Supportive study for the OECD on alternative developments in biofuel production across the world

Edward Smeets
Martin Junginger
André Faaij

Report NWS-E-2005-141
ISBN 90-8672-002-1
December 2005

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Edward Smeets
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André Faaij

This study was written for:

OECD, Directorate for Food, Agriculture and Fisheries.
2nd Rue André-Pascal
75775 Paris, CEDEX 16
France

Copernicus Institute for Sustainable Development
Department of Science, Technology & Society – Utrecht University
Heidelberglaan 2
3584 CS, Utrecht – The Netherlands
Tel: +31-30-2537643/00
Fax: +31-30-2537601
E-mail: A.Faaij@chem.uu.nl

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1. Introduction

1.1 Background and objective

The Directorate for Food, Agriculture and Fisheries of the Organisation for Economic Cooperation and Development (OECD) plans to analyse alternative developments in biofuel production across the world based on the latest agricultural baseline, as published in July 2005 in the OECD Agricultural Outlook 2005-2014 report. Scenarios could include exogenously set production developments, but may also include changes in crude oil prices and/or biofuel subsidies.

In order to carry out this analysis, new data and parameters needed to be provided for the quantitative, model-based analysis. The overall objective of the work is to support OECD Directorate Food, Agriculture and Fisheries in providing the following information:

- Performance data with respect to energy balance (efficiency) and economy (investment, variable and overall production costs) of biofuel production systems in various countries around the globe.
- An overview of current and planned strategies, policies and outlooks for biofuels in various key countries and regions. Key regions are: EU, US, Australia, Canada, Brazil, Argentina, India, China and Japan. Other regions of interest are Southern Africa and Eastern Europe.

The data and information provided is for incorporation in the Aglink and World Sugar models to be used by OECD for the proposed biofuel analysis. This consultant report is prepared by the Copernicus Institute, Department of Science, Technology and Society of Utrecht University, the Netherlands.

1.2 Reading guide

The report consists of three main parts. In the first part, national biofuels policies are described in detail. In the second part, detailed information on performance data with respect to energy balance (efficiency) and economy (investment, variable and overall production costs) of biofuel production systems is provided. In the third part, general conclusions and recommendations are presented.

2. National Biofuel policies and production targets

2.1 Introduction

In this chapter, current national biofuels policies are described in detail. It is basically an update on the biofuel policies described in chapter seven of a recent IEA/OECD publication (Biofuels for transport, IEA/OECD, 2004). The history and past policy developments for biofuels in the main countries have been left out of this update to a large extent, as they are described in the earlier OECD (2004) publication. The information presented in the fact sheets below should be seen mainly as a supplement to the OECD publication. Most literature sources are from 2004 and 2005, consisting of scientific reports, formal publications of national ministries responsible for biofuels, press releases and papers from NGOs, and various scientific presentations from conferences. Where possible, texts were summarized, but in a number of cases, reference texts have been largely reproduced in this report. For each country, all literature sources used are listed with each fact sheet.

Fact sheets have been composed for a number of countries investigated, containing information on biofuel policies and the different feedstocks employed.

For EU countries, historical production levels are given in an overview. Large parts of the information have been taken from the latest EurObservER Biofuels barometer, and the Member States 1st reports on progress under Directive 2003/30/EC. For the most important EU countries, the information has been summarized in the fact sheets.

For non-EU countries, historical production trends and details of national production targets are given (if available) per country in the fact sheet. Given the short timeframe for this assignment, and the uncertain status of some of the information provided in e.g. press releases, it cannot be guaranteed that the list of policy measures for each of these countries is fully comprehensive, especially for countries where general data availability is poor.

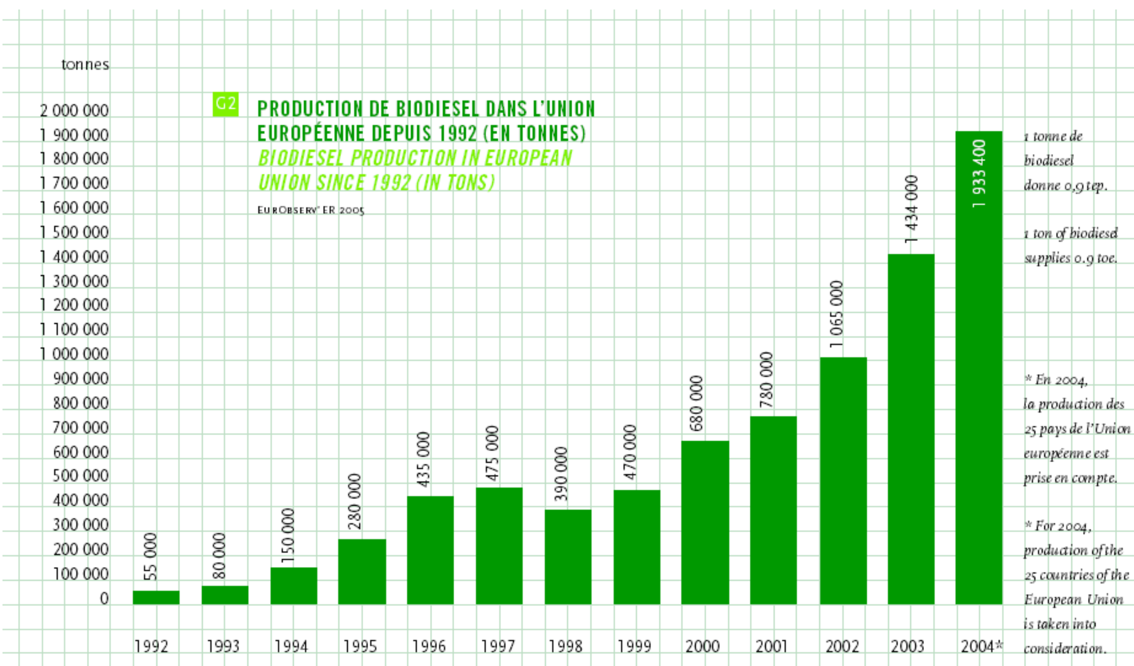
The report is organized as follows: First, the general developments in the EU in 2004-2005 are described. Second, a number of important EU biofuel producing countries (e.g. France, Germany, Italy, Spain, Sweden) are described in detail in the form of fact sheets. The report continues with fact sheets on other major global biofuel-producing counties, such as the USA, Canada, Brazil, India and China. The paper concludes with a summary of the production outlooks found in the literature and with some general recommendations.

2.2 EU-25 overview[1]

The European Union produced 2 424 440 tons of biofuel in 2004, vs. 1 928 750 tons in 2003 (including new EU member countries), representing a 25.7% increase in production. Growth prospects for 2005 are even more optimistic with the first European Directive target imposing a minimum of 2% biofuels being incorporated being effective by the end of the year 2005 and 5.75% by the year 2010[2].

The biofuels sector, which groups together all liquid or gaseous fuels obtained with organic vegetal or animal matter, is composed of two main fuels, bioethanol and biodiesel. Other biofuels such as biogas, vegetable oils, bio-methanol, biodimethylether, bio-ETBE, bio-MTBE, synthetic fuels and bio-hydrogen are also referenced by the European Commission, but have been little developed or not yet developed. Among them, development of biogas in the form of fuel still remains limited and very localised (10 836 tons consumed in Sweden in 2004). Only a few cities (like Lille in France) have decided to utilise their biogas supplies as fuel for their fleet of transport vehicles. Pure vegetable oil, which can function in modified diesel engines (with indirect injection and even with direct injection), is a recognised fuel in Germany in the same way as biodiesel and bioethanol are. This fuel is struggling however to take hold on the market due to the need for some modifications to motor vehicles for its wider use.

Biodiesel represents the biggest share of biofuels produced in the European Union with production of 1933400 tons in 2004 (79.5% market share) in front of bioethanol, which represented a production of 491 040 tons (i.e. the remaining 20.5%).



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[1] The following texts and graphs in section 2.1 have been taken from the Biofuels barometer, June 2005. Country-specific information has been incorporated in the country fact-sheets.

[2] EC Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport.

Graph 1. Biodiesel production in the European Union 1992-2004. Source: (EurObserv'ER, 2005).

Biodiesel sector

The European Union is the leading region of the world in terms of the development of a biodiesel sector. In 2004, it included 11 producer countries with the arrival of three new members (Czech Republic, Slovakia and Lithuania). The rise of biodiesel's importance in Europe, as observed over the last ten years, accelerated in 2004 (graph 1). Production was close to 2 million tons vs. 1.5 million tons in 2003 (including new member countries), i.e. 28.6% growth in a single year (table 1). This production is still below current production capacity which, according to the European Biodiesel Board (EBB), was in the range of 2.2-2.4 million tons in 2004.

Pays	2003	2004	Croissance	
Allemagne	715 000	1 035 000	+ 44,8 %	
France	357 000	348 000	-2,5 %	
Italie	273 000	320 000	+ 17,2 %	
Danemark	41 000	70 000*	+ 70,7 %	* Marge d'erreur
République tchèque	70 000	60 000*	-14,3 %	de +/- 10 %, pour
Autriche	32 000	57 000	+ 78,1 %	le Danemark
Slovaquie	0	15 000		et la République
Espagne	6 000	13 000	+ 116,7 %	tchèque.
Royaume-Uni	9 000	9 000	0,0 %	
Lituanie	0	5 000		+/- 10% margin of
Suède	1 000	1 400	40,0 %	error for Danark
				and the Czech
Total U.E 25	**1 504 000**	**1 933 400**	**+ 28,6 %**	Republic.

Table 1. Biodiesel production in the EU-25 in 2003 and 2004 (tonnes). Source: (EurObserv'ER, 2005).

Biodiesel in the rest of European Union (for Germany, France and Italy see fact sheets)

Among the other European biodiesel producer countries, Denmark can be singled out for its rapid expansion with a production level that has been multiplied by seven, albeit from a low base, in the space of two years (10 000 tons in 2002 vs. 70 000 tons in 2004) as well as Austria whose production increased by 78.1% to 57 000 tons in 2004 when compared with 2003 volumes. Other countries in the European Union have also decided to go into biodiesel production. Spain started up its biggest biodiesel production unit (250 000 tons) in May 2005 in the region of Cartagena. The company, called Biodiesel Production, is part of the German group Sauter and has invested 50 million euros in this project. A first 100-ton biodiesel production unit is also expected to be brought into service in Portugal in August 2005. The Ibersol company, a subsidiary of the German food group Nutas, is responsible for this 25 million euro investment. Other units are also under construction or in the project stage in the United Kingdom and Finland.

Biodiesel actors

The second biggest industrial producer in the European Union is France (Table 2), the Diester Industrie Group, which has two production units in Grand-Couronne (260 000 tons capacity) and Compiègne (83 500 tons capacity) and will soon have a third 160 000 ton unit in Sète at the end of the year. Diester also has Rapeseed Methyl Ester produced by Cognis France (33 000 tons) in Boussens near Toulouse. ADM (Archer Daniels Midland Company) is the second largest European producer with two production units in Germany: Ölmuhle Hamburg AG (120 000 tons) and Ölmuhle Leer Conneman (110 000 tons).

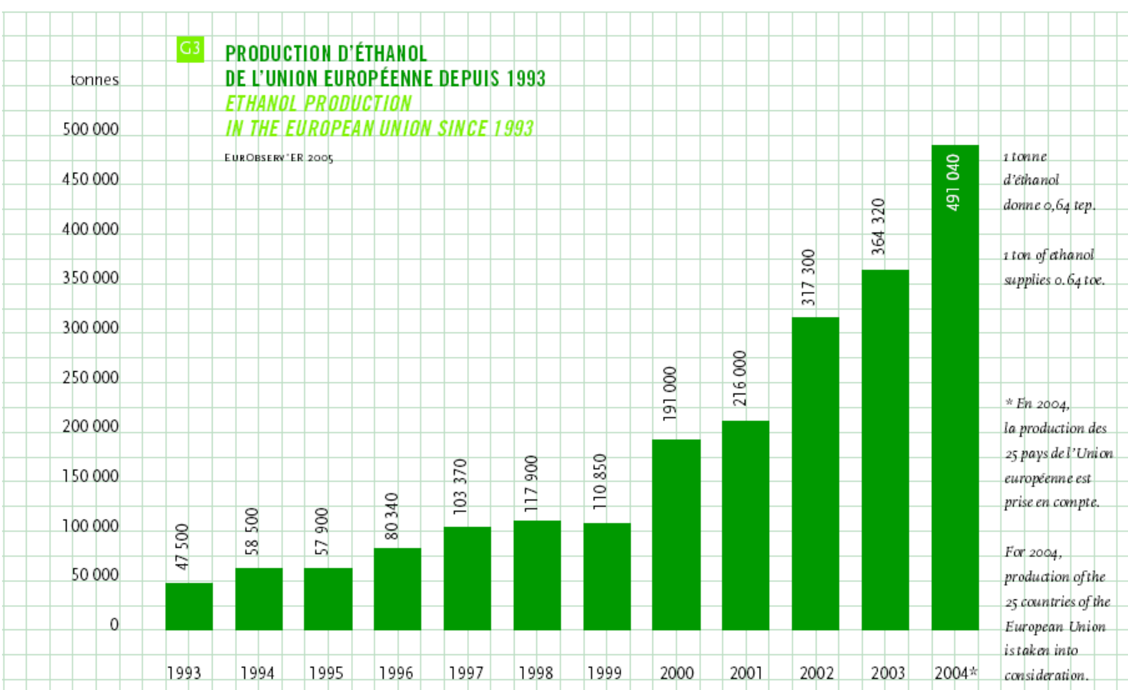
Table 2. Biodiesel Production Capacities in 2004.

COUNTRY	'000 TONNES*
Germany	1088
France	502
Italy	419
Austria	100
Spain	70
Denmark	44
United Kingdom	15
Sweden	8
TOTAL	2246

** Calculation based on 330 working days per year, per plant.*
Source: European Biodiesel Board, Source: http://www.ebb-eu.org/stats.php#

Bioethanol sector

Bioethanol represents the second biofuel market in the European Union. During 2004, ethanol production intended for automobile fuel reached 491 040 tons vs. 424 750 tons previously (including new member countries), i.e. a 15.6% growth rate (graph 2 and table 3). Since 2003, statistics have integrated bioethanol fuel production purchased and sold on the European market by the European Commission in the framework of regulation of the common market organisation of wines. In the framework of the Common Agricultural Policy (CAP),, the Commission is obliged to buy and store excess wine production. It can then decide to have a part of this wine alcohol transformed into ethanol, which it then sells on the biofuels market.



Graph 2. Ethanol production in the EU, 1993 to 2004. Source: (Biofuels Barometer, 2005).

Table 3. Ethanol and ETBE production in the European Union in 2003 and 2004 (in tons).

EurObserv'ER — UEPA 2005

	2003		2004	
	Production d'éthanol	production d'ETBE	production d'éthanol	production d'ETBE
Espagne	160000	340800	194 000	413 200
France	82 000	164 250	102 000	170 600
Suède	52 000	0	52 000	0
Pologne	60 430	67 000	35 840	n.d
Allemagne	0	0	20 000	42 500
Bioéthanol vendu par la Commission*	70 320	n.d	87 200	n.d
Total E.U 25	**424 750**	**572 050**	**491 040**	**626 300**

Source: (Biofuels Barometer, 2005).

* In the framework of common wine market management, the European Commission buys and sells wine alcohol on the European market that is transformed into bioethanol intended for automobile fuel.

Bioethanol actors

The bioethanol market is controlled by the big industrial groups and the large agricultural cooperatives of the sugar and alcohol industries. Cited earlier, the Spanish group Abengoa is the largest bioethanol maker in the European Union with a production of 226 000 tons and the fifth largest in the United States with a production of 325 000 tons. In Europe, Abengoa has two production units in Spain, Ecocarburantes Espanoles (150 000 tons) located in Cartagena and Bioethanol Galicia (176 000 tons) located in Teixero. Total capacity will be further reinforced at the end of the year when a third unit is commissioned in Spain (160 000 tons). Moreover, Abengoa has answered the European call for tenders of the French National Biofuel Plan, via its AB Bioenergy France subsidiary (controlled at 51%), for the construction of a bioethanol production unit to be based in Pardies (southwest France) and representing 180 000 tons of bioethanol. Elsewhere in France, the Tereos Group (fusion of Union SDA and Beghin Say) is producing bioethanol from wheat and sugar beets in its Origny and Provins units and in the Morains and Artenay distilleries. The company, with a production capacity of 48 000 tons per year, holds a 40% ethanol market share in France (32% for sugar) and had a turnover in the region of 1 710 million euros in 2004. For the future, the group is awaiting the granting of future production approvals from the French Biofuels Plan to construct a new production unit in Lillebonne (Seine-Maritime) with a capacity of 200 000 tons as well as a new 160 000 ton capacity production unit in Origny in the Aisne Department. Cristal Union, which groups together the Champagne- Ardenne region beet cooperatives has also filed a project for a 238 000 ton unit located in Bazancourt, near Reims in the Marne Department. Two actors are present on the Swedish market, Agroetanol AB (40 000 tons) and Svensk Etanolkemi (15 000 tons). The transformation of ethanol into ETBE is ensured by the big oil groups like Total in France, which manages, along with the ethanol producers and the organisations representing the beet and cereal growers, the three production sites (Feyzin, Nord ETBE and Ouest ETBE) representing a 219 000 ton annual production capacity.

France

Policies and Incentives

The French government supports a biofuels production programme. The biofuel production programme is a financial scheme, operated at the national level, to encourage investments for biofuel production. Biofuels benefit from advantageous fiscal measures. In France, biofuels receive exemption from excise tax on petroleum products at the rate of EUR 0.35/litre of biodiesel and EUR 0.37/litre of ethanol in 2003. For 2003, the global amount of tax exemption assigned to biofuels is estimated at about 180 M€. The excise tax exemption means that biofuels can compete cost effectively with fossil-based transport fuels. In September 2004, the French Prime Minister announced an increase the biofuel production by 800,000 tons (compared to 400,000 tonnes in 2003) to reach 1,200,000 tons in 2007.

French companies are world leaders in biodiesel production. The European leader for production and marketing of biodiesel is the French company Diester Industrie, with an annual turnover of EUR 200 million in 1997–98. Diester Industrie is owned by oilseed producers and is expected to lift its output to around 1 million tonnes a year in 2007-2008 under a new production quota established by the government at the beginning of 2005. In total, there were four plants producing biodiesel in France in 2004.

Regarding ethanol production, according to the Earth Policy Institute, France leads the European Union, with ethanol production jumping from 89 million litres in 2003 to 830 million litres in 2004. In June 2005, AB Bioenergy France (ABF), was granted an authorization by the French Government to produce 40,000 tons of bioethanol from maize, which will benefit from a hydrocarbon tax exemption from 2007 to 2012. The French government has awarded, in this first stage, authorizations for a total of 200,000 tons of bioethanol, distributed between three projects, one of these being ABF, and has announced the launching of a second phase in which the rest of the capacity will be awarded, up to a total of 450,000 tons. The additional 250,000 tons will be introduced in the French market as from January 2008 onwards, to allow for a progressive establishment of the installed capacity necessary to fulfil the objectives set out by the French Government.

Biodiesel relaunch in France

Despite having a leading role in the EU for biodiesel production, French output has decreased continually since a peak in 2001, the year in which it was the leading producer. In 2004 production of biodiesel amounted to 348,000 tons, representing a further decline of 2.5%, while the authorized amount for that year (which benefited from a 33 euro tax exoneration per hectolitre) was set at 387 500 tons (70 000 tons more than in 2003). In order to incite distributors to put the totality of the authorised quantities (biodiesel, ETBE or pure bioethanol) on the market, the 2005 Finance Law introduced a new tax called the TGAP (“General Tax on Polluting Activities”) in the case where biofuels are not made available for consumption. The situation should evolve much more favourably in the future following the Prime Minister’s announcement of last September detailing a plan targeting increasing biofuel (biodiesel and bioethanol) authorisations by 800 000 tons by the year 2007. The breakdown between the two sectors is 480 000 tons for biodiesel and 320 000 tons for ethanol. In May 2004, the Prime Minister also announced an authorisation of 80 000 tons for the esterification unit in Sète that is under construction (30000 tons of authorised quantity are already provided for Sète in the 2005 Finance Law). To sum up future prospects, 947 500 tons of biodiesel production has thus been approved by the year 2007. The French vegetal oil and protein sector is projecting sizeable industrial development through the Sofiproteol industrial pole (SAIPOL in charge of refining and trituration activities and Diester Industrie in charge of biodiesel production). The three projects are those of Le Mériot (200 000 tons), Montoir/Saint Nazaire (120 000 tons) and an extension of the Compiègne esterification unit (100 000 tons). Other European firms have also introduced projects as well.

France increases ethanol quotas

In France, the SNPAA ("National Agricultural Alcohol Producers Association") has established 2004 bioethanol production at 102 000 tons (1 275 754 hectolitres) vs. a 2003 production of 82 000 tons (1 033 481 hectolitres). Bioethanol consumption on the French market is lower than production levels, with Customs having recorded bioethanol consumption of 80 887 tons in 2004 corresponding to 170 602 tons of ETBE consumption. As is the case for biodiesel, bioethanol incorporated in the form of ETBE benefits from a tax exemption representing 38 euros per hectolitre with an approved quantity limit of 199 000 tons. In 2004, an additional approval for 12 000 tons was granted for bioethanol directly incorporated into petrol (tax exemption of 37 euros per hectolitre). In actual fact, this approval has been barely used at all. Furthermore, bioethanol also benefits from the Biofuel Plan launched by the Prime Minister with an additional approval of 320 000 tons between now and 2007. Via the Finance Law, the French government has already granted an additional approval of 130 000 tons for 2005 which should result in doubling ethanol production (200 000 tons) this same year

French to Boost Biofuel Output to Meet EU Target

France announced in May 2005 it would meet the target with the launch of a new tender for companies to produce a further 950,000 tonnes of biofuel annually "for the years 2008-2010", The quota was split between 700,000 tonnes of biodiesel and 250,000 of ethanol. France will announce new biofuel production quotas in the next few months because its current plans are insufficient to meet the EU targets for 2010, a farm ministry official said In June 2005. The EU target for 2010 implies using two million hectares of grain and oilseed for biofuel production in France and it would involve around 25,000 jobs .

Feedstocks

Main feedstocks for ethanol production are sugar beets and wheat. Main feedstock for biodiesel is rapeseed oil.

