for ethanol would produce enough fuel-ethanol to replace 5.8% to 18.3% of current gasoline consumption, depending on feedstock used. This estimate does not include the conversion of (ligno-)cellulosic raw materials to ethanol, which is not a subject of this report. For comparison, the current land-use for fuel-ethanol in France amounts to roughly 30,000 ha.

The European Union will be enlarged with a number of new member states in 2004. The European Biofuel directive will be one of the European directives which have to be implemented by these candidate states. In preparation to the enlargement Hungaria will exempt bio-ethanol from duty from 2003 on for gasoline blends with 2% bio-ethanol. The Czech government has also announced a biofuel program. In 2003, Polish parliament will come forward with a biofuel program which includes obligatory blending percentages (and duty exemption).

Recent developments in the world

The government of the United States has forwarded proposals to the Senate and the House of Representatives for a New Energy Bill. These proposals for the American energy policy for the coming years include stimulating measures for increasing ethanol use. Ethanol production in 2002 reached to 1.2% of gasoline consumption. The energy bill will mandate the use of renewables to 4% in 2016 (AUS consultants, J.M.Urbanchuk, November 2002). One of the major issues in this Energy Bill is a federal ban on the use of MTBE as oxygenate. In California (and 16 other states) such a ban already will be in place from 2004 on. All major oil companies in California have voluntarily announced to ban MTBE from 2003 on. MTBE will be substituted by (blended) bio-ethanol as oxygenate.

Japan is phasing out the use of MTBE. Last year ethanol has been exported to the Japan to fill in the oxygenate demand.

Canada is using 3.25 million hl ethanol per year. 1.0 million hl/year is imported from the United States. As part of Kyoto measures Canadian government in 2002 has set a target to increase production to 13 million hl/year in 2010. 35% of the petrol sold on the Canadian market will than contain a 10% ethanol blend.

India will blend 5% bio-ethanol into gasoline in 9 states. This first phase will come into force from 2003 on. Promotion of bio-ethanol fits India's strategy to become less depend of oil so that net trade balance will improve. Production facilities are located in sugar cane producing states.

During the second phase (from 2004 on) all states will use ethanol and, if feedstock is sufficient, be blended at percentages to 10%.

In 2002 China (Nanyang) produced 2.5 million hl/year. With stored (old) grains as a feedstock. Production capacity will be increased to 10.0 million hl in 2003 and to 13.75 million hl/year in 2004. Feedstock will vary from wheat, rice and corn. Coming decades the demand for energy will be enormous, in this way the dependence on oil will be somewhat less. It is expected that bio-ethanol will be used in city with high density of people where the Olympic Games in 2008 will take place. Bio-ethanol will therefore mainly used to improve air quality in these cities.

Thailand is increasing its production rapidly. Mid 2003 production will rise till 5.5 million hl /year. Sugar Cane and tapioca will be the major feedstock. Bio-ethanol is used as a blending component with gasoline till 5%. The government is discussing to rise this percentage to 10%, which will double production on to 11.0 million hl/year.

Since 2000 Australia is producing bio-ethanol. Sugar cane is used as feedstock. Existing ethanol production totals about 1.3 million hl/year. Gasoline with 10% blends is on the market in Queensland.

6. Reduction of Greenhouse gas emissions

6.1. Greenhouse gas emissions per km driven and costs of emission reduction

The costs of emission reduction have been calculated based on the review of data given in litreature (see chapter 2) and data given in the GAVE/ADL study (Novem, 1999b; Novem, 1999c). The results are summarised in Table 15. For the fossil fuel based transportation fuels data from the GAVE/ADL study have been used. The costs in €/litre of bio-diesel and bio-ethanol are based on the data found in the litreature review given in chapter 2, and have been converted to costs in €/km using the end-use efficiencies given in the GAVE/ADL study. The emission of Greenhouse gasses per km by bio-ethanol and bio-diesel have been calculated using the emissions of the fossil counterparts and data on the reduction of Greenhouse gas emissions found in the litreature review given in chapter 2. The costs of reduction of Greenhouse gasses have been calculated according to the methodology used in the GAVE/ADL study:

$$Costs\,emission\,redution(€\,/\,ton\,CO_2) = \frac{Extra\cos ts\,(€\,/\,km)}{CO_2\;savings(g\,/\,km)} * 10^6$$