Data sources

- FACTBOX Major Biofuel Projects Around the World. Reuters news service, 9 June 2005. www.planetark.com/dailynewsstory. cfm/newsid/31183/story.htm
- Earth Policy institute, Ethanol Production Examples Worldwide, http://earth-policy.org/Updates/2005/Update49_data.htm
- Renewable Energy Policy Review France, May 2004, Altener, www.erec-renewables.org/documents/RES_in_EUandCC/ policy_reviews/EU_15/France_policy_final.pdf
- European Biodiesel Board. Member States updates: 1st reports on progress under Directive 2003/30/EC. http://www.ebb-eu.org/legislation.php

- European Biodiesel Board, Statistics. http://www.ebb-eu.org/stats.php#
- Abengoa, June 2005, AB Bioenergy France has been granted by the French Government to produce 40,000 tons of bio-ethanol, http://www.abengoabioenergy.com/about/index.cfm?page=5&lang=1&headline=26
- Biofuels barometer, June 2005. EurObserv'ER, http://europa.eu.int/comm/energy/res/sectors/bioenergy_publications_en
- http://www.planetark.com/dailynewsstory.cfm?newsid=31226&newsdate=14-Jun-2005

Germany

Policies and Incentives

In Germany, the Mineral Oil Duty Act was amended on 1 January 2004 to allow for full exemption from duty of biofuels and heating oils produced from biomass until 2009. This means that not only biogenic fuels in pure form, as hitherto, are exempt, but also fractions of biofuels and heating oils which are produced from biomass and blended with fossil fuels and heating oils. This measure was based on Article 16 of Council Directive 2003/96/EC of 27 October 2003.

Since the beginning of 2004, rapeseed methyl ester (RME/biodiesel) has been blended with fossil-based diesel. However, biodiesel continues to be chiefly used as a pure fuel. Small amounts of ETBE are made from imported bioethanol for blending with petrol.

In 2003, only biodiesel was of any substantial importance on the German market. Biodiesel started to be used back in 1993. Since then, its use has substantially increased each year. In addition, very small volumes of pure vegetable oil were used in a small number of about 4 000 cars. This is because only pure biofuels were exempt from duty under the German Mineral Oil Duty Act as it stood until 31 December.2003. Biogenic blended fractions (bioethanol, ETBE) in fuels have only been exempt from mineral oil duty since 1 January 2004.

Regarding ethanol, 2004 production stood at 269 million litres. Three new distilleries should bring domestic capacity to nearly 560 million litres annually, requiring an additional 1.4 million tons of rye and wheat in 2005 - 3 percent of Germany's 2004 grain crop.

More than 1 million tons biodiesel produced in Germany

Germany remained the leading biodiesel producer among the European Union countries in 2004, with production reaching more than one million tons for the first time (1 035 000 tons to be exact). Germany, whose production increased by 44.8% with respect to 2003, represents more than half of European Union biodiesel production (53.5%). Such a high level of growth can be explained by the country’s very favourable legislation. Since January 1st 2004, the mineral oils tax law that governs taxation of fuels has been amended. It now allows for a total tax exemption for biofuels, and this whether they are in pure form or mixed with fossil fuels. In the same way, biofuels in Germany are not subject to the ecology tax established in 1999, which is added to the taxes levied on petroleum products.

Germany starting bioethanol production

Germany is going to have three bioethanol production units (two belonging to the Sauter Group and one to the Südzucker Group) representing a production capacity of 500 000 tons of bioethanol per year. These three units, which will produce bioethanol from cereals, are all located in eastern Germany near the Polish border. The Zörbing unit (the Sauter Group), which was commissioned last September, is the only one to have produced bioethanol in Germany in 2004 (20 000 tons). The Sauter Group’s second unit, located in Schwedt, has been operational since the beginning of 2005, while the Südzucker unit, located in Zeitz, will only start up in Spring of 2005.

Feedstocks

By far the most dominant feedstock for bio-diesel is rapeseed oil. For ethanol production, rye and wheat are used.

Data sources

- Bundesministerium fuer Umwelt, Naturschutz und Reaktorsicherheit. Bundesregierung beschließt Förderung von Biokraftstoffen. http://www.erneuerbare-energien.de/inhalt/5429/4593/
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- Biofuels barometer, June 2005. EurObserv'ER, http://europa.eu.int/comm/energy/res/sectors/bioenergy_publications_en.htm

Italy

Policies and Incentives

Italy decreases biodiesel quantity approvals in 2005

Biodiesel dominates bioethanol with respect to biofuel production in Italy. Biodiesel production continued to increase in Italy during 2004 with 320 000 tons produced (+ 17.2% with respect to 2003). More than 90% of this production was intended for the fuels market, with the rest being destined for building heating applications (in the Vatican in particular). On the contrary to France and Germany, the biodiesel situation will probably deteriorate in Italy in 2005 with a 100 000 ton decrease in the Italian approval levels, i.e. a 2005 production approval for 200 000 tons. This decrease in quotas will favour bioethanol production which now benefits from an approval representing one million hectolitres per year (79 300 tons), corresponding to a tax exoneration of 73 million euros per year over a period of three years. This decision is justified by the fact that biodiesel is mainly produced using imported vegetable oils while Italy possesses a sizeable capacity for producing its own alcohol of cereal and wine origin.

Feedstocks

Biodiesel is mainly produced using imported vegetable oils. For ethanol production, cereal and agricultural residues from grapes are used.

Data sources

- Biofuels barometer, June 2005. EurObserv'ER, http://europa.eu.int/comm/energy/res/sectors/bioenergy_publications_en.htm
- http://www.eeci.net/countries/IT.html

Poland

Policies and Incentives

Poland waiting for biofuel law

Poland is the only European Union country whose bioethanol production decreased sharply in 2004 (- 40.7% in 2004, i.e. 35 840 tons). Poland's production of bioethanol intended for use as fuel was revised strongly downward for the year 2003 (60 430 tons vs. 131 640 tons). The figures announced by the Distilleries Chamber of Commerce had anticipated the new Biofuels Law that was finally invalidated by the Constitutional Court.

This situation can be explained by the fact that in 2004 the Polish Constitutional Court did not ratify the Biofuels Law that was voted previously by the parliament in November 2003. This law provides for a tax exemption for the production of ethanol mixed with petrol, the final percentages and the amount of the exemption are to be determined on a yearly basis after approval of the annual budget. The Biofuels Law is presently (June 2005) still in revision phase.

Feedstocks

Feedstocks for ethanol production in Poland are cereals, potatoes and sugar beet molasses.

Data sources

- Biofuels barometer, June 2005. EurObserv'ER, http://europa.eu.int/comm/energy/res/sectors/bioenergy_publications_en.htm
- http://www.biomatnet.org/secure/Other/S941.htm

Spain

Policies and Incentives

Regarding the measures taken in Spain to promote the use of biofuels in the transport sector, the most important is clearly the measure referred to in Article 6(5) of Law 53/2002 of 30 December 2002 on Tax, Administrative and Social Measures, which lays down the following:

“Special tax rate for biofuels Until 31 December 2012, under the conditions laid down in the regulations and without prejudice to the provisions of paragraph 3 of this article, a special rate of zero euros per 1 000 litres shall apply to biofuels. This special rate shall apply exclusively to the volume of biofuel even when this is used blended with other products. If the comparative trend in the production costs of petroleum products and biofuels so warrants, the General Finance Law of the State may replace the zero rate referred to in paragraph 1 of this article with a positive rate of tax, which shall not exceed the rate applicable to equivalent conventional fuel”.

National indicative targets: In accordance with Article 3(1)(b) of Directive 2003/30/EC, the reference value for the national targets for biofuels and other renewable fuels in the transport sector placed on the market is 2%, calculated on the basis of the energy content of automotive petrol and diesel placed on the Spanish transport market by 31 December 2005. In 2004, this share was 1.09%.

Bioethanol success in Spain

Spain is the leading European Union country in terms of bioethanol production with a total of 194 000 tons in 2004 (160 000 tons in 2003). Like France, bioethanol production is transformed into ETBE (ethyl-tertio-butyl-ether), produced from the reaction of ethanol with a petroleum derivative (isobutylene). The success of this production can be explained to a large degree by Spain’s choice to not tax ethanol. Bioethanol fuel production growth is going to markedly increase in 2006 in Spain with the current construction of the Abengoa Group’s third production unit with a capacity of 160 000 tons. Two other plants of Abengoa produced 226 million litres of ethanol in Spain. The third unit, constructed in partnership with Ebro Puleva (the number one Spanish food processing group), will be called Biocarburantes de Castilla Y Leon and will be operational at the end of this year. Unlike the first two Abengoa plants, production of the Castilian unit is not intended for transformation into ETBE but rather is designed to be directly mixed with petrol.

Feedstocks

The main feedstocks for ethanol production are wheat and barley.

Data sources

- FACTBOX Major Biofuel Projects Around the World. Reuters news service, 9 June 2005. www.planetark.com/dailynewsstory. cfm/newsid/31183/story.htm
- Earth Policy institute, Ethanol Production Examples Worldwide, http://earth-policy.org/Updates/2005/Update49_data.htm

- First Spanish national report on the implementation of Directive 2003/30/EC of 8 May 2005 on the promotion of the use of biofuels or other renewable fuels for transport, http://www.ebb-eu.org/legislation.php
- Biofuels barometer, June 2005. EurObserv'ER, http://europa.eu.int/comm/energy/res/sectors/bioenergy_publications_en.htm

Sweden

Policies and Incentives

Tax strategy for alternative fuels

The main elements of the Swedish Government's tax strategy for alternative fuels were set out in the draft budget for 2002. Under this strategy, tax relief is available either for pilot projects, which qualify for full exemption from excise duties, or in the form of a general exemption from CO2 tax for CO2-neutral fuels. Having regard to the indicative targets required under the Biofuels Directive, and in order to ensure that CO2-neutral fuels are competitive, the Government has, in its draft 2004 budget, adjusted its tax strategy for alternative fuels so that CO2-neutral fuels are exempt from both CO2 tax and energy tax with effect from 2004 as part of a five-year programme. These tax exemption provisions will apply subject to their being approved by the Commission as compatible with EU legislation. Amongst other things, compatibility with these rules implies that amendments required to avoid over-compensation can be made at any time.

Research and development

Sweden supports research, development and demonstration measures for developing more energy-efficient and more cost-effective processes for the production of biofuels. In 2003, the Swedish Energy Agency carried out measures as part of several different programmes for developing production processes for fuels such as ethanol, methanol, dimethylether (DME), FT diesel, biogas and hydrogen. State funding for biofuel-related measures is estimated to be at least SEK 50 million per annum. However, this figure may vary significantly from year to year, and it is not always clear whether measures, e.g. those concerning the renewable production of hydrogen, are to be regarded as relating to fuel or other energy uses.

A pilot plant for the production of ethanol from forest raw materials was inaugurated at Örnsköldsvik on 26 May 2004. The plant is a research and development unit designed to verify and optimise the chosen technology and to provide the basis for a processing technology for the production of ethanol and lignin that is commercially viable for a demonstration plant. The pilot plant has the capacity to produce 500 litres of ethanol per day. The ethanol will not be sold as fuel.

Flexible fuel vehicles

In 1998, the Swedish Delegation for Sustainable Technology (Miljöteknikdelegationen) and the City of Stockholm Equipment Supply Organisation (MFO) took the initiative of launching a technology procurement procedure for ethanol-fuelled vehicles. A need had been identified, on the basis of past experience, for a small, fuel-efficient vehicle designed for Swedish conditions that would run on ethanol. Ford were the successful bidders, and an agreement was signed for the purchase of more than 3000 Ford Focus FFVs. The Ford Focus FFV is a small and modern flexible fuel vehicle, which can run on petrol or E85 (85% ethanol and 15% petrol) or any intermediate level of blend. 4300 Ford Focus FFVs were sold in 2003, and the figure has now risen to about 7000. Two-thirds of all Ford Focuses sold in Sweden in 2003 had flexi-fuel engines.

Reduction of benefit attributed to eco-friendly cars for tax purposes

In order to facilitate the introduction of eco-friendly cars, including those which run on biofuels such as ethanol and biogas, it was made possible, with effect from 1 January 2002, to attribute a reduced benefit for tax purposes to certain types of environment friendly company cars for a limited period. Cars powered wholly or partly by electricity may qualify for a 60% reduction in relation to the benefit attributed to the most closely comparable conventional car. Cars powered by alcohol or gas other than gasoil may qualify for an 80% reduction in relation to the benefit attributed to the most closely comparable conventional car. As a result of the 2004 budget adopted by the Swedish Parliament, these rules are to apply up to and including the 2008 income year.

Environmental policy for government vehicles

It is stated in the Government's 2004 spring economic policy paper that work is in progress on devising an environmental policy for government vehicles. With effect from 2005, at least 25% of all newly purchased government vehicles must be eco-friendly. Amongst other things, this policy will encourage the introduction of vehicles that can run on biofuels.

Total sales of fuels and the biofuel share in recent years

The biofuels that are used fairly widely in Sweden are bioethanol, rape methyl ester (RME) and biogas. Other biofuels, such as synthetic diesel and heavier alcohols, are used in very small quantities. As part of the European Union's CUTE project, the City of Stockholm also uses hydrogen produced from green electricity to operate three fuel cell buses. Use of ethanol in particular has increased sharply in the past few years. Imports of ethanol increased sharply in 2003, from a relatively low level. Imported ethanol now accounts for most of the ethanol used in fuel in Sweden. It is imported from Norway, Spain, Italy, France and Brazil. The most expensive imported ethanol is wine ethanol from France, and the cheapest is sugar-cane ethanol from Brazil. In Sweden, ethanol for fuel use is produced mainly at the Agroetanol plant at Norrköping. About 85% of all fuel ethanol is used in low-level blends, i.e. petrol with a 5% ethanol content. At the end of 2003, about half of all 95-octane petrol contained 5% ethanol. About 15% of fuel ethanol is used in a pure or an almost pure form (E85).

National target for 2005

As the EU-2% target will be reached already in 2004, the Swedish government adopted a target of 3% for 2005. This would correspond with roughly 350 million litre ethanol, assuming no bio-diesel is used.

Sweden consuming more than it produces

The third largest bioethanol fuel producer in the European Union, Sweden produced 52 000 tons in 2004, i.e. a stable production level with respect to 2003. Unlike France and Spain, Sweden does not transform ethanol into ETBE in order to distribute it. Sweden is also characterised by the fact that it consumes much more bioethanol than it produces, with annual consumption of 206 000 tons (261 million litres).

Feedstocks

The feedstock for ethanol production in Sweden is grain, though raw forest materials are currently been tested as feed stock for 'second generation' production of ethanol.

Data sources

- Earth Policy institute, Ethanol Production Examples Worldwide, http://earth-policy.org/Updates/2005/Update49_data.htm
- First Swedish national report on the implementation of Directive 2003/30/EC of 8 May 2005 on the promotion of the use of biofuels or other renewable fuels for transport, http://www.ebb-eu.org/legislation.php
- Biofuels barometer, June 2005. EurObserv'ER, http://europa.eu.int/comm/energy/res/sectors/bioenergy_publications_en.htm

The Netherlands

Policies and Incentives

In order to make biofuels sufficiently attractive in economic terms, a financial compensation will have to be paid in respect of the additional costs incurred in biofuel production. The provision of incentives with effect from 2005 is not feasible on the grounds that further investigations must be carried out into the correct way of providing incentives for the use of biofuels (the Netherlands does not, after all, have a tradition involving the use of biofuels) and also on the grounds that business and industry are not yet in a position to launch the introduction of biofuels as early as 2005 (as stipulated under the EC Directive No. 2003/30/EC). The Dutch government is expected to take a decision in September 2005, whether biofuels will be granted a tax exemption from 1 January 2006 onwards.

From 2006 the Netherlands is adopting a biofuel target percentage of 2% of the energy content of petrol and diesel. To this end, the Dutch Government is doing all it can to introduce incentive arrangements for biofuels with effect from 2006. The requisite investigations and preparations, including the funding of incentive measures, have already been set in train. The 2% biofuels target includes niche markets (e.g. the use of pure vegetable oil, pure biodiesel and mixtures of 85% ethanol with 15% petrol). In addition to reducing CO2 emissions, another important objective is to embark on an innovatory approach to the use of biofuels in the transport sector.

The government of the Netherlands considers that in order to provide incentives for the development of the so-called second-generation biofuels (e.g. biomass-to-liquid diesel and ethanol from cellulose), steps need to be taken to ensure the eventual imposition of sustainability requirements in respect of biofuels (sustainability criteria, which still need to be drawn up (internationally), should relate, inter alia, to C02 reduction and the maintenance of biodiversity). With a view to assessing biofuels in terms of their sustainability, an examinations are required to determine whether it would be possible to establish an (international) certification system. The possibility of providing incentives for the development of new technologies should also be examined

Based on 2002 fuel consumption (5600 million litres motor spirit, and 6900 million litres diesel / gasoil) , the Netherlands would require approximately 250 million litres of biofuels in 2006 to reach a share of 2%, and about 720 million litres in 2010 to reach 5.75% of consumption

Feedstocks

Apart from a number of small-scale demonstration projects (involving some 4 million litres of biodiesel and pure vegetable oil from rapeseed), no biofuels are being placed on the market in the Netherlands.

Data sources

- http://gave.novem.nl/novem_2005/index.asp?id=25&detail=236
- First Dutch national report on the implementation of Directive 2003/30/EC of 8 May 2005 on the promotion of the use of biofuels or other renewable fuels for transport, http://www.ebb-eu.org/legislation.php

United Kingdom

Policies and Incentives

Fuel Duty

The UK government has already taken a number of steps to promote the uptake of biofuels. To date, the main support has been through fuel duty incentives, though the UK government is currently consulting on other measures to support the longer-term growth of the UK Biofuels industry. A 20 pence per litre duty incentive on biodiesel has been in place since July 2002, and a similar duty incentive for bioethanol will be introduced from 1 January 2005. This policy has seen sales of biodiesel increase rapidly since the introduction of the incentive, and sales have increased from 150,000 litres a month in August 2002 to around 2 million litres a month. To a large extent, production is from waste vegetable oil (WVO), since this is currently the cheapest feedstock. Biodiesel is currently available at over 100 filling stations in the UK, including a number of major supermarket sites. No bioethanol is sold in the UK, though this could change after 1 January 2005 when the 20 pence per litre fuel duty incentive for bioethanol comes into effect. Budget 2004 provided a guarantee that the current duty incentives would remain in place for at least the next three years - providing greater market certainty for investors. In the UK, duty rates are set by the Chancellor of the Exchequer at Budget time and take into consideration social and economic as well as environmental reasons. The current duty incentive for biofuels places primary importance on its environmental benefits but also supports the growth of an UK industry. Industry has called for a higher level of incentive, but the cost of the current incentive already outweighs the monetised carbon benefit, and biofuels are currently an expensive method of carbon abatement. A more detailed cost-benefit analysis can be found at www.dft.gov.uk/roads/biofuelsconsultation.

Greater incentive levels at this time would largely result in imports, including from outside the EU. This would limit the potential benefits to the UK and broader EU agricultural and rural sectors of a new market. In addition, there is strong concern that greater demand from the EU for biofuels feedstocks could lead to further deforestation in South East Asia and South America - thereby undermining the environmental benefit sought through the measure.

'Input Taxation'

Budget 2004 also confirmed the Government's intention to explore new taxation methods that could enable the direct processing of bio-materials into mainstream conventional refinery processes. At present, the esterification of rape-seed is an entirely separate process from refining oil for road fuel products. The biodiesel is only blended with conventional diesel at a late stage in the process, which gives rise to inefficiencies in terms of manufacturing, storage and distribution, making the cost disadvantage of biofuel greater than it might otherwise be. At least one oil major has been experimenting with feeding the bio oils - and prospectively, the waxy materials produced from biomass - direct into the conventional refinery - in effect supplementing the crude oil. The end product is virtually indistinguishable from conventional diesel – hugely advantageous from a fuel quality perspective - but challenging for the current fiscal regime, which focuses on this final product. The industry's suggestion is that the duty concession is linked to the bio input, through a 'bio credit' concept - i.e., a tax credit allowed on approved bio input material, which is redeemed against the full duty which applies to the total final fuel production. One of the advantages of the input focus is that it is easier to handle a range of different input materials, tailoring the level of credit and incentive to the degree of environmental gain. The UK Government is very interested in such direct processing, as it could enable a significant shift in the scale of biofuel production and facilitate the mainstreaming of biofuel products. There is however much work to be done - both on fully understanding the relative carbon benefits of this process and in exploring adaptations to the tax system that could enable it economically. The UK Government is currently exploring both of these issues, and intends holding stakeholder consultations over the summer.

Capital Grants

One of the few methods of direct support for industry - allowable under the EU's single market rules - is the use of regional selective assistance (RSA) grants for developments in regions of the EU identified as disadvantaged. This somewhat limits the options in the UK, where the qualifying regions do not necessarily match up with the most suitable areas to build production facilities. A further problem is that RSA's are linked to employment enhancing projects, and biofuels production plants are not very labour intensive.

However, the UK has taken advantage of the Regional Selective Assistance system to help fund the construction of the nation's first large-scale biodiesel production unit. An RSA grant from the Scottish Executive of £1.2 million has helped support the £15 million project. The plant will be built at Argent's Scottish base near Motherwell, through a £10 million deal with Austrian manufacturer BioDiesel International. The plant will convert tallow and waste oils such as used cooking oil produced by the UK's fast food and catering industries and could produce 50,000,000 litres per annum when operating at full productivity levels, currently planned to be by 2005. The North East Regional Development Agency has also recently given a grant of £1.2million to support the development of a biofuels plant in the region.

Enhanced Capital Allowances

Capital allowances allow the costs of capital assets to be written off against a business's taxable profits. One hundred percent first-year enhanced capital allowances (ECA) allow a business to write off the whole cost of qualifying capital assets against the taxable profits of the period during which the expenditure is incurred. The accelerated tax relief can provide a cash flow benefit for businesses in profit and a net present value benefit of about five percent. The 2004 Budget announced that the Government will discuss with stakeholders the application of ECAs to support investment in the most environmentally beneficial biofuel processing plant. Stakeholder discussions are going to be held on how ECAs might apply to the best biofuel production technologies over the course of the summer.

Renewable Transport Fuel Obligation

The UK is also seriously considering the possibility of introducing a renewable transport fuel obligation (RTFO) for the road fuel sector, drawing on the experience of the Renewables Obligation that applies to licensed electricity suppliers. In essence, an obligation would require specified sections of the road transport fuel industry to demonstrate that a specified proportion of their aggregate fuel sales were 'renewable transport fuels'. The Government considers that an RTFO could provide a mechanism to ensure the gradual substitution of fossil fuels for biofuels - and other renewable fuels - over the long term. Many questions remain as to how such an obligation might work and whether it is the most effective mechanism, and invited views are included in this work. In the meantime, a clause in the Energy Bill is included that would give the Government the primary powers to introduce an RTFO, should the Government decide - in light of consultation - to proceed down this route.

Sponsoring Research & Development

The Government has commissioned and/or otherwise contributed to the funding of a number of research projects in order to inform policy making. Furthermore, next to biofuels the UK government will also assess hydrogen as a major potential low-carbon transport fuel.