For bio-diesel from rapeseed and soybeans the costs of reduction of Greenhouse gasses are 206 respectively 261 €/ton CO_2 and for corn ethanol 305 €/ton CO_2. For bio-diesel the cost per ton CO_2 are much lower than in the GAVE/ADL study due to lower costs and higher reduction of Greenhouse gas emissions. In the GAVE/ADL study ethanol from corn has been considered. In Europe it is more likely that ethanol will be produced from an other feedstock, like wheat. Therefore, in Table 15 data for ethanol from wheat produced in Europe are given. For ethanol from wheat produced in Europe the costs of emission reduction are somewhat higher than for bio-diesel because of slightly higher costs of the fuel per km and lower reduction of Greenhouse gas emissions.

		Bio-diesel rapeseed	Bio-diesel soybeans	Diesel petroleum	Ethanol from wheat	Gasoline petroleum
Costs	(NLG/GJ)			13.64		13.85
	(€/litre)	0.56	0.76	0.23	0.50	0.21
	(€/km)	0.039	0.053	0.016	0.054	0.018
Reduction CO_2 emissions (%)		57	72	-	51	-
Emissions (g CO_2/km)		85	55	198	113	231
Costs emission reduction (€/ton CO_2)		206	261	-	305	-

Table 15: Costs of emission reduction

6.2. Amount of avoided Greenhouse gas emissions

In the previous chapters it has been shown that there is a considerable potential for substitution of petroleum based transportation fuels by bio-diesel and bio-ethanol from 'conventional' feedstocks. Residues that can be used for bio-diesel production amount 210.000 ton, see Table 8, or about 3% of current diesel consumption for transportation in the Netherlands. Residues from the agro-industry can be used to produce 2.18 million hectolitre ethanol/year, see paragraph 4.1, or 2.6% of current gasoline consumption in the Netherlands. Use of set-aside land can be used to produce additional amounts of feedstocks for bio-diesel and bio-ethanol production. It is difficult to determine whether these feedstocks can be contracted for the production of bio-transportation fuels, and more importantly at which price they can be contracted. Furthermore expansion of the European Union as well as financial incentives can considerably influence the market for bio-transportation fuels.

Considering the factors given above, it is difficult to estimate the amount of Greenhouse gas emissions that can be avoided by using conventional bio-transportation fuels. In this chapter estimates are made based on the targets on fuel substitution proposed by the European Union. Furthermore, just like in the GAVE/ADL study, the CO_2 reduction obtained by complete substitution of petroleum based transportation fuels by conventional bio-transportation fuels is given.

The European Union has proposed the following targets for substitution of petroleum bases transportation fuels:

2005 2% (EU, 2002)

2010 5.75% (EU, 2002)

The degree of substitution is calculated on the basis of energy content (EU, 2002). In 2000 the consumption of gasoline and diesel in the Netherlands was 177 PJ respectively 247 PJ (ECN, 2003). Based on these data the required amount of bio-transportation fuels and the amount of avoided Greenhouse gas emissions can be calculated, see Table 16. In Table 16 it has been assumed that bio-ethanol is used to substitute gasoline and bio-diesel to substitute diesel. Furthermore, just like in the GAVE/ADL study it has been assumed that use of ethanol results in a 10% increase in end-use efficiency. The total amount of avoided Greenhouse gas emissions is in Table 16 for bio-ethanol lower than for bio-diesel mainly because the amount of gasoline used in the Netherlands is lower than the amount of diesel used.