UK Sales Levels for 2003

The total sales of biofuels in the UK in 2003 were some 19,446,000 litres (15,387,620 tons), whilst total road fuel sales were approximately 48,505 million litres. As a percentage of total road fuel sales therefore, biofuels contributed about 0.04%. Biofuels sales demonstrated a tripling over the course of 2003. Negligible quantities of bioethanol were used in road transport in 2003.

UK Target for 2005 and 2010

As illustrated above, the UK has already taken a number of steps to promote uptake of biofuels that has stimulated a rapidly expanding market. With these measures in place, and the additional incentives announced in Budget 2004, UK biofuel sales could be as much as 12 million litres a month in 2005. This would represent a six-fold increase over today's levels of biofuel sales and a significant expansion of the UK's biofuels industry. Most biodiesel is used in a blend of up to 5 percent, which would mean that as much as 10 percent of all diesel being used in the UK included an element of biofuels As a percentage of total road fuel sales, this would equate to something like 0.3% biofuels (mainly biodiesel). It is acknowledged that this is some way short of the EU's reference values. However current incentives have only been recently introduced and given the UK's low starting point; the considerable growth this target implies; and the limited time between now and the target period, it represents a challenging but realistic target for the UK. After consultation, the target will be confirmed by the end of this year. Targets for the year 2010 are not yet available, since targets for 2010 are required by July 2007.

Feedstocks

Feedstocks for UK biofuel production include re-cycled cooking oils, agricultural by-products (e.g. tallow and possibly straw) and mainstream agricultural crops (e.g. cereals and root crops for bioethanol and oilseed crops for biodiesel). Imports could include straight bioethanol and biodiesel as well as biodiesel feedstocks including tropical products such as palm oil. Most biodiesel was sold in a blend, the majority at or below the 5% level which is in line with the European road fuel diesel standard EN590.

Data sources

- FACTBOX Major Biofuel Projects Around the World. Reuters news service, 9 June 2005. www.planetark.com/dailynewsstory. cfm/newsid/31183/story.htm

- First British national report on the implementation of Directive 2003/30/EC of 8 May 2005 on the promotion of the use of biofuels or other renewable fuels for transport, http://www.ebb-eu.org/legislation.php

2.3 Other regions

United States of America

Policies and Incentives

Incentives for Alcohol Fuels

Excise tax exemptions for alcohol fuels were initially established by the Energy Tax Act of 1978 with full exemption for 10% blended gasoline (gasohol) from the then USD 4¢-per-gallon federal gasoline excise tax, an effective subsidy of USD 40¢ per gallon of ethanol. A 1980 law added an alternative blenders credit of USD 40¢ per gallon applicable to other blend levels including E-85. Various subsequent acts raised (as high as USD 60¢ per gallon) or lowered and extended the subsidy. The most recent (2004) adjustment extends the exemption through 2010 at a level of USD 51¢ per gallon of ethanol. The 2004 enactment also changes it to a "volumetric ethanol excise tax credit" so that the exemption is no longer tied to particular blend levels.

The 2004 legislation also removes obstacles (ability of farmer cooperatives to pass along savings and alternative minimum tax provisions) to use of a 1990 "small ethanol producer credit." This allows a USD10¢-per-gallon tax credit for production of up to 15 million gallons of ethanol per year for facilities with less than 30-million-gallons-per-year capacity. The federal tax code also includes other tax incentives for alcohol fuels, such as an income tax deduction for alcohol-fuelled vehicles and an alternative fuels production tax credit-all aimed at encouraging the substitution of renewable alcohol fuels for gasoline and diesel, to conserve petroleum in the transportation sector, and reduce dependence on petroleum imports.

Incentives for Biodiesel:

Biodiesel production and use in North America is not as advanced as it is in Europe. Biodiesel production and use in the United States has been actively promoted by the National Biodiesel Board (NBB) and various soyabean producer groups for over ten years. The NBB was formed in 1992 and the period between 1993 and 1996 involved various biodiesel demonstration projects. In 1997, the US Congress approved biodiesel as an alternative mechanism for complying with the Energy Policy Act (EPAct). In 1998, transport fleets began to use biodiesel for EPAct compliance and significant biodiesel use started.

New with the 2004 enactment is a tax credit for biodiesel, USD $1.00 per gallon if made from virgin oil or USD50¢ per gallon if made from recycled oil such as cooking grease. The credit is similar to the restructured ethanol subsidy so will apply to fleets exempt from gasoline excise taxes, will not affect the highway trust fund, and will not be limited in use by minimum taxes. Because biodiesel currently costs about USD $1.00 per gallon more than petroleum diesel, this credit should make it highly competitive. The new subsidy could therefore provide a very significant boost to the previously relatively small use of biodiesel. An indication for this may be the announcement that North Dakota Biodiesel plans to build what will be the largest biodiesel refinery in North America. The USD $50-million plant in Minot, ND, will produce 100,000 tons of biodiesel from canola per year Construction is due to begin in August, with the first product available in December 2006.

Next to these federal incentives, a variety of state-level incentives and targets exist for ethanol and bio-diesel. It would go beyond the scope of this paper to describe these in detail.

Renewable fuels standard

In June 2005, the U.S. Senate passed the comprehensive energy bill, that includes a renewable fuels standard (RFS) of 8 billion gallons by 2012. Senators adopted an amendment by Senate Energy Chairman [Mr.Pete Domenici (R-NM)] to complete the RFS fuels package that includes repealing the reformulated gasoline oxygenate standard, strengthening the remaining RFG air quality standards to account for the removal of oxygen and banning MTBE in four years. The RFS included in the Committee bill begins at 4 billion gallons in 2006 and increases to 8 billion gallons in 2012. It is a national program that includes flexibility for petroleum companies and numerous safeguards for consumers and air quality. However, the legislation will now go to committee, to work on the differences between the House and Senate versions. The House version contains a 5 billion gallon RFS, and MTBE liability protection.

Feedstocks

Main feedstock for ethanol production in the USA is maize, and very small amounts of grain sorghum, wheat starch, brewery wastes and beverage waste. The so far negligible amount of bio-diesel produced is made out of soyabean (ca. 89%) and animal fats (ca. 11%), and from 2006 onwards from canola (rapeseed).

Production figures and forecasts:

Historic and projected biofuel production (10^6 litres)

	1980	1990	2000	2001	2002	2003	2004	2006	2012
Ethanol	660	3400	6170	6700	8060	10600	12900		
Biodiesel			7	24	33	70			
Total								15140[a]	30280[a] / 18900[b]

a Target based on the senate version of the RFS bill (yet to be approved by the house).
b Target based on the house version of the RFS bill.

Data sources

- http://www.eere.energy.gov/biomass/federal_biomass.html
- Homegrown for the homeland. Renewable Fuels Association. Ethanol Industry Outlook 2005, February 2005.
- North American Fuel ethanol industry, review of industry growth 1999-2003, Prepared For: IEA BIOENERGY TASK 39, Prepared By $(S\&T)^2$ Consultants Inc., February 28, 2004.
- Biodiesel in North America: Implementation issues. Prepared For: IEA BIOENERGY TASK 39, Prepared By $(S\&T)^2$ Consultants Inc., February 28, 2004.
- http://www.ethanolmarket.com/legislative.html
- Construction to Begin on Largest North American Biodiesel Refinery, 25 March 2005, http://www.greencarcongress.com/2005/03/construction_to.html

Canada

Policies and Incentives

Ethanol use as a blending component of gasoline began in the Province of Manitoba in 1981 with a 10% ethanol blend being marketed. In 1987, ethanol blended gasoline with 5% ethanol were offered in the four Western Canadian provinces with about 250 service stations offering the fuel. In 1992, ethanol blends were introduced into Ontario and in 1995 in Quebec. In 2003, there were approximately 1400 services stations in six Provinces offering 5% or 10% blends of ethanol and gasoline.

Current Canadian government strategy is to direct subsidies primarily to the construction of production plants. The objective of the Federal government's National Biomass Ethanol Program (NBEP), which is an AAFC-funded CAD$140 million program, is to encourage firms to invest in the Canadian ethanol industry and encourage the production and use of renewable fuels where it is environmentally sound and economically viable. The NBEP is designed to minimize the cash flow impact of a future federal government decision to reduce or eliminate the 10.0 cent/litre excise tax exemption on fuel ethanol produced for sale and use in Canada. Under the NBEP, participating ethanol producers will be able to draw upon a contingent line of credit established by FCC if reduction or elimination of the federal excise tax exemption on fuel ethanol impairs their ability to meet scheduled long-term debt servicing commitments. The permitted draw period may extend for a period of up to ten years following a reduction in the excise tax differential. Up to CAD$135 million is directly available to firms planning to build or expand a biomass fuel ethanol plant in Canada and use biomass materials as feedstock. Biomass feedstock may include feedstock from agriculture, forestry or municipal waste streams or a combination of these. FCC will accept applications under the program until 31 March 2006.

In July 2005, the Canadian government decided that five companies in Canada will receive CAD $46 million to build or expand ethanol facilities in Canada. This is "Round 2" of Canada's Ethanol Expansion Program (EEP). When completed, these five plants will increase production by an additional 510 million litres of ethanol per year. The CAD $46 million is in addition to the CAD $72 million previously allocated to six other projects in the first round of the Ethanol Expansion Program. Projects supported under both rounds of the Ethanol Expansion Program expect to be producing a total of about 1.2 billion litres of fuel ethanol per year by the end of 2007. This would bring Canadian production to approximately 1.4 billion litres per year, seven times what it was prior to the launch of the program, and enough to meet the Government of Canada's climate change target for ethanol production two years ahead of schedule. This target is to have 35 percent of all gasoline in Canada contain a blend of 10-percent ethanol by 2010. Additionally, the CAD $118 million in funding the Government of Canada has allocated under the EEP will result in close to a CAD$1 billion investment from the companies involved in the projects.

Next to subsidizing production facilities, a number of providences have set mandatory fuel blending targets. Ethanol blending will be mandatory in Ontario, Manitoba and Saskatchewan. In Ontario, a 5% ethanol of all gas sold will be mandatory by 2007.

Regarding biodiesel, the only commercial biodiesel production in Canada has been the Ocean Nutrition operation in Nova Scotia that has been converting about one million litres of fish oil into biodiesel and using the product for power generation. The company is expanding its production and it will convert about 6 million litres oil in 2004. The increased production will be marketed by an independent petroleum marketer, Wilson Fuels, as a 5 to 20% blend with heating oil.

Feedstocks

While the main feedstock in Canada is wheat, increasingly, maize (partially imported from the USA) is used as feedstock for ethanol production (mainly in Ontario).

Production figures and forecasts

Historic and projected biofuel production (10^6 litres)

	1980	1990	2000	2001	2002	2003	2004	2007/2010
Ethanol			[a]	[a]	[a]	[a]	175[b]	1400[c]
Biodiesel						1	6	
Total								

a Ethanol production statistics are not publicly available in Canada. The production has only increased marginally over the past five years, as the same plants that were operating in 1999 are still the only plants operating in early 2004.

b Canada is a net importer of ethanol. In total about 240 million litres ethanol were consumed as biofuel in 2004

c While the target of 10% blend in 35% of gasoline is set for 2010, the required ethanol production may already be reached by the end of 2007.

Data sources

- National Biomass Ethanol Program. http://www.agr.gc.ca/progser/nbep_e.phtml
- http://www.macewenpetrol.com/cnr.asp
- Reynolds, N., The dubious politics of our ethanol policy, Friday, July 8, 2005,Workopolis, http://transobj.workopolis.com/servlet/Content/fasttrack /20050708/RREYNOLDS08?section=Energy
- Mitchell, A., Driving Clean: Government of Canada Launches Second Round of Ethanol Expansion Program. December 10, 2004, http://www.muskoka.com/andymitchell/newspaper-columns/Column12-10-2004.htm

Brazil

Policies and Incentives

In Brazil, the world's largest ethanol producer, the government decrees currently stipulate blending ratios for mixing ethanol with gasoline of between 20-25%. Currently the decree requires that the sugarcane-based ethanol additive make up 25 percent of gasoline mixes. Expectations are that ethanol production will roughly triple, increasing from 2002 tot 2013 from 12.8 million litres to 37.8 million litres (Macedo, 2004, in Volpi, 2005). The share of exported ethanol is expected to rise from 0.78 million litters in 2002 to 3.78 million litres in 2013. A somewhat more conservative outlook is given by Walter (2005), sketching a total ethanol production of 30.9 billion litres in 2013 (25 billion for domestic use and 5.9 billion litres for export).

Countries which are importing or plan to import ethanol from Brazil are amongst other the USA, Japan, India, Sweden and Germany.

Furthermore, the government has enacted a law for biodiesel obligation: 2% by the end of 2007 (800 Million litres per year), 5% by 2013 (2 Billion litres per year), and goal of 20% by 2020 (12 Billion litre per year). However, the first two large-scale biodiesel plants in Brazil have only just been opened during the spring of 2005, with a combined annual capacity of 20 million litres. To produce the required vegetable oil, in February 2005 the Brazilian government has made USD$ 41.9 million (BRL$ 100 million) available for loans to several thousand families to produce oil from castor-oil plants for biodiesel production. The biodiesel production is not only aimed for domestic use. The German government has authorized the mixture of 2% biodiesel with that derived from petroleum, and Brazil hopes to become the main supplier. A pilot project will take place in two cities, one in Brazil and the other in Germany, where official vehicles will be fuelled using the alternative fuels.

Feedstocks

The sole feedstock for ethanol production is sugar cane. For bio-diesel, the future production is to be covered by soyabean oil, castor oil, sunflower seed oil and dende oil.

Production figures and forecasts

Historic and projected biofuel production (10^6 litres)

	1980	1990	2000	2001	2002	2003	2004	2007	2013	2020
Ethanol	3700	11500	10500	11470	12500	14640	15160		37800[a] / 30900[b]	
Biodiesel							0	800[b]	2000[c]	12000[d]
Total										

a Based on Volpi (2005).
b based on Walter (2005)
c based on mandatory blending
d official governmental target

Data sources

- FACTBOX - Biofuels Take Off in Some Countries. Reuters news service, 9 June 2005. http://www.planetark.com/dailynewsstory.cfm/newsid/31182/story.htm

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- http://anba.com.br/ingles/noticia.php?id=7791
- http://anba.com.br/ingles/noticia.php?id=6305

Argentina

Policies and Incentives

Recent developments

Argentina's senators have proposed a national Biofuels Bill in 2004. The world's top soyabean oil exporter and No. 2 maize exporter wants to produce more ethanol, (a fuel additive usually made from maize or sugar cane, and) vegetable oil-based biodiesel.

Argentina hopes to join the United States and Brazil in supplying this growing market for biofuels as the European Union and Japan try to meet new fuel-mixing targets. The senate bill, enjoying two-third majority support, would boost the industry at home by offering tax breaks to both ethanol and biodiesel producers and setting mandatory fuel mixes. It would require gasoline mixes in Argentina to contain 5 percent ethanol. Diesel fuel would include a 5-percent biodiesel component.

Government efforts to boost biofuels fell flat in the past. But Argentina suffered natural gas shortages this year, and the spectre of blackouts convinced some members of the government and parliament that alternative energy sources must be found.

Feedstocks

Argentina already produces ethanol from maize and grain sorghum on a small scale. Brazil's state oil firm Petrobras is researching whether biodiesel could be made from rapeseed in Patagonia. The main feedstock for biodiesel would probably be soyabeans.

Production figures and forecasts

Historic and projected biofuel production (10^6 litres).

	1980	1990	2000	2001	2002	2003	2004	2007	2013	2020
Ethanol							159[a]			
Biodiesel										
Total										

a Total ethanol production. Share for fuel is unknown.

Data sources

- Argentine Senate pushes plant-based green fuels. Reuters, July 9, 2004, Hilary Burke, http://www.climateark.org/articles/reader.asp?linkid=33404

Australia

Policies and Incentives

Australia uses 20 billion litres of petrol and 15 billion litres of diesel annually, that is 35 billion litres of fuel. The Federal Government's support program is aimed at a modest 350 million litres of biofuels (ethanol and biodiesel) production by 2010. This equals about 1% of the total current transport fuel market. Once reached, the target means that by 2010, 3.3 billion litres of the fuel sold in Australia could contain ethanol or biodiesel, provided the fuel companies were willing to blend and distribute it.

The Federal Government has also implemented a AUD$37m grants scheme to kick start new and existing biofuel production. However, until mid-2005, no grant agreements have been signed and no new formal off take agreements are in place. All indications are that unless the Government takes some action to secure the market, the government's commitment to 350 million litres of Biofuel production by 2010 will not be able to be met.

Feedstocks

Ethanol is currently produced from cereal grains and molasses (from sugar cane). It is produced by Manildra Mills in Nowra, NSW, CSR Pty Ltd at Sarina and Rocky Point Mill and Distillery at Woongoolba in Queensland.

Production figures and forecasts

Historic and projected biofuel production (10^6 litres)

	1980	1990	2000	2001	2002	2003	2004	2010
Ethanol					50[a]		125	
Biodiesel								
Total								350

a For fuel use only. Total domestic ethanol production was 135 million litres in 2002.

Data sources

- The Howard government. Biofuels for Cleaner Transport. 2001.
- Ethanol, fuelling the future - a proposal for a mandatory renewable fuel target (MRFT). The Prime Minister's biofuels taskforce, June 2005. http://www.ronboswell.com/sub2005.01.html
- Current Issues Brief no. 12 2002-03, Fuel Ethanol-Background and Policy Issues, Mike Roarty, Richard Webb, 10 February 2003. http://www.aph.gov.au/library/pubs/CIB/2002-03/03Cib12.htm#Table
- Homegrown for the homeland. Renewable Fuels Association. Ethanol Industry Outlook 2005, February 2005.

Japan

Policies and Incentives

To date the Japanese government has allowed blending gasoline up to 3% with ethanol. Japan may need up to 1.8 billion litres of fuel ethanol a year if it made this optional 3 percent ethanol content in national fuel supplies mandatory. A blending ratio of 10 percent would boost demand to around 6 billion litres per year.

Japan is conducting advanced research on the addition of ethanol to the fuel used by its motor vehicle fleet and is interested in the alcohol produced in Brazil. It imported 149 million litres from Brazil in 2004. Furthermore, the world's biggest sugar-ethanol cooperative, Brazil's Copersucar, has signed a deal to sell 15 million litres of ethanol to Japan's independent fuel distributor, Kotobuky Nenryo Co.

However, in July 2005, it was reported that the introduction of environmentally friendly biofuel for cars has been delayed in Japan despite a decade-long government effort aimed at cutting greenhouse gas emissions. In Japan, a country that consumes about 1.04 million barrels of gasoline a day, the Environment Ministry had aimed to introduce auto fuel containing 3 percent bioethanol on the retail market from April 2005, the start of the fiscal year. However, scarce availability of domestically produced ethanol made from grains and the concern of heavy dependence on imports are blocking gasoline blended with bioethanol from being made increasingly available to the market. As well as requiring huge investments in facilities to make bioethanol-blended gasoline, the government policy would also create risks for the oil industry through additional import costs and possible added volatility in freight rates.. Despite these concerns, the government is currently planning to replace all retail gasoline with ethanol-blended fuel by 2012, eventually helping to cut carbon dioxide emissions by as much as 2 million tonnes a year.

Feedstocks, production figures and forecasts

No data was found on any biofuel production in Japan, or targets for biofuel consumption. However, in the case that Japan would introduce a E10-blend (10% ethanol mix with gaseoline), this would correspond approximately to a demand of 6 billion litres of ethanol per year.

Data sources:

- FACTBOX - Biofuels Take Off in Some Countries. Reuters news service, 9 June 2005. http://www.planetark.com/dailynewsstory.cfm/newsid/31182/story.htm
- http://www.brazzilmag.com/content/view/203/41/
- Hamilton, C. Biofuels made easy. Mg engineering. Lurgi Life Science, March 2004. http://www.aie.org.au/melb/material/hamilton/Biofuels.pdf
- http://today.reuters.com/News/CrisesArticle.aspx?storyId=T272289

China

Policies and Incentives

China, the world's second-largest energy consumer, is also the third-largest ethanol producer in the world, with annual production of around 3.6 billion litres (2.8 billion tons). However, most of that is not for fuel use. The government subsidizes production at four plants with a combined annual capacity of 1.02 million tonnes and sells small amounts of ethanol-blended gasoline in its Northeast maize belt and in wheat-rich Henan province. China has selected several provinces to use trial blends of 10 percent ethanol to meet growing demand for gasoline. In November 2003, China 's first fuel ethanol production line (and largest ethanol production line) with an annual productivity of 760 million litres (and a possible final capacity of about 1000 million litres) was completed and put into production in China 's northeast Jilin province. Rosillo-Calle claims that China aims to increase ethanol production to 6 billion litres per year, though this target was not found elsewhere in the literature.

Regarding biodiesel production, in one literature source (Mixon et al.) it was claimed that four biodiesel factories existed, producing about 50 million litres of bio-diesel in 2003, though this number has not been confirmed by any other source. In November 2004, D1 Oils announced it is to enter into a joint venture with Chinese Chuan Technology Company Ltd, Chengdu. D1 Oils will own 51% of the new joint venture, which will develop jatropha-based biodiesel for the Chinese market. Under the agreement, D1 Oils China will have the rights to D1 Oils' proprietary planting, growing and refining technology, and the ability to distribute blended biofuel in China under the D1 Oils brand. D1 Oils China will include a refinery, currently under construction, with a capacity of 20,000 tonnes (approximately 6.1 million gallons) of biodiesel per year. The joint venture will have rights over an estimated 200,000 tonnes of existing jatropha nuts and two million hectares of land dedicated to future jatropha growth. The refinery is expected to come into operation next year

No further policy targets were found for future stimulation and production of biofuels.

Feedstocks

Feedstocks for ethanol production are maize, wheat, sweet sorghum, cassava and sugar cane. Potential feedstocks for biodiesel are oilseed crops (soybean, rapeseed), native high oil-content tree (Huang Lian Mu), acid oil food, waste cooking oil and animal fat / tallow. Mixon et al. claim that in total these feedstocks may potentially cover the production of 3400 million litres biodiesel (900 million gallons).

Production figures and forecasts

Historic and projected biofuel production (10^6 litres)

	1980	1990	2000	2001	2002	2003	2004
Ethanol			2970[a]	3090[a]			3650[a]
Biodiesel						50	
Total							

a Total domestic ethanol production. Fraction for fuel use unknown.