		Bio-ethanol		Bio-diesel	
Percentage substitution	**(%)**	**2**	**5.75**	**2**	**5.75**
Bio-fuel consumption	(PJ/year)	3.2	9.3	4.9	14.2
	(million litre/year)	151	434	149	428
	(kton/year)	120	345	131	376
Emission reduction	(Mton/year)	0.16	0.45	0.23	0.66

Table 16: Bio-ethanol/diesel consumption and emission reduction for different percentages substitution

In the GAVE/ADL study (Novem, 1999b) also the amount of Greenhouse gas emissions avoided when all transportation fuels are substituted was calculated. ADL estimated transportation fuel consumption in the Netherlands in 2010 to be 125071 bbl/day gasoline and 109926 bbl/day diesel. Assuming that bio-diesel results in 57% reduction of Greenhouse gas emissions, see paragraph 2.2, complete substitution of all fossil transportation fuels in the Netherlands in 2010 by bio-diesel from rapeseed would result in reduction of Greenhouse gas emissions with 24 Mton $CO_{2,eq}$. For ethanol from wheat this would be 19 Mton $CO_{2,eq}$.

7. Socio-economic factors

In the Netherlands mitigation of the Greenhouse effect through a reduction of Greenhouse gas emissions is the main motive for the use of biomass to displace fossil fuels. It is absolutely clear that the highest effect on reducing the Greenhouse effect is reached through displacing coal for electricity production. Hence the question is why bio-transportation fuels are promoted if they are considered to have a lower effect on Greenhouse effect mitigation? Clearly other environmental and socio-economic factors play an important role here.

In a recent report (Stevens, 2001) three phases are distinguished in the development of alternative fuels:

Phase 1 = Experiments and small scale tests

Phase 2 = Pilot projects and demonstration

Phase 3 = Commercial activity

Many countries are in phase 3. For example, Brazil and the USA with ethanol and Germany with bio-diesel. In the Netherlands some pilot projects and demonstrations have been implemented particularly with bio-diesel (bio-diesel powered boats in canals in Amsterdam and some activities in Friesland, recent introduction in Venlo). These developments are based on support for a limited period and will die out if support and a structure for a longer period is not available.

The question would be how could development to phase 3, commercial activity be implemented in the Netherlands both for bio-diesel and for ethanol?

It will be necessary to have political support based on a mix of benefits (environmental, economic, and agricultural) and supported by a coalition of groups.

The motives that have been put forward to utilise bio-transportation fuels vary over time and between countries.

In Table 17 a list of the most important motives has been compiled that have been used as arguments to implement bio-transportation fuels world-wide. Which mix of motives will lead to successful implementation of bio-transportation fuels? The motives deemed most relevant to the Netherlands are in italics.

General motive	Specific	Country	Reference
Environmental			
Reduction in greenhouse gas emissions. Kyoto protocol	Discussion about the impact continues	EU, Japan	EU, 2002.
Reduction in air, water and soil, pollution.	Lower CO, hydrocarbons, particulates, air toxics, mutagenicity. Higher Nox	USA, China, EU,	Enguidanos, 2002; EU, 2002.
The reduced pollution leads to specific implementation in areas where the impact is largest (example; captive fleets).	Bio-diesel for: diesel powered boats (canals, recreation); Inner-city busses,	USA, EU,	EPA, 2002.
	Ethanol for: smog reduction (in winter),	USA,	
Economic			
Depletion of fossil fuels		USA, EU,	
Reduce dependency on foreign oil		USA, EU, (NL Min of Economic affairs, less with other entities)	EOS presentations 2002, EU, 2002
Cost		Brazil	
Trade balance		Asia, USA	EU, 2002
Getting experience – broadening the way for new developments			GAVE, 1999
Agriculture			
Alternative utilisation options for organic by-products		NL, UK, USA,	Elbersen, 2002; Rabobank, 2001; EU, 2002.
Utilisation of set-aside land		EU, USA	EU, 2002
Rural income		EU, USA, not NL	EU, 2002
Stabilisation of farmer income (sugar)	Recent examples are ethanol production from sugar beets or wine if prices are low. This will result in stable prices and income	EU, France	
Promote more market oriented CAP (Common Agricultural Policy)	Multifunctional agriculture, new agro-products, sustainable rural development		EU, 2002

Table 17 : Overview of motives arising from concern about the environment, economy and agriculture that contribute to implementation of the use of bio-transportation fuels by different countries, entities or organisations. The most relevant motives for the Netherlands are in italics

An analysis of important factors that determine success of implementation of bio-transport fuel projects in the EU and USA was made in a recent report (Stevens, 2001). Some of the most relevant conclusions are:

- In all countries where alternative fuels have been implemented to the commercial phase Agriculture has been one of the stakeholders. Politically, the potential effects of alternative fuels on agriculture and regional development have played an important role.

- Because alternative fuels are more expensive than fossil fuels (gasoline, diesel) support to cover the difference in costs is imperative. No implementation has occurred without this support and in cases where it has been removed, implementation has halted.
- Successful implementation of alternative fuels has been incorporated by the oil companies (distributors, blenders) in all cases.
- Commercial actors require definite rules, preferably over a long time, such as legislation on fuels and magnitude of financial support.
- Countries in the phase of experiment, pilot projects and demonstration should benefit from the experiences in other countries already in the commercial phase.

The Netherlands

Agricultural pressure to introduce bio-fuels has been limited over the last decade in the Netherlands, mainly due to the small area of set aside land approximately (10,000 ha) and the focus on other issues.

Since 1998 some factors that are important for introduction of bio-transportation fuels have changed in the Netherlands:

- Animal diseases (Foot and Mouth Disease, BSE, Swine pest), feed contamination, increased environmental restrictions (nitrate, smell, etc) and popular pressures have led to political decisions to limit the use of many by-products in animal feed and to reduce the total number of farm animals over the coming decades (VROM, 2001). This has led to a decreased demand for by-products, used as fodder, from the large Dutch agri-processing industry (potato peels, molasses, seed crushing industry, etc). An interest for alternative uses both for oil and fat and for sugar and starch containing by-products has arisen see paragraph 3.2 (Elbersen, 2002; Rabobank, 2001). The availability of these by-products will depend on alternative uses and on the price that can be paid when it is used as a bio-fuel feedstock.
- An EU directive has been put forward to replace an increasing amount of renewable transportation fuels, starting with 2% in 2005 and increasing to 5.75% in 2010 (EU, 2002).

Decisions have not been made on the EU directive but it is clear that bio-transportation fuels will have to be introduced in the Netherlands in the short term. The question is not if but how and when exactly bio-transportation fuels utilisation will have to be implemented.

It seems likely that utilisation of by-products and taking maximum advantage of the environmental effects that bio-transportation fuels offer could create the broadest support for a commercial introduction of biofuels.

8. Conclusions

The costs and emission data for the production of the conventional bio-transportation fuels in recent studies have been reviewed. For bio-diesel from rapeseed and from soybeans the average price in recent studies are 0.56 €/litre (=17 €/GJ) respectively 0.76 €/litre (=23 €/GJ). For ethanol from sugar and starch crops the average price in recent studies is 0.50 €/litre (=23 €/GJ). Use of the conventional bio-transportation fuels results in considerable reduction of Greenhouse gas emissions, but they do not meet the criterion of a 80% reduction of Greenhouse gas emissions used currently in the GAVE programme. Bio-diesel from rapeseed results in a 52-61% reduction of Greenhouse gas emissions and for bio-diesel from soybeans and ethanol from wheat these ranges are 65-78% respectively 41-61%. Use of pure plant oil can result in a somewhat higher reduction of Greenhouse emissions than for use of bio-diesel.