Data sources

- FACTBOX - Biofuels Take Off in Some Countries. Reuters news service, 9 June 2005. http://www.planetark.com/dailynewsstory.cfm/newsid/31182/story.htm
- Mixon,J., Kraucunas, I., Dack, J., Feng, J. The Case for Biodiesel. http://depts.washington.edu/poeweb/gradprograms/envmgt/2003symposium/biodiesel_presentation.pdf
- Berg, C. World fuel ethanol analysis and outlook, April 2004,
- Rosillo-Calle, F. a short history of ethanol fuel, DEST/EPMG, Imperial College London.
- D1 Biodiesel JV in China. http://www.greencarcongress.com/china/index.html

India

Policies and Incentives

India, the world's biggest sugar consumer and a major importer in recent years, produces about 1.5 billion litres of ethanol, although only around a quarter of that is suitable for use as fuel. The rest is used for beverages or export. The Indian sugar industry emphasized that producing fuel ethanol would absorb the sugar surplus and help the country's distillery sector, which is presently burdened with huge overcapacity, and also allow value adding to by-products, particularly molasses. India's Minister for Petroleum and Natural Gas gave his approval in December 2001 to a proposal to launch pilot projects to test the feasibility of blending ethanol with gasoline. Mid-March 2002 the government decided to allow the sale of E-5 (5% ethanol mix with petrol) across the country. On 13 September, 2002, India's government mandated that nine states and four federally ruled areas will have to sell E-5 by law from 1 January 2003. Oil companies had needed 363 million litres of ethanol in the 2003/04 year to satisfy the requirement of the 5% mandate, but only 196 million litres had been available due to declining sugarcane output with drought. Further, India planned to make this mandatory throughout the country later, but back-pedalled on the plan due to poor output and high costs. In response of these plans, India's sugar producers reportedly planned to build 20 ethanol plants before the end of the year in addition to 10 plants already constructed. Most of the plants were being constructed in Uttar Pradesh, Maharashtra and Tamil Nadu, the key sugar producing states and will chiefly use cane sugar molasses as a feedstock. At the end of 2004, it was reported that an estimated 800 million litres per year capacity has been installed and 80% of petrol consumed in the country is being blended with bio-ethanol (Winrock, 2004).

The enormous potential of bio-diesel is, however, yet to be realized in India. Concrete plans are being formulated to utilize wastelands for tree-borne oilseed (TBO) plantations such as of Jatropha curcas and Pongamia pinnata. The have been several trials with trains and government buses running on bio-diesel. Many state governments, universities and R&D institutes are actively working for the promotion of biofuels in India. Among others, CSIR and Daimler Chrysler have jointly sponsored a Jatropha curcas plantation project and undertaken a successful 5,000 km trial run of a Mercedes car using bio-diesel as a fuel.

Feedstocks

Ethanol is produced from sugar cane molasses. Biodiesel is envisioned to be produced from oil crops such as Jatropha and Pongamia.

Production figures and forecasts

Historic and projected biofuel production (10^6 litres)

	1980	1990	2000	2001	2002	2003	2004
Ethanol			1650[a]	1700[a]	1775[a]	1870[a]	1970[a]/196[b]
Biodiesel							
Total							

a total production of ethanol
b Ethanol for biofuel use

Data sources

- FACTBOX - Biofuels Take Off in Some Countries. Reuters news service, 9 June 2005. http://www.planetark.com/dailynewsstory.cfm/newsid/31182/story.htm
- Berg, C. World fuel ethanol analysis and outlook, April 2004, www.distill.com/World-Fuel-Ethanol-A&O-2004.html
- Rosillo-Calle, F. a short history of ethanol fuel, DEST/EPMG, Imperial College London
- Biofuels in India. Winrock international, September 2004, www.xnri.com/news/2004/pdf/ 0917_Brochure_Biofuel_Conference_2004.pdf
- http://www.ethanolindia.net/sugarind.html

Thailand

Policies and Incentives

Thailand has mandated a 10 percent ethanol mix starting in 2007 (i.e. an E10 blend) , which would boost production from 74 million gallons (221 million tons) in 2004 to 396 million gallons (1182 million tons). 18 new ethanol plants are being developed, and producers will enjoy several tax breaks. The Industry Ministry said in September that Thailand's ethanol production capacity would rise 33 times to 1.5 billion litres a year in 2006 when all 24 ethanol plants are up and running. But other officials have said they were targeting output of just 1 billion litres a year by 2010. The government calculates an E10 blend would be USD$0.01-0.02 cheaper per gallon than conventional gasoline.

Thailand's interest in establishing a large-scale bio-ethanol industry using feedstock such as cassava, sugar cane and rice, was manifested in September 2000, and reflects the nation's rising import bill for oil (the country is 90% reliant on imports) and high-energy prices which were adversely impacting the economy at that time. At the same time low prices for commodities such as sugar and cassava were a matter of concern for the government.

The Thai government moved swiftly in supporting the ethanol opportunity with the oil import bill given as the main reason for pursuing the bio-ethanol programme. More recently, the role of ethanol in replacing MTBE has been offered as another justification for the ethanol program. The National Ethanol Development Committee has estimated that if 10% ethanol were blended with petrol or diesel, to replace MTBE, about 2 mln litres of ethanol would be required on a daily basis.

In order to encourage manufacturers to develop and market gasohol the Finance Ministry will waive the excise tax on gasohol as well as contributions to the State Oil Fund and Energy Conservation Fund. Furthermore to encourage investment in new capacity, promotion privileges are to be given by the Board of Investment. Tax privileges will be granted including duty exemptions on machinery imports and an eight-year corporate tax holiday. The Industry Ministry calculates the gasoline/ethanol blend would be 0.7-1.0 Baht/litre (US$0.01-0.02/litre) cheaper than conventional gasoline.

Late in 2001, eight private companies were granted licences by Thailand's Ministry of Industry to build ethanol production plants. The plants had a capacity to produce 1.5 mln litres of ethanol a day, or an annual capacity of around 0.495 bln litres. Four plants would use molasses as a feedstock and the others would use cavassa (tapioca). Five of the plants were expected to start production late in 2002 with a combined annual output of 114 mln litres. However, progress in constructing the plants has faltered. By mid 2003, only one distillery had advanced to construction stage and many had not submitted feasibility plans.

According to the latest news in July 2005, ethanol-mixed gasoline now accounts for a quarter of premium gasoline consumption in Thailand, two years after its commercial launch. The biofuel, also known as gasohol, was now consuming 1.4 million litres a day, a five-fold increase from January. According to the Energy Ministry, Thailand is on target to reach 4 million litres a day consumption by the end of this year.

Demand for gasoline, which lost government price subsidies in October 2004, declined 7 percent to 127,000 barrels per day (bpd) in the first four months of 2005, from a year earlier. Diesel, which continued to receive subsidies, jumped 9.5 percent in the same period to 366,500 bpd. The government wants to reduce a ballooning imported oil bill by mixing 9 parts gasoline and 1 part ethanol -- made from sugarcane or cassava -- to produce gasohol. It sells for 1.50 baht/litre, 6 percent cheaper than 95-octane gasoline. The price difference is the result of a tax waiver on gasohol.

Thailand, which imports 90 percent of its crude oil, spent 1.0 trillion baht ($25 billion) on all fuels last year, the equivalent of 15 percent of its gross domestic product, and needed to cut back on the rising bill. High oil prices have sharply inflated Thailand's import bills, giving the country a hefty trade deficit in each of the past 5 months of 2005. The government plans to end the use of oil-based MTBE in sales of 95-octane gasoline and 91-octaine grade by January 2007 and 2008, respectively, in favour of gasohol.

Data sources

- Earth Policy institute, Ethanol Production Examples Worldwide, http://earth-policy.org/Updates/2005/Update49_data.htm
- FACTBOX - Biofuels Take Off in Some Countries. Reuters news service, 9 June 2005. http://www.planetark.com/dailynewsstory.cfm/newsid/31182/story.htm
- Berg, C. World fuel ethanol analysis and outlook, April 2004, www.distill.com/World-Fuel-Ethanol-A&O-2004.html
- http://www.planetark.com/dailynewsstory.cfm?newsid=31597&newsdate=11-Jul-2005

South Africa

Policies and Incentives

The South African Sugar Technologists' Association (Sasta) reports that the South African sugar industry is investigating the generation of renewable energy in the form of ethanol and electricity from sugar cane, due to the fact that it is fast becoming cost-competitive as oil prices rise. These investigations may lead to the construction of ethanol plants where sugar cane products would be used to produce ethanol. It was not economically viable to produce ethanol from sugar cane given the low petrol price and high ethanol production costs in the past. However, new technology has enabled the production of ethanol at almost the same price as petrol, even though its cost-competitiveness is still dependent on fluctuating petrol and sugar prices and the exchange rate. Sasta has reached the point at which serious discussions between government and other interested and affected stakeholders should take place to prepare the way for enabling legislation. This includes the relationship between sugarcane growers and millers. It is expected that it will take between two and three years to enact this enabling legislation; hence, the commissioning of physical production plants is not expected within the next five years (i.e. before 2009). Significant preparation is required, including detailed environmental-impact assessments. Hopes are that the enabling legislation will provide for the blending of relatively small percentages of ethanol with petrol, probably in a specific geographic region initially.

In June 2005, the sugar industry and the government have been reviewing the Sugar Act and formulating a charter to fast-track ethanol production. According to Tim Murray, the chairman of South African Canegrowers, production of ethanol would enhance the viability of the industry, but government support was needed in the form of a rebate of duties on fuel ethanol and access to the fuel market.

In addition to ethanol from sugar cane, maize prices have dropped from over 1,000 rand (USD$171.6) a tonne in November 2004 to under 600 rand in March 2005. Under these circumstances, there is growing enthusiasm to produce ethanol. Grains SA has plans to build 8 ethanol plants, consuming 370,000 tonnes of maize a year, totalling 2.96 million tones. Their combined annual capacity would be 1.2 billion litres of ethanol. The first plant is due to come online in autumn of 2006. The plants, likely to be built in rural maize-producing areas in the Free State, North West and Mpumalanga provinces that suffer high unemployment, would each cost around 350 million rand.

For comparison, South Africa's state gas company is a leading producer of synthetic ethanol from coal. Total ethanol production in 2004 was 416 million litres.

Feedstocks

Maize and sugar cane are expected to be the feedstocks for ethanol production.

Data sources

- http://www.planetark.com/dailynewsstory.cfm/newsid/29938/story.htm
- http://www.busrep.co.za/index.php?fArticleId=2524264
- http://www.busrep.co.za/index.php?fArticleId=2564966

Other Asian and African countries

For these countries, only brief information was found, mainly in press releases, short communiqués etc.

Malaysia

Malaysia, the world's top producer and exporter of palm oil, is pushing to create a mandatory blending of a certain amount of the oil with retail diesel. A cabinet meeting is due to consider the proposal next week. Leading oil palm planters IOI Corp and Kuok Oil & Grains are separately building two refineries in Rotterdam to process more than 1 million tonnes of palm oil a year. Industry experts say the plants will deliver much-needed supply to Europe's biodiesel plants in future.

Indonesia

Indonesia, the world's second-biggest palm oil producer, is exploring the biodiesel market as world palm oil demand stagnates. It plans to double the palm oil area to 10 million hectares (25 million acres) over the next 30 years.

The Philippines

The government of the Philippines is to introduce a 1-2% blend of coconut biodiesel for its own transport industry, so this kind of production work will ultimately benefit both the Philippines and Japan. The country decided last July to use a 1 percent blend of methyl ester made from coconuts in diesel for public transport. The government has pressed bagasse, or sugar cane pulp, into service to relieve the oil-poor archipelago's chronic power shortage. About 267,000 tonnes of raw sugar are slated to fire power plants by 2007. Pending legislation would require ethanol use from 2007.

Saudi Arabia

U.K. biodiesel developer D1 Oils has started a joint-venture project to produce biofuel in Saudi Arabia for export to Europe. Saudi company Jazeera for Modern Technology will provide land to grow jatropha, a non-edible plant producing oil for blending with diesel, while D1 will build a processing plant in Saudi Arabia to come on stream in the second half of 2006. The plant will be able to process 8 million litres a year.

Zimbabwe

Most gasoline sold in Zimbabwe for the past 20 years has contained 12-15 percent ethanol. Production capacity has exceeded 38 million litres since 1983, though actual production stood at only 23 million litres in 2004.

Other Latin American countries – ethanol perspectives[3]

Peru and other Latin America

In 2002 **Peru** announced the "Mega-Project," a plan to build up to 20 distilleries and an ethanol pipeline from the interior to the port of Bajovar and to become a leading ethanol exporter. Under the so-called Mega-project the country plans to construct a pipeline from the central jungle in the north of Peru to the port of Bajovar. Under the project up to 20 distilleries will be built which all plan to use sugar cane juice as a raw material. The overall investment costs are estimated at around $200 mln. Peru is planning that by December 2004 it will begin exporting the first lots of ethanol to California. Under the first stage of the project, some 100 mln litres will be exported by 2005, rising to 1.2 bln litres by 2010. In order to sustain the project, the country plans to introduce up to 240,000 ha of sugar cane in jungle areas, now home to the production of much of Peru's coca leaf. This is used to make cocaine of which Peru is the world's second biggest producer. The government hopes that coca farmers will see that sugar cane growing is a much more profitable enterprise.

In September 2001, the **Colombian** government approved a law that will make mandatory from 2006 the use of 10% ethanol in fuel in cities with populations larger than 500,000 inhabitants. According to the Ministry of Agriculture, this program will require the cultivation of an additional 150,000 ha of sugar cane. This compares with the present area under cane for sugar production of around 200,000 ha. Another 230,000 ha under cane are used for the production of non-centrifugal sugar, in Colombia's case panela. In order to supply the domestic market, nine new ethanol plants have to be built from scratch in order to achieve the required production capacity of around 1 bln litres a year. To attract sufficient investment, the country will completely exempt ethanol from the tax on gasoline, which would result in a significant price advantage of the green fuel. Whether or not this investment drive in Colombia will result in any surplus capacity is unknown at this time.

The Association of **Central American Countries** is also looking at the possibility to expand fuel alcohol production. Total output by 2010 is expected to reach around 500 mln litres, which would allow for a 10% ethanol blend in gasoline. However, the association is also looking at diversifying its export markets. At the moment, Costa Rica, Jamaica and El Salvador are exporting fuel ethanol to the United States under the Caribbean Basin Economic Recovery Act. Under this programme, the countries mentioned may import raw alcohol and re-export it duty-free to the United States.

[3] The following section has been taken over from the World fuel ethanol analysis and outlook (Berg, 2004).

2.4 Biofuels policy summary for selected countries

Summary of most important policies and instruments listed in detail in the previous sections (not exhaustive)

France	The biofuel production programme is a financial scheme, operated at the national level, to develop investments for biofuel production. Biofuels benefit from advantageous fiscal measures. In France, biofuels receive exemption from excise tax on petroleum products at the rate of EUR 0.35/litre of biodiesel and EUR 0.37/litre of ethanol in 2003. It also has production quota for ethanol and biodiesel of 700.000 tons biodiesel and 250,000 tons ethanol in 2008-2010.
Germany	The Mineral Oil Duty Act was amended on 1 January 2004 to allow for full exemption from duty of biofuels and heating oils produced from biomass until 2009. This means that not only biogenic fuels in pure form, as hitherto, are exempt, but also fractions of biofuels and heating oils which are produced from biomass and blended with fossil fuels and heating oils.
Italy	Annual production approval levels
Poland	In 2004 the Polish Constitutional Court did not ratify the Biofuels Law that was voted previously in November 2003. This law provides for a tax exemption for the production of ethanol mixed with petrol, the final percentages and the amount of the exemption are to be determined on a yearly basis after approval of the annual budget. The Biofuels Law is presently (June 2005) still in revision phase
Spain	Full tax exemption for ethanol and biodiesel
Sweden	CO2-neutral fuels are exempt from both CO2 tax and energy tax with effect from 2004 as part of a five-year programme
The Nether-lands	The Dutch government is expected to take a decision in September 2005, whether biofuels will be granted a tax exemption from 1 January 2006 onwards.
The UK	A 20 pence per litre duty reduction incentive on biodiesel has been in place since July 2002, and a similar duty incentive for bioethanol is introduced since January 2005.
European Union	EC Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport requires a minimum of 2% biofuels being incorporated by the end of the year 2005 and 5.75% by the year 2010 .
USA	Excise tax exemptions for alcohol fuels were initially established by the Energy Tax Act of 1978 with full exemption for 10% blended gasoline (gasohol) from the then USD4¢-per-gallon federal gasoline excise tax, an effective subsidy of USD40¢ per gallon of ethanol. A 1980 law added an alternative blenders credit of USD40¢ per gallon applicable to other blend levels including E-85. The most recent (2004) adjustment extends the exemption through 2010 at a level of USD51¢ per gallon of ethanol. In June 2005, the U.S. Senate passed the comprehensive energy bill, that includes a renewable fuels standard (RFS) of 8 billion gallons by 2012. The House version contains a 5 billion gallon RFS. The legislation will now go to committee, to work on the differences between the House and Senate versions.
Canada	Current Canadian strategy will direct subsidies primarily to the construction of production plants. Next to subsidizing production facilities, a number of provinces have set mandatory fuel blending targets. Ethanol blending will be mandatory in Ontario, Manitoba and Saskatchewan. In Ontario, a 5% ethanol of all gas sold will be mandatory by 2007.
Brazil	In Brazil, the world's largest ethanol producer, the government sets by decree annual blending ratios of ethanol in gasoline between 20-25% mix It currently requires that the cane-based additive make up 25 percent of gasoline mixes. Furthermore, the government has enacted a law for biodiesel obligation: 2% by the end of 2007 (800 M l/y), 5% by 2013 (2 B l/y), and goal of 20% by 2020 (12 B l/y).
Australia	The Federal Government's support program is aimed at a modest 350 million litres of biofuels (ethanol and biodiesel) production by 2010. This equals about 1% of the total current fuel market. Once reached, the target means that by 2010, 3.3 billion litres of the fuel sold in Australia could contain ethanol or biodiesel, if the fuel companies were willing to blend and distribute it. The Federal Government has also implemented a $37m grants scheme to kick-start new and existing biofuel production. However, until mid-2005, no grant agreements have been signed and no new formal off take agreements are in place. All indications are that unless the Government takes some action to secure the market, the government's commitment to 350 million litres of Biofuel production by 2010 will not be able to be met.
Japan	In July 2005, it was reported that the introduction of environmentally friendly biofuel for cars has been delayed in Japan despite its role as the Kyoto protocol leader. The Environment Ministry in

	Japan had aimed to introduce auto fuel containing 3 percent bioethanol on the retail market at the start of the fiscal year from April 2005. The government also wants all retail gasoline to be replaced with ethanol-blended auto fuel by 2012, eventually helping to cut carbon dioxide emissions by as much as 2 million tonnes a year.
China	The government subsidizes production at four plants with a combined annual capacity of 1.02 million tonnes and sells small amounts of ethanol-blended gasoline in its Northeast maize belt and in wheat-rich Henan province. China has selected several provinces to use trial blends of 10 percent ethanol to meet growing demand for gasoline. In November 2003, China 's first fuel ethanol production line (and largest ethanol production line) with an annual productivity of 760 million litre (and a possible final capacity of about 1000 million litre) was completed and put into production. Rosillo-Calle claims that China aims to increase ethanol production to 6 billion litre per year, though this target was not found elsewhere in the literature
India	India's Minister for Petroleum and Natural Gas gave his approval in December 2001 to a proposal to launch pilot projects to test the feasibility of blending ethanol with gasoline. Mid-March 2002 the government decided to allow the sale of E-5 across the country. On 13 September, 2002, India's government mandated that nine states and four federally ruled areas will have to sell E-5 by law from 1 January 2003.
Thailand	Thailand, a ranking world sugar exporter after Brazil and the EU, plans to replace regular gasoline with a mix that includes 10 percent ethanol in 2007. The Industry Ministry said in September 2004? that Thailand's ethanol production capacity would rise 33 times to 1.5 billion litres a year in 2006 when all 24 ethanol plants that are being brought on line are up and running. But other government sources have indicated that targeted output is likely to be closer to 1 billion litres a year by 2010.
South Africa	No concrete policy or production targets have yet been introduced.
Colombia	In September 2001, the Colombian government approved a law which will make mandatory from 2006 the use of 10% ethanol mix in fuel in cities with populations larger than 500,000 inhabitants

2.5 Biofuels production outlooks

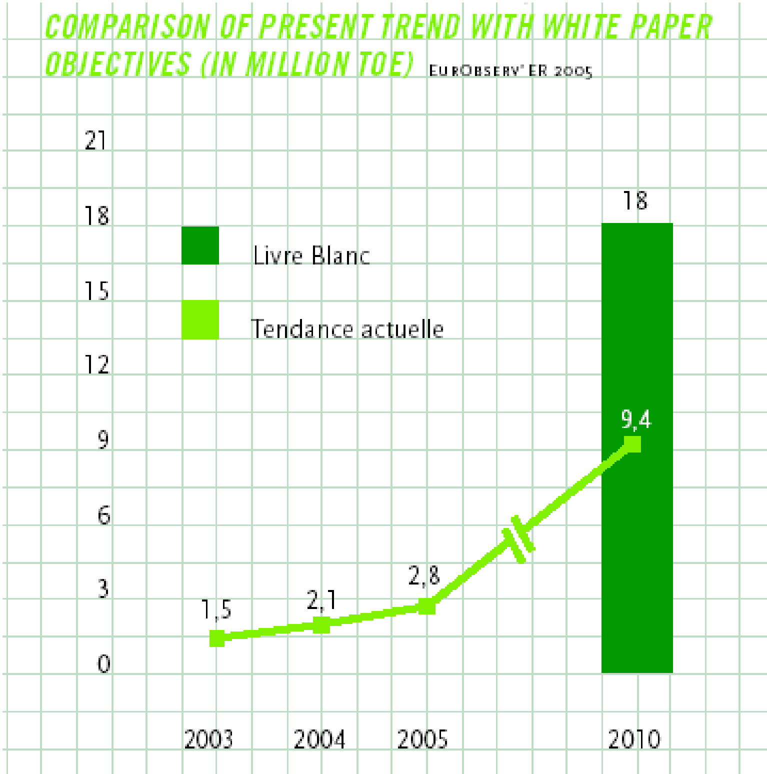
EU-25 biofuels production outlook: 18 Million toe targeted in 2010[4]

The biofuels market is not like any other market because its commercial development is intimately linked to its total or partial exemption from the excise tax on petroleum products. The costs linked to the tax exemption of biofuels has led certain member states to define overall financial packages corresponding only to production quotas authorised to benefit from tax exemption. Biofuels are thus found in certain cases in a closed market or in one where competition takes place between the different sectors in a context of winners and losers. This is especially the case in Italy, which has decided to limit its biodiesel approvals so as to favour bioethanol. Today, this limit is still a purely political one because European law allows the member states to benefit, after authorisation, from a total exemption of taxes on biofuel consumption without any production restrictions. This is the direction that Germany and Spain have decided to follow in choosing a total tax exemption and absence of quantity approvals, thus making it possible for the two sectors to develop very rapidly.

The political will of a number of other member countries to respect the EC biofuels directive is not well defined as yet. Moreover, last March 16th, the European Commission gave notice to nine member states which had not yet communicated their objectives concerning 2005 market share, as provided for by European legislation in the matter. These countries are Belgium, Italy, Luxembourg, Poland, Slovenia, Estonia and Cyprus, as well as France and Portugal whose announced objectives are not yet definitive.

The Biofuel Plan should however make it possible for France to reach the EC directive's minimum targets. If the current trend in the EU is compared with European Commission objectives, it appears that the target of reaching a 5.75% biofuel share in the transportation sector by the year 2010 will not be achieved. The Joint Research Centre of the European Commission estimates the biofuel consumption necessary to meet the directive at 5.9 million toe in 2005 and 18.2 million toe in 2010, i.e. very near to the European Commission's White Paper objectives for 2010 (18 Mtoe). Taking current development into consideration, biofuel production is estimated at 2.8 million toe in 2005 and 9.4 million toe in 2010 (graph 3). Nevertheless, the situation can evolve very rapidly. The implementation of biofuel sectors in other member states like the United Kingdom, Portugal, Belgium, Finland, Czech Republic, etc., and the suppression of quantity approval limits in countries like France and Italy, can make it possible for Europe to reach its objectives. The potential is there and exists, the biofuel industry is ready and able, and the rest is a question of political will and economics (budgetary cost of tax concessions).

[4] The following texts and graphs in this section have been taken over from the Biofuels barometer, June 2005.



Graph 3 Comparison of present trend with white paper objective. Source: (EurObserv'ER, 2005).

Global ethanol production outlook[5]

World ethanol trade flows now

How will all this translate into world ethanol trade flows? It may be useful to take a look at the last 15 years of fuel ethanol trade in order to be able to assess the fundamental change, which might be expected in the future. Fuel ethanol trade in the 1990s and in the early years of the new millennium was a rather minimalist affair. There was a regular trade flow of wine alcohol from the European Union to the countries of the Caribbean where this product was refined and then shipped on to the United States as motor fuel. The second trade flow, which lasted for a couple of years only in the mid-1990s, consisted of synthetic alcohol and methanol from South Africa to Brazil. Moreover, Brazil imported considerable amounts of maize alcohol from the United States to bolster its domestic supplies. As has been mentioned earlier, in the mid-1990s the Brazilian sugar millers found the economics of sugar production much more profitable than that of ethanol. As a result, they had to import large quantities of alcohol to cover domestic needs. More recently, Brazil has again become a large ethnaol exporter.

World ethanol trade flows in the future

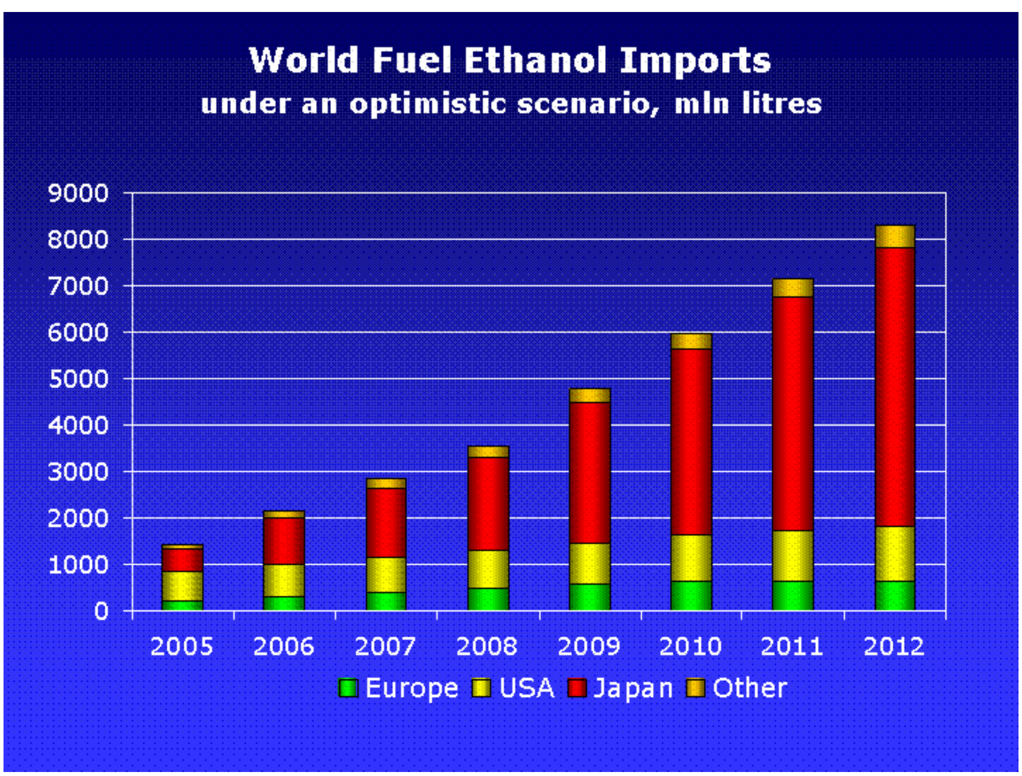
How could the world trade in fuel ethanol look in the future? Let us start with the Americas. Latin America is likely to continue to lead the world in fuel ethanol production. This may be explained with the high yields in sugar cane production and the fact that many of these

[5] Text and graphs have been adopted from the World fuel ethanol analysis and outlook (Berg, 2004).

economies are agriculturally based and the technology of ethanol production continues to improve. Several projects in Latin America such as Peru, Colombia or the Central American states were already mentioned. Large trade flows could be observed from South America to North America in general and California in particular. Another trade flow may be directed at the Asian/Pacific region and here Japan and possibly Korea could take a top position. Moreover, there is the possibility of a developing export flow from South America to the European Union. As has been mentioned earlier, the European Union could develop into a net importing country if the Commission's directives are implemented. Several countries in Latin America enjoy duty-free access to the European market and they would be in a prime position to act as suppliers. A third trade flow in the Americas will consist of raw alcohol from Brazil to the Caribbean and onwards to the United States. This sort of trade is likely to continue as long as Brazil does not enjoy duty free access to the US market.

Southern Africa is another potential supplier to the world market also because of relatively high sugar cane yields and some under-utilized production areas. Several Southern African countries also enjoy duty-free access to the European Union and therefore, some quantities may go there. Another potential export market for distillers in sub-Saharan Africa could be the Far East. In Asia, India, Thailand and Australia may emerge as smaller to medium sized exporters with South Korea and Japan the major destinations for these shipments.

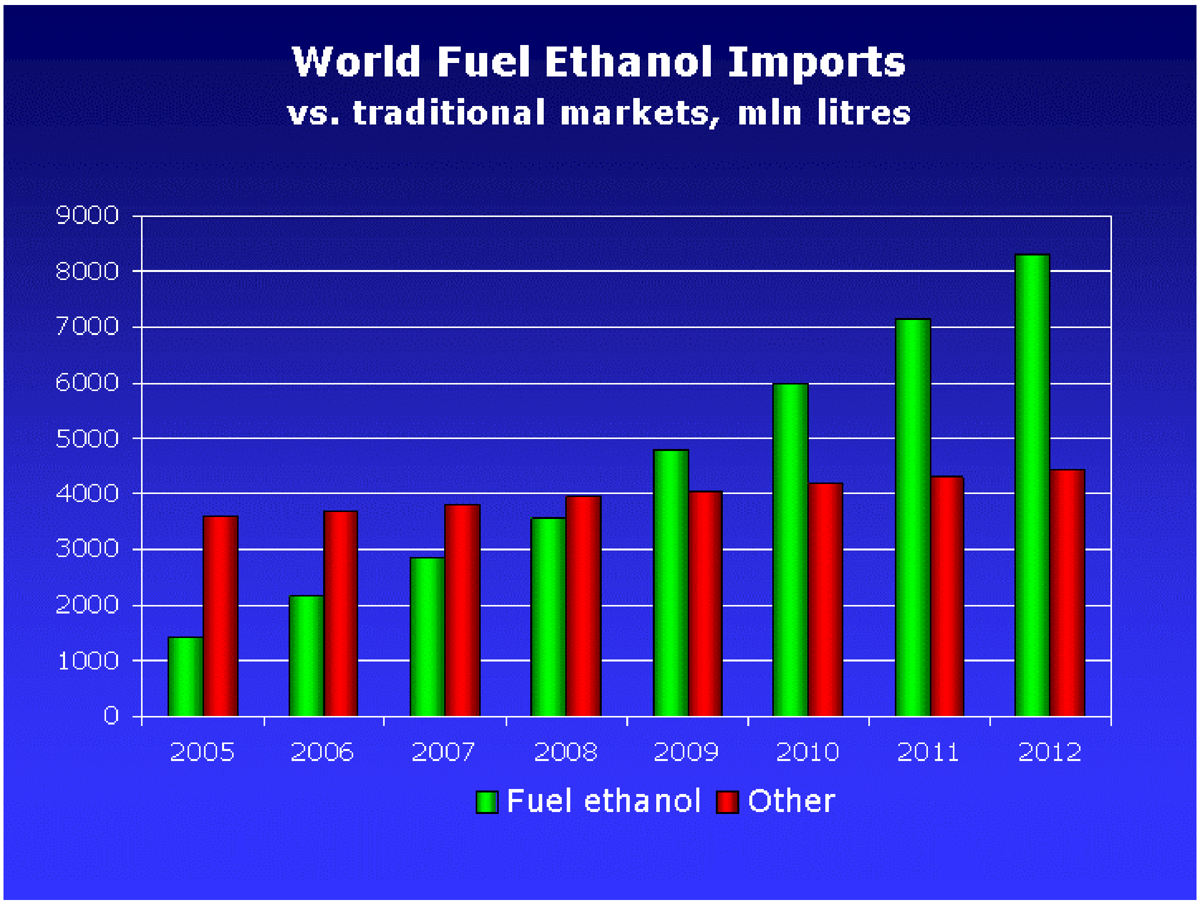
It has to be emphasised that this is a future scenario and it cannot be expected that this structure will emerge before the end of this decade and that additional barriers to trade are not imposed by prospective importing countries. However, if all the ambitious goals that have been formulated in the various biofuel programs around the world are implemented then there is tremendous scope for growth, not only on the domestic market but also on the export markets.



Graph 4. World Fuel Ethanol Imports under an optimistic scenario. Source: (Berg, 2004).

In Graph 4 the growth in fuel ethanol trade under very optimistic assumptions is forecast. A most optimistic assumption seems to be that Japan would indeed source all its ethanol requirements from the world market first in order to produce E-5 and, at the end of the Kyoto period, even E-10 mixes with petrol.

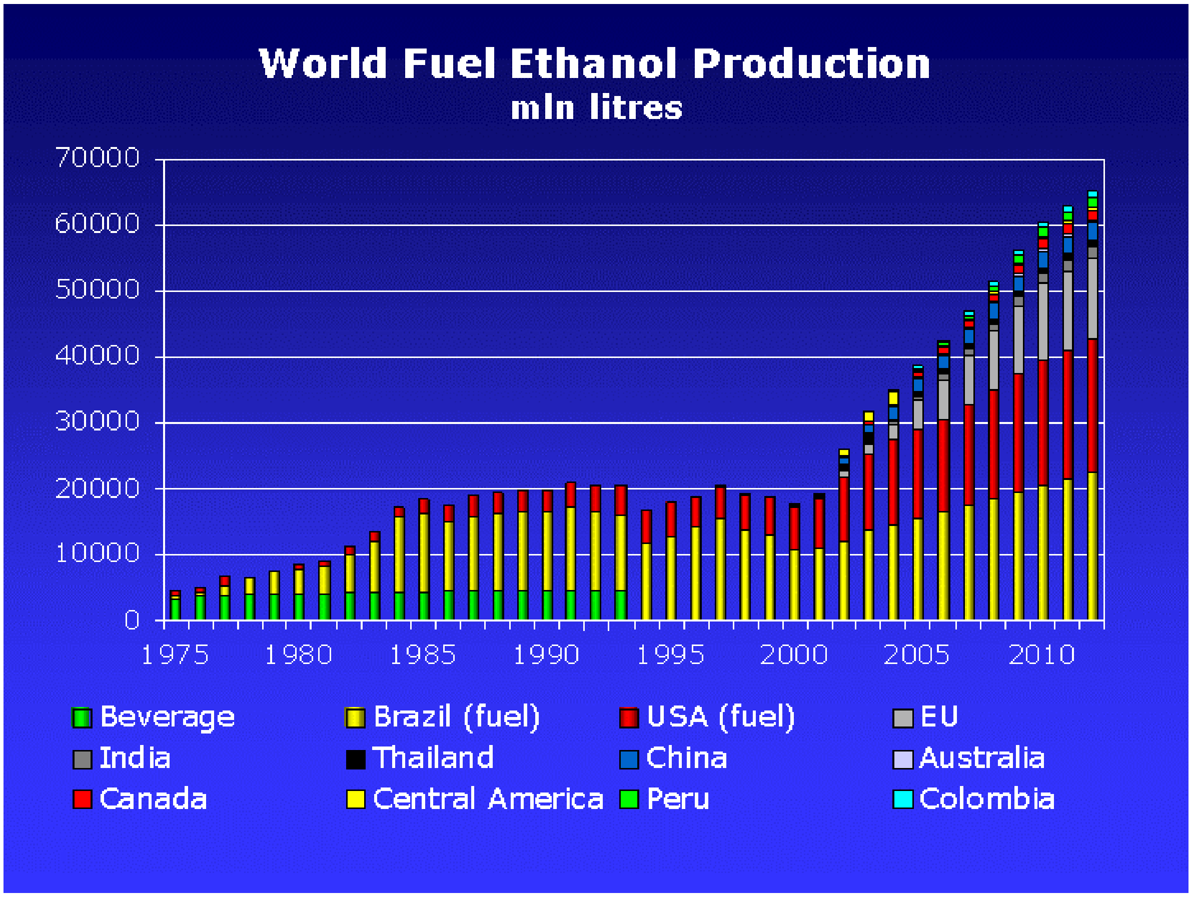
For the US it was assumed that the RFS would go through and that the country would source about 5% of its demand from overseas. The strong growth in requirements in Europe would mean that their nations would have to source at least 5% of their requirements from imports. Other countries that might need fuel ethanol from the world market comprise, among others, China, South Korea and Taiwan.



Graph 5. World Fuel Ethanol Imports vs traditional markets. Source: (Berg, 2004).

In order to put this development into perspective it might be useful to compare it with what would have normally been traded on the world ethanol market assuming an optimistic rate of growth of 3%. It is obvious that with the emergence of fuel ethanol on the market the total would immediately be equivalent to a third of world ethanol trade. By 2009, it would be double the trade volume in industrial and beverage applications.

This is quite a task to achieve even assuming that the complete volume of imports may not be reached. However, as a possibility this forecast provides a benchmark against which strategies in the export countries as well as in the importing nations will have to be matched.



Graph 6 World Fuel Ethanol Production. Source: (Berg, 2004).

Of course, such a strong increase in import requirements would have to be preceded by an increase in output in exporting countries. Indeed there are several projects under way which could facilitate such a development. From Graph 6 it may be gleaned that most of the growth will happen in the United States under the renewable fuels standard. Growth would also be strong in Brazil, mostly because of the promises in the export market and continuing low sugar prices. The EU will be the third largest producer of fuel ethanol by 2005 and the rates of growth would be considerably above those seen in Brazil and the United States.

Conclusions

Fuel ethanol will not go away in the foreseeable future. On the contrary, world production is set to continue to grow vigorously at least up to 2012. Table 4 and 5 show the biofuel targets of countries for which data are available.

Table 4. Ethanol production targets of countries that report those (kt).

(kt)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
EU	191	216	317	425	491						1497		9700	
Of which														
Spain				160	194									
France				82	102									
Sweden				52	52									
Poland				60	36									
Germany				0	20									
EU commission				70	87									
USA	4880	5300	6375	8385	10204		11976				23951		16000	
Canada					138						1107		1200	
Brazil	8306	9073	9888	11580	11992								18000	24442
India													1200	
Thailand													1000	
China													2200	
Canada													1200	
Central America, Peru, Colombia													2400	

Sources: various.

Table 5. Biodiesel production targets of countries that report those (kt).

(kt)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
EU	680	780	1065	1434	1933						9384			
Of which														
Germany				715	1035									
France				357	348									
Italy				273	320									
Denmark				41	70									
Czech republic				70	60									
Austria				32	57									
Slovakia				0	15									
Spain				6	13									
United Kingdom				9	9									
Lithuania				0	5									
Sweden				1.0	1.4									
USA	6.3	22	30	63	0									
Canada				1.9	5.4									
Brazil								720						1800

Sources: various

There are various fuel ethanol projects in the pipeline around the world and, even though their implementation may be delayed in some instances, there is enough momentum in the political arena to push them through. Political support is there and in many instances the industry and the authorities are very close to reaching an agreement over a viable framework of support for fuel ethanol.

World trade is likely to grow as well but the rate of growth will depend on several factors. First of all, sugar and alcohol economics as has been illustrated in the case of Brazil. Unless the strong link between sugar and alcohol production can be severed an additional element of volatility will be present in the equation. The same applies to the maize and maize products market in the United States, even though this relationship is not very obvious at present because of the depressed state of the maize sweeteners market.

Before significant increases in ethanol exports can be expected, new investments will have to be made. It cannot be expected that the sugar and alcohol industries in these countries will be able to make these investments all by themselves. Instead, a new partnership between the producers and the importers will have to be created in order to provide the significant funds, which are required to facilitate this growth.

Moreover, a viable trading system would have to be established. A futures market in particular would be required in order to provide the possibility to hedge against price fluctuations. There cannot be any doubt that the big futures markets in London or New York would be willing to create such a contract as long as it can be assured that there would be sufficient liquidity in the market to make it sustainable.

Finally, the problem of subsidized production and exports and other barriers to ethanol trade would have to be resolved. At the moment, the fact that fuel ethanol is being subsidized almost anywhere in the world provides a powerful justification for high import tariffs in order to neutralize these subsidies. An additional complication is that existing crop support policies in some countries means that some feed stocks available for ethanol production (such as grains, sugar beets) are priced above world market levels. In fact, potential producers in the European Union argue strongly in favour of high import tariffs so that the fledgling industry in the Community can establish itself. However, if this notion forms the basis for future policy making there is every reason to be pessimistic about the prospective development of world trade. Without an effective system of international exchange fuel ethanol supplies are bound to be volatile resulting in fluctuating prices and consumer uncertainty.

Despite these controversies the outlook for fuel ethanol is bright and strong rates of growth in both production and trade can be expected for the next several years.

3. Technical and economical performance of biofuel production systems

3.1 Introduction

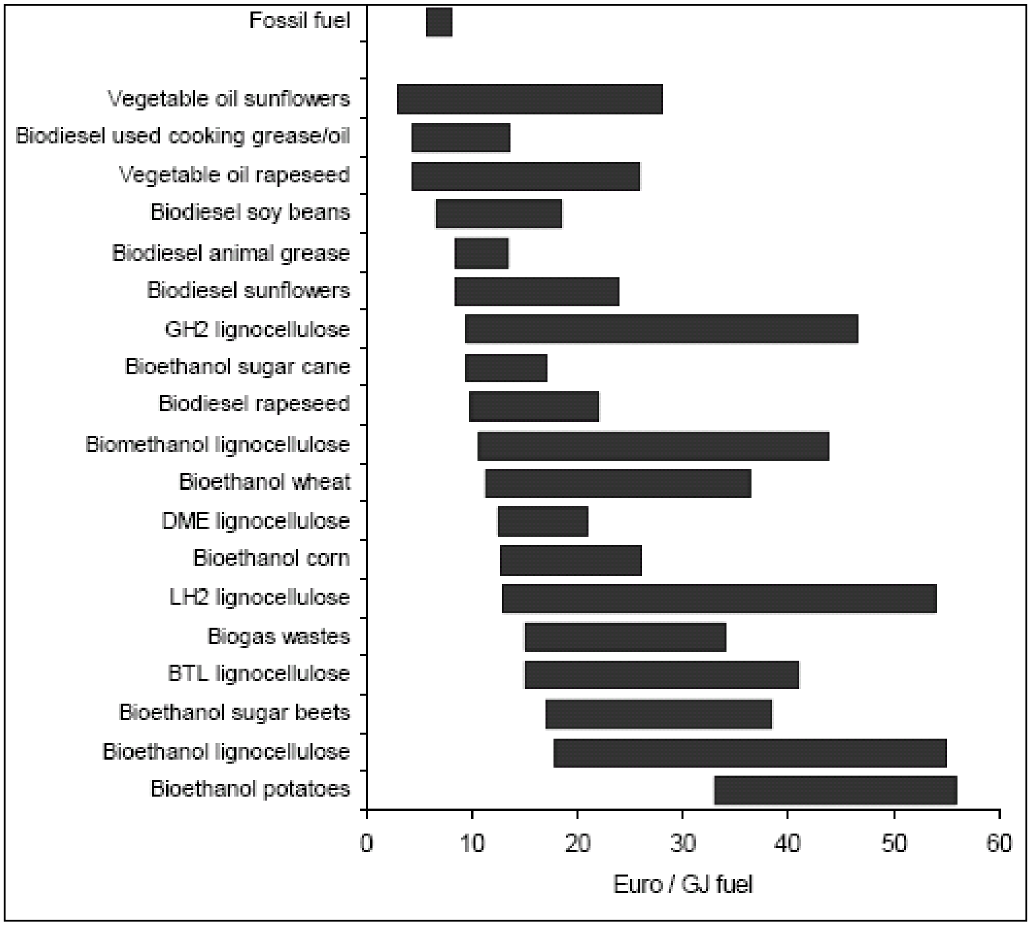
In this chapter, data on the technical and economical performance of various biofuel production systems are presented that allow the calculation of total production costs based on projections of the Aglink and World Sugar model, which are utilised by the OECD Secretariat and Member Countries. The chosen data on technical and economical performance are suggested to calculate the production costs of various biofuels, based on the data provided in this study and based on data on feedstock and energy prices calculated by the Aglink model.