For bio-diesel, a major recent development is the use of waste streams as feedstock. Animal fats released by the food and feed industry and used frying oils can be used to produce bio-diesel. Up to now most of these products have been used in the animal feed industry. The legislation with respect to the use of waste streams for the production of animal feed has become more strict and the quantities of waste streams grew. For the Netherlands it is estimated that about 210,000 ton of feedstock is available for the production of bio-diesel, enough to replace about 3% of the current diesel consumption in the Netherlands.

High costs for production of alcohol esters from crops has generated considerable efforts to develop conversion processes for vegetable oils based on waste-fats and greases, or application of microemulsions of vegetable oils with lower alcohols. R&D efforts continue into developing acceptable fuel properties, engine performance as well as air emissions. It is expected that productions costs for bio-diesel will be reduced in the coming years, with anticipated improvements in conversion technologies, upscaling of present conversion facilities and a more constant fuel quality.

For bio-ethanol the conventional feedstocks considered are sugar beets, sugar cane and different sorts of grains. Generally, feedstocks that are used for food production have high prices because of quality demands and therefore are not considered for ethanol production. Waste streams released by the agri-processing industry are worthwhile to consider for ethanol fuel production. Currently Royal Nedalco uses molasses from sugar beet processing and C-starch from milling industry for ethanol production. A recent study by the Rabobank showed that by-products from the agri-processing industry give a potential for the production of 2,18 million hectolitre ethanol/year. This amount is sufficient to replace about 2.6% of gasoline consumption in the Netherlands.

Developments in ethanol production show continuous improvements in all parts the production chain. Increasing yields and decreasing tillage and fertiliser use improve costs and environmental performance of crop production. Process development decreases energy use and capital costs of the ethanol production.

In the European Union a number of countries have already implemented the production of bio-transportation fuels. Bio-diesel is already used on a considerable scale in Austria, France, Germany, Italy and Austria. The total production of bio-diesel in the European Union amounted 700,000 ton. Countries in the European Union using major amounts of bio-ethanol (or bio-ethanol derived products) are France, Spain and Sweden. In all these countries bio-transportation fuels are partly or completely exempted from taxes. Total bio-ethanol consumption for transportation purposes in these countries was about 4 million hectolitres in 2002.

Based on the costs and reduction of Greenhouse gas emissions found in recent studies, the costs of emission reduction are 206 €/ton CO_2 for bio-diesel from rapeseed, 261 €/ton CO_2 for soybeans and 305 €/ton CO_2 for ethanol produced from wheat in Europe. Using the draft guidelines for substitution of fossil transportation fuels, the reduction of Greenhouse gas emissions in the Netherlands amount 0.16 Mton CO_2 in 2005 to 0.45 Mton CO_2 in 2010 for bio-ethanol from wheat and 0.23 Mton CO_2 in 2005 to 0.66 Mton CO_2 in 2010 for bio-diesel. Complete substitution of all transportation fuels by bio-ethanol from wheat or bio-diesel would result in a reduction of Greenhouse gas emissions of 24 Mton CO_2 for bio-diesel and 19 Mton CO_2 for ethanol.

Contrary to other countries, pressure by the agricultural industry to introduce bio-transportation fuels in the Netherlands is limited as a result of the small amount of set-aside land. Other factors as the political decisions to limit use of by-products in animal feed and the decrease in the total number of animals farms might be important for successful the introduction of bio-transportation fuels in the Netherlands in the near future.

9. Discussion and recommendations

Although one can argue about the input data used for, and hence results of, life cycle analyses, it is the general opinion that liquid fuels production from woody and herbaceous biomass outperform the conventional bio-transportation fuels with respect to costs and reduction of Greenhouse gas emissions. However, it should be kept in mind that production of liquid fuels from woody and herbaceous biomass are long-term options and the input data used for life cycle analysis are theoretical data that need to be verified. On the contrary, the conventional bio-transportation fuels can be produced today and data used are based on commercial experience.

It is questionable whether the conventional bio-transportation fuels can fulfil the official objective of the GAVE programme, i.e. at least 80% reduction of Greenhouse gas emissions[10], and when they do it whether it is purpose of the GAVE programme to stimulate the conventional bio-transportation fuels. Technology for feedstock cultivation and for conversion of the feedstock to liquid fuels is ready and already used. Furthermore, experience with the use of these fuels already exists on a considerable scale in other countries. The scale is probably best illustrated by the current use of bio-transportation fuels in the European Union. Current use within the European Union is about 700 kton, this is about 0.25% of total gasoline and diesel consumption in the European Union, but also equals 7.6% of the current gasoline and diesel consumption in the Netherlands. The objective of the GAVE programme is to develop options that result in more reduction of Greenhouse gas emissions at lower costs.

Nevertheless the role of the conventional bio-transportation fuels in the transition path should not be underestimated. Use of residues and the feedstock required for conventional bio-transportation fuels will play a major role in the transition to more favourable options. In a study on Fischer-Tropsch synthesis within the GAVE programme a plant with a capacity of 80000 barrels per day diesel was considered (BIG-FiT, 2002). This equals a production capacity of about 4000 kton diesel/year or about 1.4% of the current consumption of gasoline and diesel in the European Union or about six times the current consumption of bio-transportation fuels in the EU. A considerable development of the market for bio-transportation fuels will be required before investment in these large-scale future options is justified. Furthermore, it is likely that these large-scale future options are still more expensive than their fossil competitors and hence require subsidies. Development and stabilisation of mechanisms for subsidies is required prior to decisions for investments in these large-scale facilities. Furthermore, these facilities require (large amounts of) input of feedstock. This requires a development of a market for cultivation of feedstocks for bio-transportation fuels.

In conclusion: the conventional bio-transportation fuels will play a major role in market development for the long-term options. This concern the production of feedstock, as well as the outlet of products and the development of subsidy mechanisms required.

[10] In the GAVE/ADL study it was required that bio-fuels result in at least 50% reduction of Greenhouse gas emissions. Later on in the GAVE programme this criterion was sharpened to at least 80% reduction of Greenhouse gas emissions.

Looking at the short term it is important that the conventional bio-transportation fuels discussed in this report offer the opportunity for Greenhouse gas emissions *now*. Furthermore, they seem to be the only alternative to fulfil the targets drafted by the EU up to 2010.

The discussion above sketches the role of the conventional bio-transportation fuels in the short-term. Even the short-term implementation of bio-transportation fuels will rise questions on amount of Greenhouse emission reduction. Current life cycle analyses often use data synthesised at different continents. However, feedstocks considered and characteristics of conversion processes and end-user characteristics differ from continent to continent, as already noted in chapter 4. The GAVE/ADL study considered import of corn ethanol from the USA, whereas wheat, barley and rye are expected to become feedstocks for ethanol production in Europe. A specific European life-cycle analysis will be required to assess the prospects of conventional bio-transportation fuels.

10. References

Novem (1999a): Analyse en evaluatie van GAVE ketens: Management summary. Arthur D. Little International Inc., Rotterdam, GAVE-rapport 9908

Novem (1999b): Analyse en evaluatie van GAVE ketens: Final report (sheet presentation). Arthur D. Little International Inc., Rotterdam, GAVE-rapport 9909

Novem (1999c): Analyse en evaluatie van GAVE ketens: Appendices. Arthur D. Little International Inc., Rotterdam, GAVE-rapport 9910

Armstrong, A.P. et.al. (2002): Energy and greenhouse gas balance of biofuels for europe – an update. Concawe, Brussels, Report no. 2/02

Austrian Biofuels Institute (2001): Bio-diesel – a success story: The development of bio-diesel in Germany. Appendix 7 in: Stevens, D.J.et.al. IEA Bioenergy Task 27, Liquid biofuels Final Summary Report, Non-technical policy, regulatory, and market influences on the use of liquid bioduels. IEA Bioenergy Agreemeent.