Nine production systems are considered:
- Biodiesel from oilseed rape and other oilcrops
- Ethanol from sugar beet.
- Ethanol from sugar cane.
- Ethanol from wheat
- Ethanol from maize
- Ethanol from woody biomass
- Hydrogen from woody biomass
- FT diesel from woody biomass
- Methanol from woody biomass

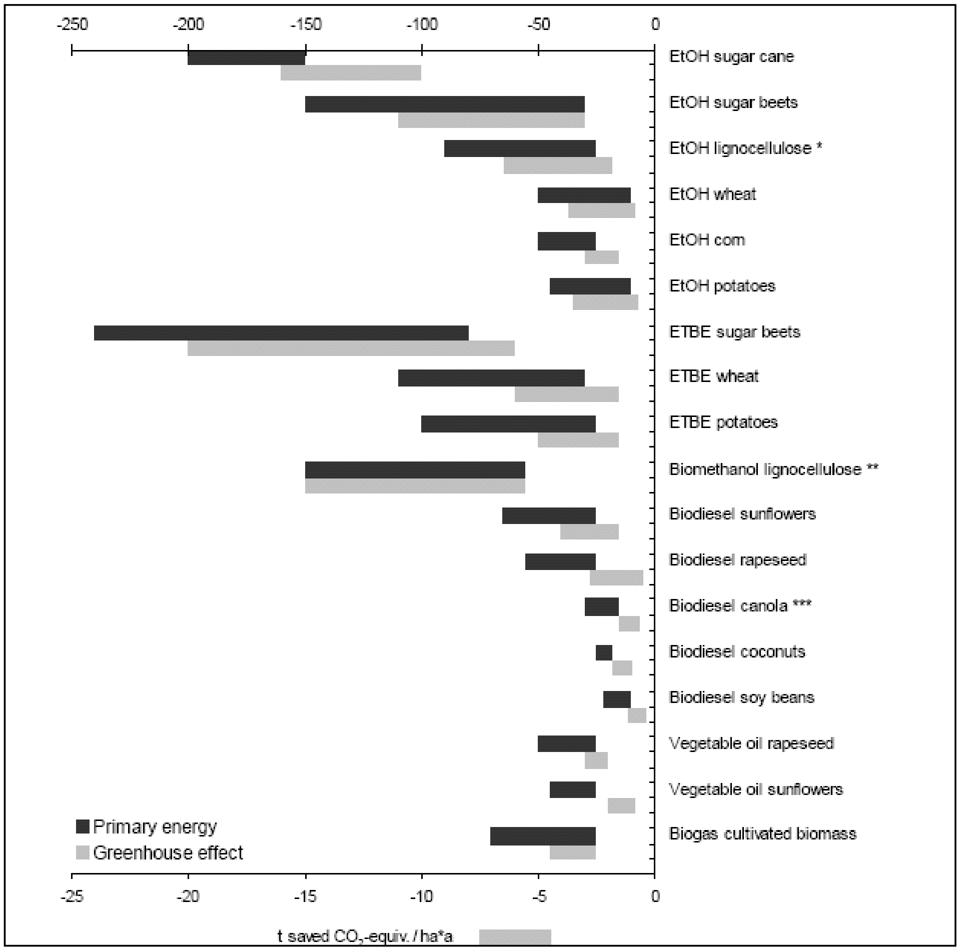
The production of 'advanced biofuels', which use ligno-cellulosic biomass as feedstock is covered in less detail than the production of 'conventional biofuels'.

Many studies are available on the technical and economical performance of biofuel production systems (e.g. (Hamelinck, 2004; IFEU, 2004; VIEWLS, 2005). Values on the performance of various biofuel options vary considerably. The difference in performance resulted from differences in e.g.:
- Specific regional and national conditions.
- Yields of crops.
- Process technology (including scale and capacity).
- Co-products (allocation of co-products and market value of co-products).
- Assumed policies (subsidies and taxes).
- System boundaries.

Consequently, results from various studies are difficult to compare without a detailed analysis of the technology, scope and data basis included. For example, graph 7 and graph 8 show results of a comparison of 63 studies. These results show that the range in performance, in this case production costs, is considerable. Therefore, data on the technical and economical performance in this study are presented in ranges. In addition, recommendations are included on which values are most appropriate to be used in the Aglink and World Sugar models.



Graph 7. Costs per GJ fuel for various biofuel production systems based on an extensive literature survey. Source: (IFEU, 2004).



Graph 8. Saved primary energy per hectare per year for various biofuel production systems. Source: (IFEU, 2004).

The following technical performance data are required for Aglink and World Sugar model applications:

- Conversion efficiency
- Co-products production
- Chemicals use
- Energy input

All in unit mass or energy per unit biofuel. However, most studies report the technical performance in total energy input per energy output, including all energy inputs and outputs. More detailed data are more difficult to find and if data are available. They vary often considerably e.g. due to differences in scope, definition and technology applied. In this study, for each biofuel production system ranges on the technical performance are derived from the literature. For each biofuel production system an advice is given on which values are the most appropriate to be included in the Aglink and World Sugar models.

The following economical performance data are required for Aglink and the World Sugar Model:

- Capital costs.
- Operation and maintenance costs (excluding energy and chemicals use and co-product credits).

All data are required in € per unit biofuel.

Most studies report the economic performance in total costs per unit of biofuel or costs per unit of saved CO_2 equivalent. Data on the share of various cost items (e.g. feedstock, capital, operation and maintenance) are also generally available, but detailed data on e.g. the invested capital and the assumed interest rate are more difficult to find.

3.2 Technical and economical performance data of biofuel systems

Overview

Table 6 and 7 show an overview of the technical and economical performance of various biofuel production systems. In addition, the uncertainty of each value in table 6 and 7 is estimated and valued + (uncertainty is below +/-25%), +/- (uncertainty is +/-50%) or – (uncertainty is above +/-50%). Both the assessment of the uncertainty and the boundaries of the uncertainty categories may not be considered as hard boundaries, because they are the result of (subjective) judgements by the authors of this study and are only included to give the reader a feeling of the order of magnitude of uncertainty.

Table 6. Technical and economic performance of conventional biofuel production systems. data are in crude (fresh) weight unless otherwise indicated. Data on the generation of co products are given in ton per ton of feedstock.

Biofuel system	Parameter	Value	Unit	Uncer-tainty	Remarks
Biodiesel from rapeseed	conversion efficiency	422	l/t	+	
	capital costs	0.06	€/l	-	Present, based on a 52M€ 400 MWth input plant, and assuming an interest rate of 10%, lifetime of 15 years and load factor of 6000 hour.
		0.04	€/l	-	Future, based on a 91 M€ 1000 MWth input plant and assuming an interest rate of 10%, lifetime of 15 years and load factor of 6000 hour.
	O&M costs	0.02	€/l	-	Present, based on 5% annually of total invested capital.
		0.02	€/l	-	Future, based on 5% annually of total invested capital.
	Methanol	0.03	€/l	+/-	
	Electricity	0.25	kWh/l	+/-	
	Glycerol	0.04	€/l	+	Present.
		0.00	€/l	-	Future, assuming a strong increase in biodiesel production.
	Straw	0.4	t/t	+	
	cake/meal	0.4	t/t	+	
Ethanol from sugar beet	conversion efficiency	98	l/t	+	
	capital costs	0.16	€/l	-	Present, based on a 149 M€ 400 MWth input plant and assuming an interest rate of 10%, lifetime of 15 years and load factor of 5000 hour.
		0.08	€/l	-	Future, based on a 190 M€ 1000 MWth input plant and assuming an interest rate of 10%, lifetime of 15 years and load factor of 5000 hour.
	O&M costs	0.06	€/l	-	Present, based on 5% annually of total invested capital.
		0.03	€/l	-	Future, based on 5% annually of total invested capital.
	Electricity	0.42	kWh/l	+/-	Present, based on a 400 MWth input plant.
		0.23	kWh/l	+/-	Future, based on a 1000 MWth input plant.
	Heat	5.6	MJth/l	+	Present, based on a 400 MWth input plant.
		4.2	MJth/l	+	Future, based on a 1000 MWth input plant.
	Pulp	0.06	t/t	+	
Ethanol from sugar cane	conversion efficiency	85	l/t	+	Present, standard plant in Brazil.
		95	l/t	+	Long term, plant with a Biomass Integrated Gasification Combined Cycle (BIG-CC) system.
		177	l/t	+	Long term, plant with a hydrolysis unit.
	capital costs	0.04	€/l	-	Present, 48M€ 400 MWth input plant.
		0.04	€/l	-	197 M€ 1951 MWth input plant with a Biomass Integrated Gasification Combined Cycle (BIG-CC) system
		0.02	€/l	-	153 M€ for a 1951 MWth input plant with a hydrolysis unit.
	O&M costs	0.04	€/l	-	Present.
		0.02	€/l	-	Future , plant with a BIG-CC system
		0.01	€/l	-	Future , plant with a hydrolysis unitn
	electricity (surplus)	0	kWh/l	-	Present.
		0.16	kWh/l	-	Future , plant with a BIG-CC system
		0.09	kWh/l	-	Future , plant with a hydrolysis unit
	Bagasse	0.05	t/t	+	Present.
		0	t/t	+	Future , plant with a BIG-CC system.
		0	t/t	+	Future , plant with a hydrolysis unit.
	Trash	0.05	t/t	+	Present.
		0	t/t	+	Future , BIG-CC system.
		0	t/t	+	Future , hydrolysis unit.
Ethanol from maize	conversion efficiency	396	l/t	+	Present, average of dry and wet milling in US.
		417	l/t	+	Future, average of wet and dry milling in US.
	capital costs	0.06	€/l	-	Average of wet and dry milling.
	O&M costs	0.05	€/l	-	Average of wet and dry milling.

	Electricity	0.24	kWh/l	-	Average of wet and dry milling.
	Heat	13	MJth/l	-	Average of wet and dry milling.
	dried distillers grain with solubles (DDGS)	0.3	tdw/t	+	Dry milling (50% of ethanol comes from dry milling in US).
	corn gluten feed	0.2	tdw/t	+	Wet milling (50% of ethanol comes from dry milling in US)
	corn gluten meal	0.1	tdw/t	+	Wet milling (50% of ethanol comes from dry milling in US)
	maize stover	1	t/t	+	
Ethanol from wheat	conversion efficiency	362	l/t	+	
	capital costs	0.10 0.06	€/l €/l	- -	Based on a plant with a annual 50 Ml capacity in Germany. Based on a plant with a annual 200 Ml capacity in Germany.
	O&M costs, including energy	0.21	€/l	-	Based on data for Germany.
	Electricity	0.28	kWh/l	-	Based on production of maize in US via dry milling.
	Heat	11	MJth/l	-	Based on production of maize in US via dry milling.
	dried distillers grain with solubles (DDGS)	0.4	t/t	+	
	Bran	0.03	t/t	+	
	Straw	0.5	t/t	+	

Table 7. Technical and economic performance of advanced biofuel production systems, present situation (upper figure) and future situation (lower figure). kg of wood is kg dry weight wood. Negative values for electricity indicate a cost, positive values indicate a benefit.

biofueld production system	parameter	value	unit
methanol	conversion efficiency	58 56	kg/kg kg/kg
	electricity	-0.217 0.054	kWh/kg kWh/kg
	capital costs	4.9 4.0	€/GJ €/GJ
	O&M costs	1.4 1.2	€/GJ €/GJ
hydrogen	conversion efficiency	0.06 0.07	kg/kg kg/kg
	electricity	0.913 1.067	kWh/kg kWh/kg
	capital costs	8.65 6.1	€/GJ €/GJ
	O&M costs	2.5 1.7	€/GJ €/GJ
Fischer-Tropsch diesel	conversion efficiency	0.19 0.19	kg/kg kg/kg
	electricity	0.172 0.172	kWh/kg kWh/kg
	capital costs	8.4 6.8	€/GJ €/GJ
	O&M costs	2.7 2.1	€/GJ €/GJ
ethanol	conversion efficiency	0.26 0.35	kg/kg kg/kg
	electricity	0.913 1.067	kWh/kg kWh/kg
	capital costs	10.2 5.6	€/GJ €/GJ
	O&M costs	4.6 1.4	€/GJ €/GJ

In the remainder of this section, for each biofuel production system a mass balance is presented. The sum of mass inputs may not be equal to the sum of mass outputs, because only the input of feedstock and the output of biofuel are included, thereby excluding inputs and outputs in the form of water and additional chemicals.

Production of biodiesel from oilseed rape and other oilcrops

Conversion efficiency

Table 8 shows values for the conversion efficiency of rapeseed to biodiesel found in literature.

Table 8. Conversion efficiency of rapeseed to biodiesel (l biodiesel/t crude(fresh) weight rapeseed).

Source:	l/t
Gover et al., 1996 in (Armstrong et al., 2002)	409
Levy, H. (1993) in (Armstrong et al., 2002)	443
Reinhart (2000 and 2001) in (Armstrong et al., 2002)	420
Scharmer, K. and G. Gosse (1996) in (Armstrong et al., 2002)	432
Richards, I.R. (2000) in (Armstrong et al., 2002)	420
(Elsayed et al., 2003), as in graph above	398
(Ecobilan/PWC, 2002)	446
ITPS study in (Van den Broek et al., 2003)	389
IEA (1996a) in (ECN, 2003)	454
(Wörgetter et al., 1999)	422

The conversion efficiency of rapeseed to oil ranges between 389 l/t to 454 l/t. No information was available about the reasons why the conversion efficiency varies between various studies. Further, no information was available about regional differences in conversion efficiency, partially because biodiesel production is presently concentrated in one region (the EU) and particularly Germany, France and Italy.

We advise to use a conversion efficiency of 422 l/t in the Aglink model, which is the average of the lowest and highest conversion efficiency found in literature. The technology for extracting oil from oilseeds and the conversion from the oil to biodiesel are relatively well-established technologies with little potential for further efficiency increases (DfT, 2003; ECN, 2003).

The conversion efficiency of vegetable oil from other oil crops (rapeseed, soyabean, sunflowerseed) to biodiesel is very similar to the conversion efficiency of rape seed oil (excluding the oil extraction phase) (Tapasvi *et al.*, 2004). No data were found for the conversion of oil derived from other oil bearing crops, such as jatropha, pongana and castor, because there is limited experience with these crops and consequently there is no or little data available. However, it can be expected that the efficiency of the etherification process is the same as for oil from all oil crops.

Co products

Three types of co-products generated during the production of biodiesel: cake/meal, straw and glycerine. Profits from the sales of co-products may account for up to 0.32 €/l biodiesel (IFEU, 2004). In this study, only the value of glycerine is analysed in detail, because for straw and rape cake/meal the credits can be calculated using the protein content of the residues and the value of proteins for animal feed as projected by the Aglink model.

The generation of straw ranges widely, from 2.17 t straw per ton of rapeseed to 5.08 t straw per ton rapeseed, see Table 9.

Table 9. Generation of straw (t straw/t biodiesel).

Source:	t/t
Gover et al., 1996 in (Armstrong et al., 2002)	2.17
Levy, H. (1993) in (Armstrong et al., 2002)	4.38-5.08
Scharmer, K. and G. Gosse (1996) in (Armstrong et al., 2002)	3.34
Richards, I.R. (2000) in (Armstrong et al., 2002)	2.65

We advise to use a value of 3 t/t (2.6 t/l) in the Aglink model. The protein content of rapeseed stalks and husks is 5% on dry mass basis; the moisture content and of rapeseed stalks and husks 10% (Wirsenius, 2000).

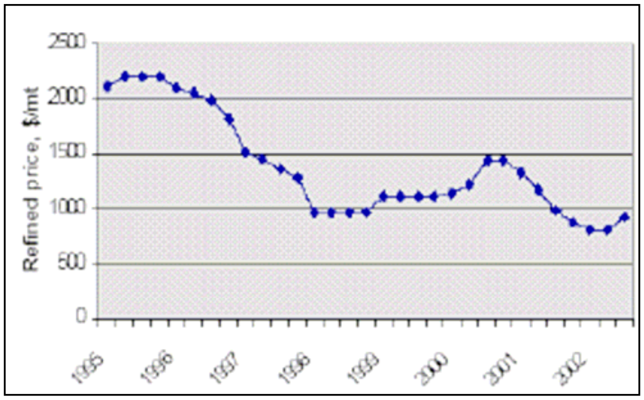
The generation of cake/meal ranges between 1.01 t cake/meal per ton rapeseed to 1.58 t cake/meal per ton rapeseed, see Table 10.

Table 10. Generation of cake/meal (t cake/meal /t biodiesel).

Source:	t/t
Gover et al., 1996 in (Armstrong et al., 2002)	1.58
Levy, H. (1993) in (Armstrong et al., 2002)	1.51
Scharmer, K. and G. Gosse (1996) in (Armstrong et al., 2002)	1.01
Richards, I.R. (2000) in (Armstrong et al., 2002)	1.57
(Elsayed et al., 2003)	1.58

For use in the Aglink model we recommend that a value of 1.55 t/t (1.4 t/l) is used, because most studies report a value of around 1.55 t/t. The protein content of rapeseed cake is 39.6% on a dry mass basis (NRC, 1998 in (JRC, 2003), the moisture content is 11 % (Wirsenius, 2000). Prices for rapemeal with a protein content of 35% are 135-150 €/t (Statcom, 2004).

Glycerine is produced at a rate of 0.1 t per ton biodiesel produced. A literature scan revealed that there is little variation in the amount of glycerine produced per ton biodiesel. Glycerine prices in Europe range from about 400-800 €/t, depending on quality (IEA, 2004). The glycerol credit is estimated at 0.04-0.08 €/l in the EU and at 0.08 €/l biodiesel in the US (IEA, 2004), also another source reports a glycerol credit in the US of 0.02 €/l (IBFG, 2002). However, prices of glycerine may decrease in case the production of biofuels is increased and could eventually be zero or even negative. Prices of glycerol have already fallen as a result of increasing biodiesel production, as shown in Graph 9.



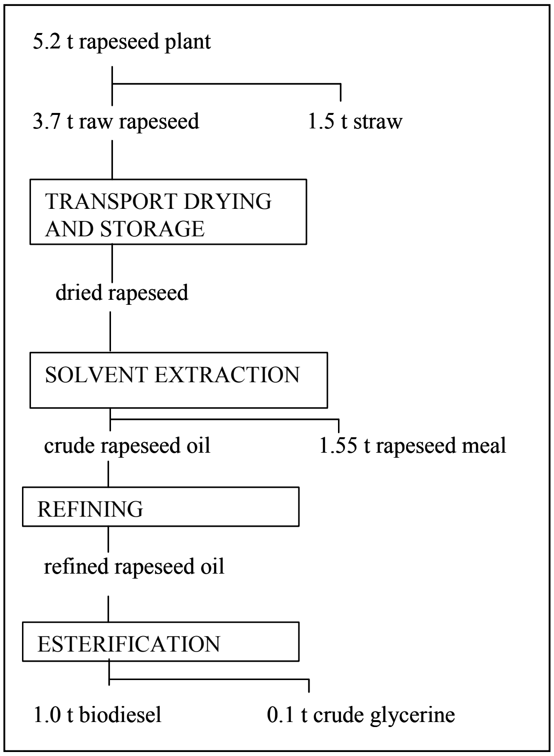
Graph 9. World price of refined glycerol (in $/mt).
Source: (VES, 2004)

It is expected that if biodiesel production increases and thus also glycerol production increases, the price of refined glycerol could decrease from ca. 850 €/t in 2003 to 500 €/t in 2010 (VES, 2004). Note that the price of refined glycerine shown in graph 9 is higher than the price of crude glycerol that is generated during biodiesel production. The data are only shown as an indicator.

For the calculations of biofuel production costs, we recommend to use a glycerol credit of 0.04 €/l now and 0 €/l on the long term.

Mass balance

Graph 10 shows the mass balance for biodiesel production based on the assumed conversion efficiency and the generation of co-products (straw and rape meal) per ton of rapeseed as discussed above.



Graph 10. Mass balance for the production of biodiesel from rapeseed.

Capital costs

Capital costs largely depend on a number of factors e.g. the scale of the plant, the interest rate, the lifetime, the load factor and the type of technology. As a result, conversion costs found in the literature range roughly between 0.065-0.320 €/l biodiesel (based on a comparison of 11 studies) (IFEU, 2004).

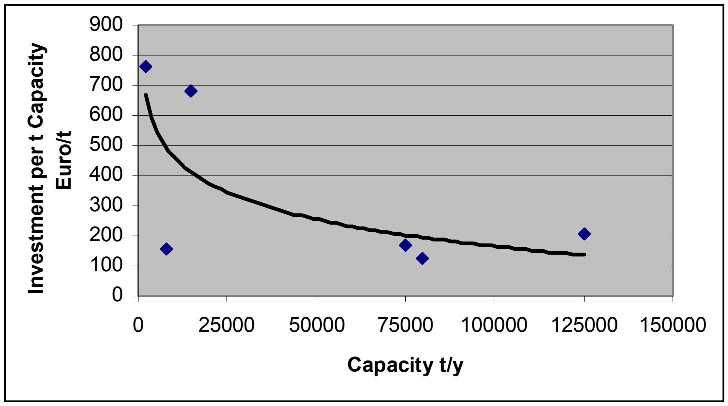
A key factor for the capital costs per unit of output is the scale of the plant. This goes for all bioenergy production systems. As an example, we present some data for biodiesel production plants in Germany, but similar dynamics apply for other biofuel production systems. Table 11 shows an overview of range of operating costs for six biodiesel plants in Germany that differ mainly with respect to the scale (Conneman and Fischer, 1998 in (IEA, 2000).

Table 11. Operating costs and capital costs for biodiesel production from rapeseed (€/l biodiesel).

	€/l
Operating costs	0.06-0.29
of which energy	0.01-0.02
of which depreciation + interest	0.02-0.10
Operating costs, excl. depreciation + interest + energy	0.04-0.17

Source: (Conneman and Fischer, 1998 in (IEA, 2000).

The values given by Connemann and Fischer indicate total conversion costs vary from 0.06-0.09 €/l for big scale plants up to 0.29 €/l for small-scale plants. Similarly, according to a IEA study, the conversion costs range from 0.02-0.09 €/l, depending on the scale of the plant (IEA, 2000). The lower conversion costs in small plants compared to large plants is partially the result of higher investment costs, as shown in graph 11.



Graph 11. Invested capital (€/t biodiesel) as a function of plant size.
Source: (IEA, 2000).

For use in the Aglink model, we recommend to use data provided by (Faaij and Hamelinck, 2002), because data are available for two plants with different scale and because the interest rate, economic lifetime and load factor can be adjusted. Also, data are based on state-of-the-art technologies, which are representative for future biodiesel plants. The total investment costs are calculated at:

- 52 M€ short term (400 MWth HHV input ; for comparison with graph 11 this equals 527 €/t capacity,)
- 91 M€ long term (1000 MWth HHV input)

Capital costs are calculated at 0.06 €/l for a 400 MWth HHVinput and 0.04 €/l for a 1000 MWth HHVinput plant. However, according to one source (JRC, 2002), conversion costs for a typical biodiesel plant in the EU are much lower: 0.012 €/l for a plant with an annual capacity of 1000 kt biodiesel, which requires an investment of about 100 k€ and assuming an interest of 10% and a lifetime of 15 years.

Capital costs related to investments for biodiesel production exclude data on power generation, which are estimated at 155 M€ on the short term (400 MWth) and 215 M€ on the long term (1000 MWth) (Faaij and Hamelinck, 2002).

Operation and maintenance (O&M) costs

Operation and maintenance costs (excluding chemicals and energy) account for 5% of the total investment costs (Faaij and Hamelinck, 2002). O&M costs are calculated at 0.02 €/l biodiesel for both plants, assuming an interest rate of 10%, an economic lifetime of 15 yr and a load factor of 6000 hours (JRC, 2002). Typical O&M costs in the EU are calculated at 0.152 €/l, which indicates that O&M costs may vary widely.