Beer, T. et. al. (2000): Comparison of transport fuels: Final report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of Life-cycle emissions for heavy vehicles. Csiro.

BIG-FiT (2002): Climate neutral transport fuels from biomass: the BIG-FiT concept. Samewerkingsverband Duurzame Energie

CBS (2002): Centraal Bureau voor de Statistiek. www.cbs.nl

Connemann (1998): www.bio-diesel.de

Davis, S.C. and Diesel, S.W. (2002): Transportation energy databook: edition 22. Oak Ridge National Laboratory, Centre for transportation analysis, ORNL-6967

De Jager, D., Faaij, A.P.C. and Troelstra, W.P. (1998): Kosteneffectiviteit van transportbrandstoffen uit biomassa. EWAB-rapport 9830

Dunn, R.O. et. al. (1996): Improving the low-temperature properties of alternative diesel fuels: vegetable oil-derived methyl esters. JAOCS, 73(12), 1719-1728.

Dunn, R.O. et.al. (2000): Low-Temperature phase behaviour of vegetable oil/Co-solvent blends as alternative diesel fuels. JAOCS, 77(12), 1315-1323.

ECN (2003): Energie in cijfers. Energieonderzoek Centrum Nederland, www.energie.nl

Ecobilan/PWC (2002): Bilans énergétiques et gaz à effet de serre des filières de production de biocarburants en France. Note de synthèse.

Enguidanos, M., Soria, A., Kavalov, B. and Jensen, P. (2002a): Techno-economic analysis of Bio-diesel production in the EU: a short summary for decision-makers. Institute for Prospective Technological Studies, Report EUR 20279 EN

Enguidanos, M., Soria, A., Kavalov, B. and Jensen, P. (2002b): Techno-economic analysis of Bio-alcohol production in the EU: a short summary for decision-makers. Institute for Prospective Technological Studies, Report EUR 20280 EN

EPA (2002): A comprehensive analysis of bio-diesel impacts on exhaust emissions. United States Environmental Protection Agency, Draft technical report. EPA 420-P-02-001.

EU (2002): Directive on the promotion of the use of biofuels or other renewable fuels for transport. Council of the European Union, Interinstitutional file: 2001/0265 (COD), Brussels, 12 november 2002

Financiën (2001): Fiscale stimulering biobrandstoffen. Brief van de staatssecretaris van Financiën aan de Voorzitter van de Tweede Kamer der Staten-Generaal.

GM Europe (2002): GM Well-to-wheel analysis of energy use and greenhouse gas emissions of advanced fuel/vehicle systems a European study, 27 september 2002, Download at: http://www.lbst.de/gm-wtw

Haas, M. et.al. (2000): Simple, High-efficiency synthesis of fatty acid methyl esters from soapstock. JAOCS, 77(4), 373-379.

Lee, I. et.al (1996): Reducing the crystallisation Temperature of Bio-diesel by Winterising Methyl Soyate. JAOCS, 73(5), 631-33.

Muniyappa, P.R. et.al.(1996): Improved conversion of plant oils and animal fats into bio-diesel and co-product. Biores. Technol., 56, 19-24.

MVO (2003): Product Board Margarine Fats Oils. Personal communication

Rabobank (2001): De Nederlandse akkerbouw, het geheel is meer dan de som der delen. Rabobank Food en Agribusiness Research, Utrecht

Reinhardt, G.A., Jungk, N. (2001): Pros and cons of RME compared to conventional diesel fuel. Institut für Energie- und Umweltforschung Heidelberg. Proceedings of the 3rd international colloqium fuels, 17-18 januari 2002, Ostfildern.