Energy costs and chemical costs

For the production of biodiesel 0.01 GJe/GJbiodiesel is required, which is equivalent to 0.25 kWh/l biodiesel (Faaij and Hamelinck, 2002).

In addition, 115 kg methanol per ton of biodiesel are required (Conneman and Fischer, 1998 in (IEA, 2000). The costs of methanol are 0.03 €/l biodiesel, assuming a price of methanol of 0.22 €/kg.

Production of ethanol from sugar beet

Conversion efficiency

Table 12 shows the conversion efficiency of sugar beet to ethanol.

Table 12. Conversion efficiency of sugar beet to ethanol (l ethanol/t fresh weight sugar beet).

Source:	l/t	Remark
(Elsayed et al., 2003)	98	clean sugar beet
Okö-institut (2004) in (IFEU, 2004)	98	
(Mornier and Ianneree, 2000)	100	
Levy, 1993 in (IEA, 2004)	101	
EC, 1994 in (IEA, 2004)	54	
(JRC, 2003)	20	

Values for the conversion efficiency of sugar beet to ethanol ranges from 54-101 l/t sugar beet. The value of 54 l/t is much lower than compared to other values found in literature, which may be caused by e.g. differences in the scope or definitions. Therefore, for use in the World Sugar model, we recommend the use of a value of 98 l/t.

The production of ethanol is a relatively well-established technology with little potential for further efficiency increases. (Elsayed *et al.*, 2003). For example, it is estimated the potential overall efficiency increase to 2020 at +5% (on energy basis).

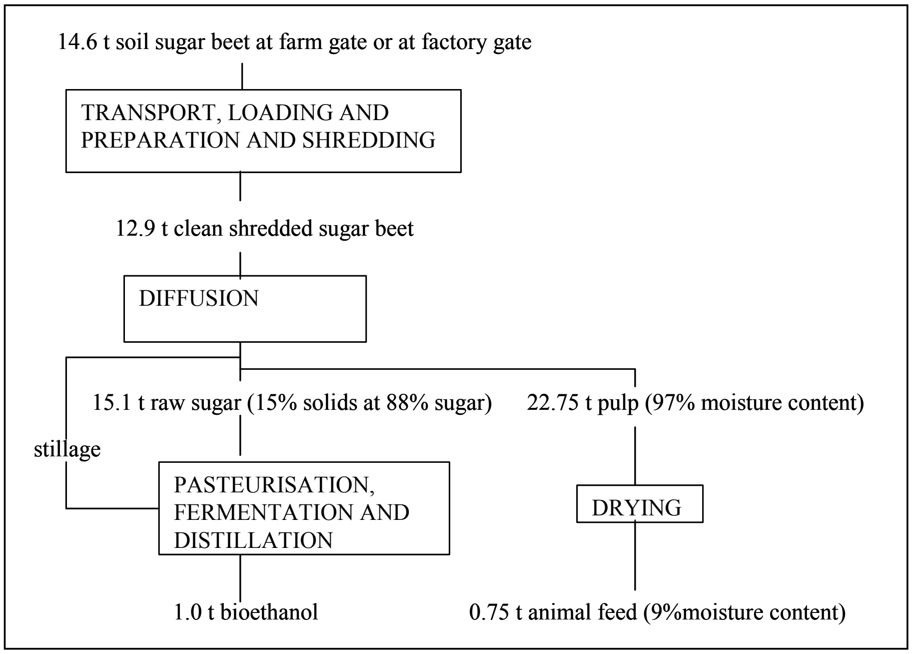
Co products

Beet pulp is a co-product from the production of ethanol from sugar beet. Per ton ethanol ca. 75 kg beet pulp at 9% moisture content is generated (0.059 kg/l) (Elsayed *et al.*, 2003), which can be used as animal feed. The protein content of beet pulp is calculated at 10% (Wirsenius, 2000). The beet pulp can also be converted into biogas using a biogas fermentor or converted into ethanol by means of simultaneous saccharification and fermentation (SSCF). The latter two are excluded, because it is likely more economically attractive to use the beet pulp as animal feed (JRC, 2003).

Results derived from a review of studies indicate that profit for the sales of co-products can be a high as 247 €/ton ethanol, although all other studies calculated a credit of 100 €/ton ethanol or below (IFEU, 2004).

Mass balance

Based on values on the production of ethanol and co-products from sugar beet, the following mass balance is included:



Graph 12. Mass balance for the production of ethanol from sugar beet.
Source: (Elsayed *et al.*, 2003).

Capital costs

Capital costs are largely dependant on the size of the plant, the interest rate, the load factor and the economic lifetime. A comparison of 12 different studies shows that conversion costs range between 204-640 €/t ethanol (IFEU, 2004).

For use in the World Sugar model, we recommend to use of data provided by (Hamelinck, 2004), because the load factor, interest rate and economic lifetime can be adjusted. Total investment costs are estimated at 149 M€ short term (400 MWth HHV input, 123 Ml output) and 190 M€ long term (1000 MWth HHV input, 305 Ml output). Total capital costs are calculated at 0.16 €/l ethanol short term and 0.08 €/l long term, assuming an interest rate of 10%, an economic lifetime of 15 years and a load factor of 5000 hours. F.O. Lichts calculated capital costs at 0.10 €/l for a 50 million litre plant and 0.06 €/l for a 200 million litre plant (F.O. Lichts 2003 in (IEA, 2004).

Sugar factories using beet are generally not in operation year round, because sugar beet cannot generally be stored for long period after harvest. Beet processing 'campaigns' last between 60 days (Poland) and 150 days (Britain). The average for EU25 is about 90 days. However, it may be possible to keep the ethanol part of the plant working continuously by storing pasteurised syrup (JRC, 2003). In this study we use a load factor of 208 days or 5000 hours.

Operation and maintenance costs

Annual operation and maintenance costs (O&M) are calculated at 5% of the total investment costs (Faaij and Hamelinck, 2002). The total O&M costs are calculated at 0.06 €/l ethanol short term and 0.03 €/long term. O&M costs calculated by F.O. Lichts (2003 in (IEA, 2004) are calculated at 0.18-0.22 €/l, dependant on the scale of the plant.

Energy costs

For the production of ethanol from sugar beet electricity and heat are required: 0.065 GJe/GJ ethanol and 0.24 GJth/GJ ethanol (short term) and 0.035 GJe/GJ ethanol and 0.18 GJth/GJ ethanol (long term), respectively (Faaij and Hamelinck, 2002).

Production of ethanol from sugar cane

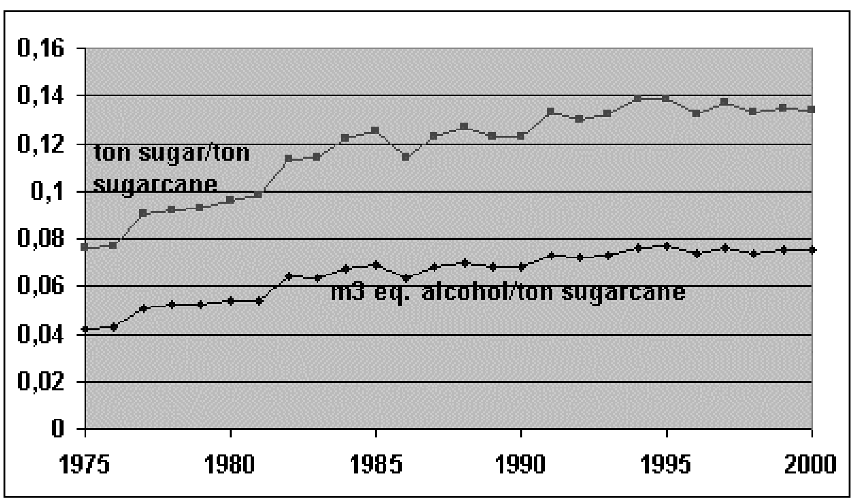
Conversion efficiency

Values for the conversion efficiency from sugar cane to ethanol varies considerably (Table 13). Note that data are however not necessarily comparable, due to differences in definitions.

Table 13. Conversion efficiency of sugar cane to ethanol (l ethanol/t fresh weight sugar cane).

Source:	l/t	remark
(Shleser, 1994), see mass balance	76	excluding conversion of bagasse, based on 110 t clean cane at factory gate
(Ferreira, 2003)	45	average in 1975 (estimated from graph)
(Macedo and Koller, 1995)	73	average in 1985
(Ferreira, 2003)	77	average in 2000 (estimated from graph)
(DfT, 2003)	80	
(Macedo and Koller, 1995)	83	best value in 1985
(Macedo et al., 2004)	92	best value in 2000
(Damen, 2001)	85	short term
(Damen, 2001)	95	long term
(Damen, 2001)	177	long term, including conversion of bagasse

The large range in conversion efficiencies the result of e.g. differences in definitions, scope and year of reference. Particularly the year of reference is important, because the conversion efficiency of sugar cane to ethanol increased considerable in Brazil during the previous years (Graph 13).



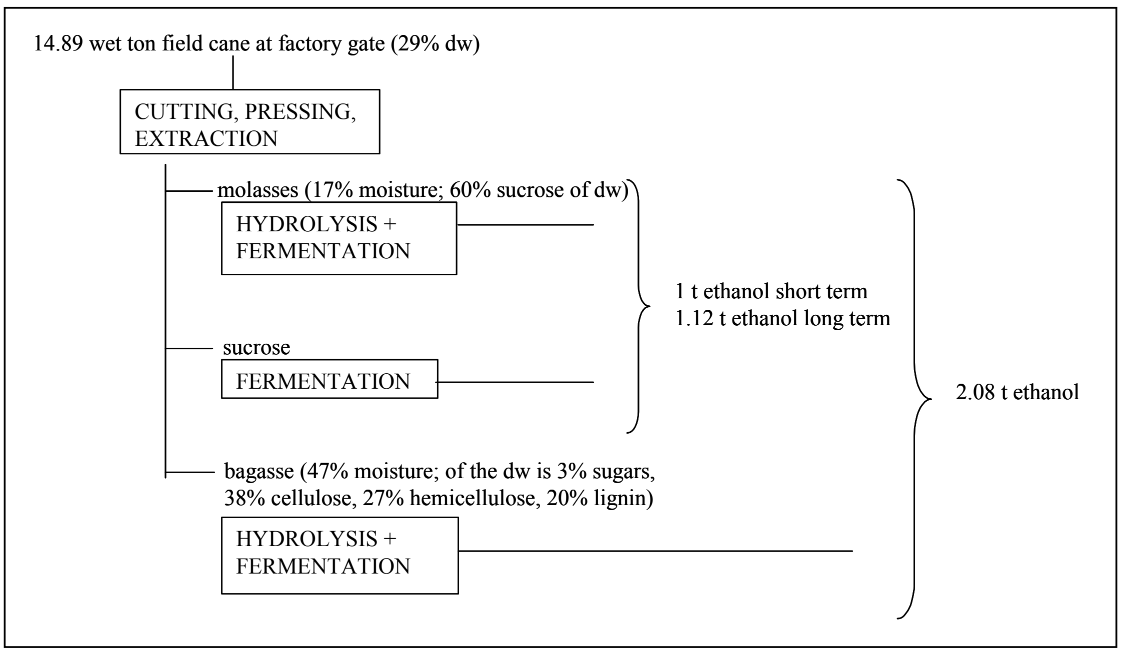
Graph 13. The conversion efficiency of sugar cane to sugar (t/t) and the conversion efficiency of sugar cane to ethanol (m^3/t fresh weight).
Source: (Ferreira, 2003).

The increase in conversion efficiency is primarily achieved through increasing the total reducing sugars (TRS) content subtracted from cane. Further, the conversion efficiency is depending on the sugar content of the sugar cane, which varies from 10% to 15% (FAO, 2003). For use in the World Sugar model, we advise to use the data given by (Damen, 2001), because data on economic processes are derived from the same source and thus inconsistencies are avoided: 85 l/t cane for a standard plant (short term), 95 l/t cane (long term in ethanol plant with BIG-CC system) and 177 l/t cane (long term in ethanol plant with hydrolysis unit) (Damen, 2001). Note that ethanol plants at this moment in general do not have a BIG-CC system or a hydrolysis unit, because these technologies are not commercial yet.

Co products

In the short term, the ethanol plant generates an excess bagasse of 0.052 t/t cane and an excess trash of 0.053 t/t cane. Bagasse has a moisture content of 47% (Elsayed *et al.*, 2003) and a protein content of 1.5% (Wirsenius, 2000), similar values for trash are 73% and 5%. Due to the low protein content, excess bagasse and trash are generally discarded. In the long term, excess bagasse and trash can be used for electricity generation or ethanol production, which reduces the excess to zero.

Mass balance



Graph 14. Mass balance for the production of ethanol from sugar cane.
Source: (Shleser, 1994).

If no burning of leaves is applied, than the amount of dry weight bagasse increases by 54% (Shleser, 1994). It also results is sucrose losses, which reduce the ethanol yield by 0.7-2 l/t cane (Damen, 2001). For the conversion of sugars to ethanol a conversion efficiency of 50% is included for all sugars (Shleser, 1994).

Capital costs

As with all biofuel production systems, capital costs vary largely. In this study we recommend the use of a total investment cost of 48M€, short term (standard plant of 400 MWth HHV input), (Hamelinck, 2004). In the long term, plants with BIG-CC cycles or plants with hydrolysis units may become economically attractive, which result in investment costs of 197 M€ and 153 M€, respectively, for 1951 MWth input. However, these technologies are presently not commonly used because of technical or economic limitations. These values correspond with capital costs of 0.04 €/l (short term), 0.04 €/l (long term, BIG-CC system) and 0.02 €/l (hydrolysis unit), respectively. These data match with data found in literature: Goldemberg *et al.* (1993) report a value of 0.05 €/l to 0.07 €/l, for a 6% and 12% interest rate.

Operation and maintenance (O&M) costs

Operation and maintenance costs are estimated at 13% of the total investment costs for a standard plant, short term (Damen, 2001) and 6% and 10% of the total investment costs for the plant with the BIG-CC and hydrolysis unit, respectively. The total O&M costs are calculated at 0.04 €/l, 0.02 €/l and 0.01 €/l, respectively. These data are also in line with data from Goldemberg *et al.* (1993) calculate O&M costs at 0.04 €/l.

The total conversion costs are thus 0.08 €/l (short term). Data found in literature are: 0.09 €/l-0.11€/l for production in Brazil, depending on the interest rate (Goldemberg *et al.*, 1993), 0.12 €/l for production on Hawaii (Shleser, 1994), and 0.12 €/l-0.29 €/l for production in Australia, depending on the scale of the plant (Nguyen and Prince, 1996). Assuming a feedstock cost of ca. 0.2 €/l (Nguyen and Prince, 1996; Damen, 2001; DfT, 2003) the total production costs are calculated at 0.28 €/l (short term), which is in line with figure derived from literature: 0.29 €/l-0.31€/l for Brazil (Goldemberg *et al.*, 1993), 0.32 €/l for Hawaii and 0.38 €/l-0.49€/l for Australia (Nguyen and Prince, 1996). Existing ethanol prices are however presently lower, as low as 0.15 US$/l (IEA, 2004), which could be the result of:

1.) Some ethanol plants are beyond their economic lifetime and thus capital costs for these plants are zero and
2.) The costs of feedstock is linked to the sugar market, which results in fluctuations in feedstock prices
3.) Ethanol is sold under the cost price. In (DfT, 2003) the ratio cane feedstock costs to ethanol price is calculated at 169%. Although the latter number is based on a comparison of data from different sources which could vary in scope, it may also be an indicator that ethanol is sold under the cost price. This conclusion is supported by the cost of cane reported in various sources, which is ca. 0.2 €/l (0.2 US$/l), which is higher than the total costs of ethanol production of 0.15 US$/l mentioned above.

Energy costs

The production of ethanol requires steam and electricity, which are generated by the burning of bagasse. In the short term, ethanol plants are assumed to produce or consume no additional electricity, but over the long term ethanol plants produce electricity of 3.4 kWh/l in case of a plant with BIG-CC system and 0.16 kWh/l in case of a plant with a hydrolysis unit (Damen, 2001). The demand for heat is already included in the data on electricity production.

Production of ethanol from maize

For the production of ethanol from maize two types of processes are commonly used: wet milling and dry milling. In the wet milling process, the grain is separated into its components, including starch, fibre, gluten and germ (steeping as it is called in the industry). The starch component is used for ethanol production. In the dry milling process, the clean maize is ground and mixed with water to form a mash, after which enzymes are added to convert start to sugar and than yeast is added to convert sugars into ethanol. Dry and wet milling each account for roughly half of the ethanol production in the US, which is the largest producer of ethanol from maize.

Conversion efficiency

Table 14 shows the production of ethanol per ton of maize.

Table 14. Production of ethanol per ton of maize (l ethanol/ t fresh weight maize).

Source	l/t	Remark
(IEA, 2004)	366-470	range found in 6 studies
Levelton, 1999 in (IFEU, 2004)	470	Canada, 2005
Levelton, 1999 in (IFEU, 2004)	475	Canada, 2010
Wang, 1999 in (IFEU, 2004)	384	USA, 2000
Wang, 1999 in (IFEU, 2004)	399	USA, 2005
(Graboski, 2002)	392	USA, present, dry milling
(Graboski, 2002)	399	USA, present, wet milling
(Graboski, 2002)	417	USA, future, dry+wet milling
(USDA, 2005)	471	theoretical yield

Values for the production of ethanol per ton of maize found in literature vary from 366 l ethanol/t maize to 471 l ethanol/t maize. We advise to use the conversion efficiencies reported by (Graboski, 2002) in the Aglink model for three reasons. First, the data reported by Graboski are based on US data and the US is the main producer of ethanol from maize. Second, specific attention is given to dry milling and wet milling. Third, the data are based on recent research and are therefore assumed to be more up-to-date than the other studies.

Graboski reports a yield for dry milling of 392 l ethanol/t maize and for wet milling 399 l ethanol/t maize. Presently, ethanol produced by dry milling and wet milling each contribute ca. half to the total ethanol production, thus the average yield is ca. 396 l ethanol/t maize. This figure is projected to increase to 417 l/t in 2012 (Graboski, 2002).

Co products

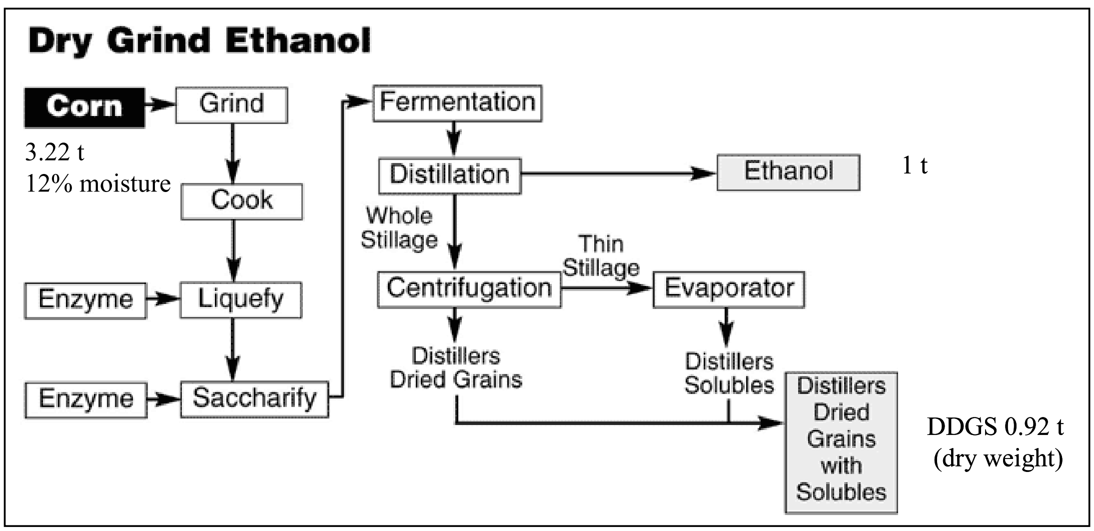
For the production of maize, the maize grain is separated from the maize stovers. As a rule of thumb the ratio maize grain to maize stover is 1:1, on a fresh weight basis. Thus for each ton of maize, one ton of maize stovers is produced, which can be used as e.g. feed. The moisture content of maize stover is 15% and the protein content is 5.5% on dry-weight basis. The price of collected and baled maize stover in the US is roughly 30 €/t dry weight.

In the dry mill, the protein, maize oil, unconverted starch, and non-reactive dry matter are combined to produce a feed supplement termed Distillers Dried Grains (DDG). Often, this is combined with a second residue called thin silage to produce DDGS (Distillers Dries Grains with Solubles). DDGS has a protein content of 24% and a fat content of 8% based on a moisture content of 10% (Graboski, 2002). The credit of DDGS in the US accounts for 0.07 €/l (Shapouri *et al.*, 2002).

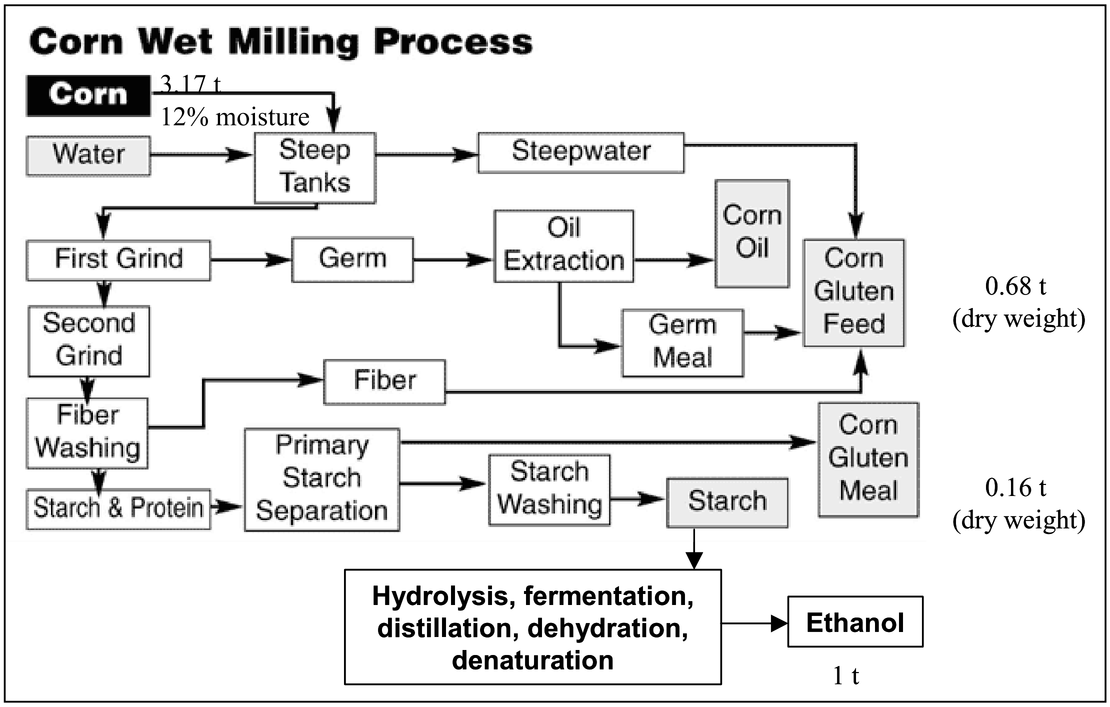
In the wet mill, maize oil and two feed grain products, maize gluten meal (CGM) and maize gluten feed (CGF) are typically recovered. The CGF yield depends on the maize composition and ethanol yields and consequently, some minor inconsistencies may be included in the data presented in this section, because data used in this report on the production of ethanol and CGF per ton maize is taken from different sources. The protein and fat content of gluten feed are 21% and 2%, respectively and the protein and fat content of gluten meal are 60% and 2%, respectively (Graboski, 2002). The credit of co products from dry milling in the US is estimated at 0.11 €/l ethanol (Shapouri *et al.*, 2002).

Mass balances

Graph 15 and 16 show the process diagram and mass balance for dry milling and wet milling, respectively.



Graph 15. Mass balance for the production of ethanol from maize, dry milling. Source: (Kim and Dale, 2002; IC, 2005).



Graph 16. Mass balance for the production of ethanol from maize, wet milling. Source: (Kim and Dale, 2002; IC, 2005)

Capital costs

As with all biofuels production facilities, investment costs are largely dependent on e.g. the scale, interest rate, load factor, type of technology, and use of used equipment. As a result, conversion costs vary roughly between 0.08 €/l ethanol to 0.40 €/t ethanol (IFEU, 2004).

In this study, the focus is on average capital costs for existing facilities in the US. No information was readily available on the capital costs of future installations. We acknowledge that future capital costs are likely lower for two reasons. First, only dry milling plants are presently being build which have lower investment costs than wet milling plants (Shapouri *et al.*, 2002). Second, the total invested capital of standardised dry-mill ethanol plants that are recently build are much lower than of earlier plants: 0.28 €/annual l , while the capital costs of earlier plants are estimated at 0.46-0.53 €/annual l (Shapouri *et al.*, 2002). This equals a capital cost of 0.04 €/l and 0.07-0.08 €/l respectively, assuming an interest rate of 10% and a lifetime of 15 years. As a result of the decrease in capital costs and increasing conversion efficiencies, total ethanol production costs have decreased considerably during the previous decades, from 0.69 €/l in 1978, 0.40 €/l in 1994 to 0.24 €/l in 1999, for dry mill operations.

For use in the Aglink model, we recommend to use the average capital recovery costs of dry and wet milling reported in table 15. Table 15 shows a breakdown of processing costs for bioethanol production from maize in the US is shown, for both wet and dry milling (excluding energy costs).

Table 15. Breakdown of processing costs for bioethanol production from maize. Source: USDA 2002 in (DfT, 2003).

		labour + maintenance	overheads	capital recovery	total
wet milling	€/l	0.03	0.01	0.06	0.10
	%	32	11	57	100
dry milling	€/l	0.04	0.01	0.06	0.11
	%	35	10	54	100
average	€/l	0.04	0.01	0.06	0.11

Capital recovery costs are estimated at 0.06 €/l, for both wet and dry milling. The total average processing costs are calculated at 0.11 €/l, which is broadly line with the conversion costs of 0.15 €/l ethanol reported by (F.O. Lichts, 2003 in (IEA, 2004) for a plant with a capacity of 53 Ml per year. It can be expected that in newly emerging biofuel-producing regions the latest technologies are adopted, which results in lower conversion costs compared to the US. Although one could also argue that due to the lack of experience, costs will be higher.

Operation and maintenance costs

As shown in table 15, average operation and maintenance costs in the US account for ca. 0.05 €/l ethanol.

Energy costs

The consumption of ethanol from maize requires both heat and electricity, see table 16.

Table 16. The consumption of heat and electricity for maize production (Graboski, 2002).

	thermal	electricity
	MJ/l ethanol	kWh/l ethanol
dry milling	11	0.28
wet milling	15	0.20
average	13	0.24

According to the United States Department of Agriculture, energy costs account for 0.04 €/l ethanol produced in the US (USDA 2002 in (DfT, 2003).

Production of ethanol from wheat

Conversion efficiency

Table 17 shows the production of ethanol per ton wheat.

Table 17. Production of ethanol per ton wheat (l ethanol/ t fresh weight wheat).

Source	l/t	Remark
(IEA, 2004)	348-385	range found in 4 studies
Okö-institut (2004) in (IFEU, 2004)	370	for Germany, 2000 to 2030
(Elsayed et al., 2003)	362	

The conversion efficiency expressed in l ethanol per to fresh weight wheat varies roughly from 348 to 385 l/t. For use in the Aglink model, we recommend to use a value of 362 l/t, which represents the middle of the range found in literature.

Co products

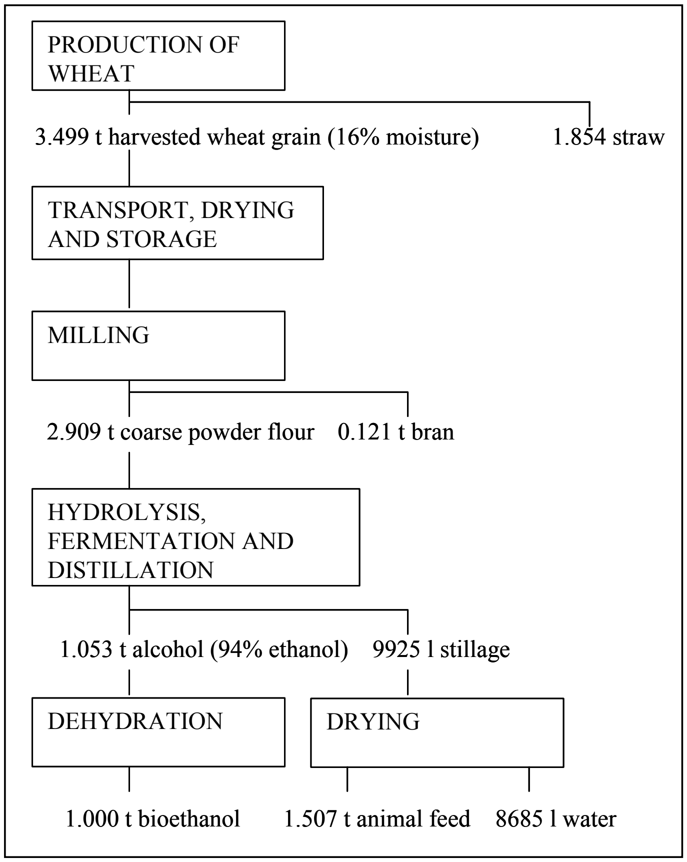
During the production of ethanol from wheat, three co-products are produced: straw, bran and DDGS.

For every ton wheat produced, roughly 0.5 t straw is generated, equal to 1.5 kg/l ethanol. Bran is produced at a rate of 0.1 kg/l ethanol. DDGS is produced at a rate of ca. 1.5 t/t bioethanol or 1.2 kg/l ethanol, which can be used as animal feed. DDGS has a protein content of 24% and a fat content of 8% based on a moisture content of 10% (Graboski, 2002). In France, the value of DDGS is calculated at 0.13 €/l ethanol (Mornier and Ianneree, 2000).

Profits from co-products are estimated at 0.21 €/l ethanol maximum, based on a comparison of 11 studies included in (IFEU, 2004).

Mass balance

Graph 17 shows the process diagram and mass balance for the production of ethanol from wheat.



Graph 17. Mass balance for the production of ethanol from wheat. Source: (Elsayed *et al.*, 2003).

Capital costs

For use in the Aglink model, we recommend to the use a value of 0.10 €/l, which is based on a plant with a capacity of 50 Ml (F.O. Lichts, 2003 in (IEA, 2004). On the longer term, larger plants may become feasible, which reduces the capital costs to 0.06 €/l in case of a plant with a capacity of 200 Ml (longer term).

Operation and maintenance costs

Operation and maintenance costs for a ethanol plant with an annual capacity of 50 Ml and 200 Ml, O&M costs are calculated at 0.21 €/l, including energy costs.

Thus, the total costs of ethanol production in Germany are ca. 0.31 €/l ethanol. Total conversion costs of ethanol production in France are calculated at 0.34 €/l (Mornier and Ianneree, 2000). Data on conversion costs found in literature are calculated at 0.10 €/l ethanol to 0.65 €/l (IFEU, 2004).

Energy costs

No data were readily available on the energy use of wheat production. Energy costs are already included in O&M costs. However, a valid proxy would be to use energy consumption data of ethanol production from maize via the dry milling process.

Production of advanced biofuels

The technical and economic performance of the conversion of lignocellolusic biomass to ethanol via hydrolysis and hydrogen, methanol and Fischer-Tropsch diesel via gasification, is favourable compared to conventional biofuels. However, the conversion of lignocellulosic biomass to these so called 'advanced biofuels' requires further technological developments and large-scale plants are at this moment not commercially feasible. As a result, limited data are available on the technical and economic performance of these production systems.

In this study, data calculated based on detailed flow sheet and economic analysis of various process configurations and capacities are included (Hamelinck, 2004). Data on four advanced biofuels are included: methanol, hydrogen, Fischer-Tropsch diesel and ethanol production. Data are shown in table 18. The consumption of heat is already included in the conversion efficiency. The consumption of chemicals is not specifically included, but is of minor importance and therefore left out.

Table 18. Technical and economic performance of the production of ethanol, methanol, hydrogen, Fischer Tropsch diesel from lignocellulosic biomass. Operation and maintenance (O&M) costs are given as annual % of total invested capital.

biofueld production system	Parameter	value	unit
methanol	conversion efficiency	58	kg/kg
		56	kg/kg
	Electricity	-0.217	kWh/kg
		0.054	kWh/kg
	invested capital	235	M€
		188	M€
	O&M costs	4.0	%
		4.0	%
hydrogen	conversion efficiency	0.06	kg/kg
		0.07	kg/kg
	electricity	0.913	kWh/kg
		1.067	kWh/kg
	invested capital	247	M€
		207	M€
	O&M costs	4.0	%
		4.0	%
Fischer-Tropsch diesel	conversion efficiency	0.19	kg/kg
		0.19	kg/kg
	electricity	0.172	kWh/kg
		0.172	kWh/kg
	invested capital	292	M€
		235	M€
	O&M costs	4.4	%
		4.4	%
ethanol	conversion efficiency	0.26	kg/kg
		0.35	kg/kg
	electricity	0.913	kWh/kg
		1.067	kWh/kg
	invested capital	291	M€
		218	M€
	O&M costs	6.4	%
		3.6	%

Source: (Hamelinck, 2004).

At a feedstock price of 3 €/GJ_{HHV} for cultivated wood in Western Europe, total production costs of methanol, hydrogen, FT diesel and ethanol are calculated at 12-9 €/GJ_{HHV}, 16-9 €/GJ_{HHV}, 18-13 €/GJ_{HHV} and ethanol 22-11 €/GJ_{HHV}, respectively (the lower figure is based on a 400 $MWth_{HHV}$ input and the higher figure for a 1000 $MWth_{HHV}$ input plant). For comparison: ethanol in Brazil costs ca. 7-9 €/GJ_{HHV}.

Production of ethanol from other feedstocks

Virtually all oil, starch, sugar or fibre containing feedstocks are suitable for ethanol production. However, data on the technical and economic performance of these production pathways are scarce, because there is very limited or no experience with these feedstocks. Therefore, in this study we included only data on conversion efficiencies found in literature, see Table 20.

Table 20. Conversion efficiency of (l ethanol/t fresh weight feedstock).

	value	unit
barley	295	l/t
jerusalem artichoke	95	l/t
sorghum	359	l/t
soyabeans	195	l/t
animal fats and oils	2.3	l/l
(apples	49	l/t)
(water melons	11	l/t)
switchgrass	265	l/t
potatoes	151	l/t
verge grass	152	l/t

Sources: various, including data from internet pages.

4. Discussion, conclusions and recommendations

4.1 Biofuels policy

As was shown in the Outlook assessment for biofuels in the EU-25 and the ethanol world Outlook in the previous section, three regions are likely to be dominant in biofuel production until 2013: These are the EU-25, the USA and Brazil.

The EU directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport established a goal of 2% of domestic transport fuel consumption as the target for EU biofuel use by the end of 2005. As several European Union states had failed to implement rules promoting biofuels by the stipulated date of July 2005, the European Commission has indicted an intention to commence or advancing legal action against the offending countries. The European Commission said the bloc's 25 governments had an obligation to turn EU rules on biofuel usage into national law in 2004[6]. In addition, they had to send a report to the Commission with "an indicative target for the share of the petrol and diesel market that will be taken by biofuels at the end of 2005." In terms of member state compliance, Estonia, Finland, Greece, Italy, Luxembourg, the Netherlands, Portugal and Slovenia had not yet notified the Commission of the national law. Italy, Luxembourg, and Slovenia had not submitted reports, while France and Estonia's reports lacked concrete targets, the Commission said. The Commission also rejected targets submitted by seven states, ranging from 0.0 percent to 0.7 percent, saying they did not comply with EU rules. Those countries were Denmark (0.0 pct target), Ireland (0.06 pct), Finland (0.1 pct), the UK (0.3 pct), Hungary (0.4-0.6 pct), Poland (0.5 pct) and Greece (0.7 pct).

So far, the EU-25 has basically been the sole major producer of bio-diesel. This may change over the next 10 years: Brazil has plans to produce 2000 million litres biodiesel (approximately the volume produced by the EU in 2004) by 2013, mainly from soyabeans, but also from other oil crops such as Castor and Dende. Also India and China are experimenting with Jatropha as a feedstock for biodiesel production, and other South-East Asian countries are starting to experiment with diesel from palm oil or coconut oil. However, it is very hard to estimate how biodiesel production may develop over the next decade in most South-East Asian countries, as in most countries, no (information on) government policy and targets are available. Still, it would probably be advisable to integrate these new oil-plant species (e.g. Jatropha, Pongana, Castor and Dende) into the Aglink model.

Regarding ethanol, it can be expected that in 2013, over 80% of the global fuel ethanol production will take place in Brazil, the USA and Europe. These expectations are based on the EU white paper, the US Energy Bill (for which still a compromise has to be found between the House and the Senate versions), and the growth expectations of the Brazilian ethanol sector, based on a large domestic demand and export opportunities to e.g. Japan and South Korea. Also Peru, Colombia or the Central American states may become large ethanol producers with markets in North America, and possibly also for Japan and possibly South Korea and the European Union. While South-East Asian countries such as Thailand and India may have reasonable potential to increase their fuel ethanol production, it is again difficult to

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[6] Derived from press release, available at:
http://www.planetark.com/dailynewsstory.cfm/newsid/31557/story.htm

forecast their production levels due to (limited information on) current biofuels policies and targets.

Given the fact that developments in the EU, the USA and Brazil are relatively transparent, it is recommended to keep a close eye on the developments in promising Latin American countries, South East Asian countries like India, China, Thailand and Malaysia, and Australia, Southern African countries (especially South Africa, but possibly also Zimbabwe, Madagascar, Malawi, Mozambique etc.) as well as Eastern Europe (such as Romania, Ukraine and Russia).

In addition, it must be remarked that most of the growth expectations are based on policy-based incentives. In the longer term, market factors such as global (rising) oil prices, prices for competing products (e.g. for sugar, vegetable oils, fodder), (removal of) trade barriers and technology development of (advanced) biofuels options may become more important than policy incentives alone to determine the growth of global biofuels markets. Given the fact that European ethanol is a factor of 2-3 times more expensive than ethanol from Brazil, domestic agricultural policy reforms might influence domestic production levels of ethanol in Europe and removal of trade barrier could encourage production in regions such as Latin America and (in a negative way) Europe.

4.2 Technical and economical performance of biofuel production systems

Numerous studies exist on the technical and economic performance of biofuel production systems that focus on the total production costs and the greenhouse gas balance of biofuel production systems. Most studies present aggregated results in costs per unit of fuel produced or in avoided greenhouse gas emissions per unit of fuel. As shown in graph 3 and 4, large differences exist between results from various studies.

The large range in technical and economic performance reported in various studies is caused by differences in system boundaries, scope, definitions or conversion factors, as well as differences in assumptions on feedstock costs, interest rate, labour costs, economic lifetime, type of technology and scale of the plant, load factor, value of co-products and whether production subsidies are included or excluded. For example, the scale of the plant is a crucial factor for total investment costs. The impact of the scale on total investment costs can be estimated using the scale factor R and the following equation:

$$\frac{\text{investment cost 1}}{\text{investment cost 2}} = \left(\frac{\text{size 1}}{\text{size 2}}\right)^{R}$$

R≤1. The scale factor for various biofuel production facilities is shown in table 21.

Table 21. Scale factor for biofuel production systems, valid for 400 MWth input to 2000 MWth input.

	scale factor R
Biodiesel from rapeseed	0.95
Ethanol from sugar beet	0.75
Ethanol from sugar cane	0.75
Ethanol from maize	0.75

Ethanol from wheat	0.75
Methanol from lignocellulosic biomass	0.79
Ethanol from lignocellulosic biomass	0.84
Hydrogen from lignocellulosic biomass	0.81
FT diesel from lignocellulosic biomass	0.85

Source: (Hamelinck, 2004)

The scale factors are in generally lower in case of smaller scale plants. Thus, the total investment costs per unit capacity decreases with increasing scale, although the rate of decline levels off with increasing plant size. The combined impact of the scale effect and the interest rate, lifetime and load factor, is one of the reasons for the large differences and large uncertainties related to capital and O&M costs.

In practice, it is usually very difficult to distinguish between the impact of the various factors included in the literature, due to a lack of disaggregated (detailed) data on the technical and economic performance. Similarly, it is also very difficult to derive one representative set of data on the technical and economic performance. It is also difficult to differentiate between various regions, particularly because at this moment most biofuel production systems are geographically concentrated in regions: ethanol from sugar cane is mainly used in Brazil, biodiesel from rapeseed in Europe and ethanol from maize in the USA.

Therefore, the data presented must be regarded with caution and may represent only a fraction of the available literature. Although data on the technical and economic performance of various biofuel production systems comes with a certain degree of uncertainty, the overall impact on the total biofuel costs is limited, because processing costs generally account for only a fraction of the total processing costs, see Table 22.

Table 22. Share of processing costs in total production costs (%).

biofuel	feedstock	region	feedstock
biodiesel	oil seeds	US	20
ethanol	maize	US	50
ethanol	sugar cane	Brazil	20
ethanol	sugar beet	EU	30
ethanol	wheat	EU	50

Source: (DfT, 2003).

Obviously, due to the differences in processing costs and feedstock prices, these percentages must be viewed as indicators only. For example, for biodiesel production feedstock costs account for 8% to 40% of the total production costs, depending on the feedstock price and plant scale (IEA, 2000).

Further research is required to compose a more detailed and accurate set of data with specific attention to the technical and/or economic performance due to:

- Regional circumstances
- Scale effects
- Type of technology
- Differences in key data
- Co-products

This goes particularly for the 'advanced biofuels', which are produced from lignocellulosic biomass via gasification-synthesis or via hydrolysis-fermentation. These advanced biofuels are projected to have a better technical and economic performance, but for which at this moment more limited data are available. Such an exercise requires in-depth analysis and comparison of existing data in combination with bottom-up calculations. The result of such an exercise would be a detailed set of data in which the impact of various assumption is clearly visible. In combination with data on feedstock prices projected by the Aglink and World Sugar model projections and additional data on, for example,. interest rates, labour costs, energy costs, the technology and biofuel production system can be identified which results in the lowest costs in each region.

4.3 General discussion, conclusions and recommendations

The production of bio-diesel and bio-ethanol is based on traditional processes that have been researched and applied over the last decades. With the exception of ethanol from sugar cane, the energy and CO_2 balances of these 'first-generation' biofuels are in general not so beneficial. In some cases, when total production chains are poorly managed (e.g. ethanol from maize), the energy balance can in some cases even be negative.

It is generally expected, that in the midterm future, the share of advanced biofuels which use lignocellulosic biomass (e.g. wood waste, residues, wood from dedicated crops, grasses etc.) as feedstock will increase. Lignocellolosic biomass can (partly) be produced from different land areas than agricultural land, including forest areas and marginal lands no longer required for food production. To allow for meaningful (macro-economic) analysis, considerable expansion of the current modelling work are needed. Competition of wood use with power and heat production as well as biomaterial applications (e.g. timber, pulpwood) should than also be considered. This would probably require an extension of the Aglink model, and we would recommend to give some attention to this, especially for the longer-term (e.g. from 2015 onwards).

Appendix 1 Conversion units

All quantities are expressed in million litres. The density and heating value of both presented blow, as are conversion factors to gallons. Conversion to gallons and metric tonnes of (pure) ethanol and bio-diesel are given below:

Table 23: Conversion factors

	Density (kg/l)	HHV (MJ/kg)
Ethanol	0.79	29.7
Bio-diesel	0.88	37.8
Methanol	0.79	19.8
Fischer-Tropsch	0.77	42.9
Hydrogen	0.71 (liquid) 0.0848 (gas)	120
1 gallon =	3.78 l	
1 barrel =	158.9 l (= 42 gallons)	

Appendix 2 Converting energy costs to oil prices

The following formula shows the energy costs as a function of the key parameters.

$$\text{Costs of energy} = \frac{(\text{investment} \times \alpha + \text{O\&M}) + \text{cap}/\eta_e \times \text{load} \times \text{fp}}{\text{cap} \times \text{load}}$$

COE	= costs of energy (€/Wh)
investment	= total investment costs (€)
α	= annuity factor (1/y)
O&M	= operation and maintenance costs (€/y)
cap	= capacity of the facility (W)
load	= load factor (h)
η_e	= efficiency (%)
fp	= fuel price (€/J)

Typical present COE from various fuels are:

- 3 €cent/kWh electricity from coal in EU
- 1.5-2 €cent/kWh electricity from coal in South Africa and Chine
- 4-6 €cent/kWh from gas and oil in EU and US and various other regions.
- 5-6 €/GJ heat from gas, based on a gas price of ca. 4 €/GJ

Thus, the correlation between the COE and the oil price depends on the correlation between the prices of the fuel used to produce the energy with. This correlation varies per type of fuel

- The price of coal is ca. 1-1.5 €/GJ and this price is independent of the oil price and is expected to remain stable in the near future.
- The price of gas is ca. 4 €/GJ and is closely correlated to the oil price.
- The price of oil is ca. 8 €/GJ, assuming an oil price of 60 $ (50€) per barrel; 1 barrel is 159 l, or 5.8 MBTu or 6.12 GJ oil).

Thus, the correlation between the price of energy and the price of oil can be calculated if data are available on:

- The share of the various types of fuel in the fuel mix used to produce the energy that is consumed during the production of bioenergy.
- The investment and O&M costs of various biofuel production systems and the efficiency of energy production.

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