Rice, B. et.al. (1998): Bio-diesel production form camelina oil, waste cooking oil and tallow. Teagash – Irish Agriculture and Food Development Authority

Röder, A. (2001): Integration of life-cycle assessment and energy planning models for the evaluation of car powertrains and fuels. A dissertation submitted to the Swiss Federal Institute of Technology, Zürich

S&T Consultants, Inc. (2000): Liquid fuels from biomass: North-America impact of non-technical barriers on implementation. Appendix 1 in: Stevens, D.J.et.al. IEA Bioenergy Task 27, Liquid biofuels Final Summary Report, Non-technical policy, regulatory, and market influences on the use of liquid bioduels. IEA Bioenergy Agreemeent.

Sheehan, J., Camobreco, V., Duffield, J., Graboski, M. and Shapouri, H. (1998): An overview of bio-diesel and petroleum diesel life cycles. National Renewable Energy Laboratory, NREL-TP-580-24772

Stevens, D.J., Hogan, E., Östman, A., Segerborg-Fick, A. and Wörgetter, M. (2001): IEA Bioenergy Task 27, Liquid biofuels Final Summary Report, Non-technical policy, regulatory, and market influences on the use of liquid bioduels. IEA Bioenergy Agreemeent

Van Walwijk, M., Bückmann, M. Troelstra, W.P. and Elam, N. (1998): Automotive fuels survey, Part 3: Comparison and selection, IEA/AFIS

VROM (2001): Vierde nationaal milieubeleidsplan (NMP4), den Haag

Wang, M., Saricks, C. and Santini, D. (1999): Effects of fuel ethanol use on fuel-cycle energy and greenhouse gas emissions. Argonne National Laboratory, Centre for Transportation Research, Energy Systems Division, ANL/ESD-38

Wu, W.H. (1998): Low Temperature Property and Engine Performance Evaluation of Ethyl and Isopropyl esters of Tallow and Grease. JAOCS, 75(9), 1173-1178

GAVE-PROGRAMMA

GAVE staat voor GAsvormige en Vloeibare klimaatneutrale Energiedragers. Novem voert het GAVE-programma uit in opdracht van de Ministeries van Volkshuisvesting, Ruimtelijke Ordening en Milieu, Economische Zaken en Verkeer en Waterstaat. Hoofddoel van GAVE is om voor het jaar 2030 demonstraties te realiseren van gehele ketens voor de productie tot en met de toepassing van klimaatneutrale gasvormige en vloeibare energiedragers. Het traject dat GAVE doorloopt om dit te bereiken, is als volgt opgebouwd. Ondersteund door GAVE zijn in 2001 en 2002 allianties gevormd die nodig zijn om gezamenlijk een keten voor klimaatneutrale brandstoffen op te zetten. In 2002 is partijen de mogelijkheid geboden hun plannen uit te werken tot een blauwdruk voor demonstratie. Met ingang van 2003 kunnen partijen voor het eerst het ontwerp feitelijk realiseren door middel van demonstratieprojecten.

BEDRIJFSPROFIEL VAN NOVEM
NEDERLANDSE ORGANISATIE VOOR ENERGIE EN MILIEU

Dienstverlener in duurzaamheid

Novem stimuleert duurzame ontwikkeling van de (inter)nationale samenleving op het gebied van energie en milieu. Als agentschap van het Ministerie van Economische Zaken biedt Novem overheid en marktpartijen ondersteuning bij duurzame ontwikkeling en zorgt dat ambities van de overheid realiseerd worden. Als intermediair brengt Novem de doelen van overheid en markt samen, stemt vraag en aanbod op elkaar af, ontsluit kennis en stimuleert (technische) ontwikkeling.

Swentiboldstraat 21	Catharijnesingel 59	Novem op internet
Postbus 17	Postbus 8242	www.novem.nl
6130 AA Sittard	3503 RE Utrecht	
tel: 046 420 22 02	tel: 030 239 34 93	GAVE op internet
fax: 046 452 82 60	fax: 030 231 64 91	www.gave.novem.nl

Novem is een agentschap van het Ministerie van Economische Zaken. Novem voert beleid uit voor verschillende overheden en draagt hiermee bij aan de ontwikkeling naar een duurzame samenleving.