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Biofuels and their global influence on land availability for agriculture and nature

A first evaluation and a proposal for further fact finding

Report

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Summary

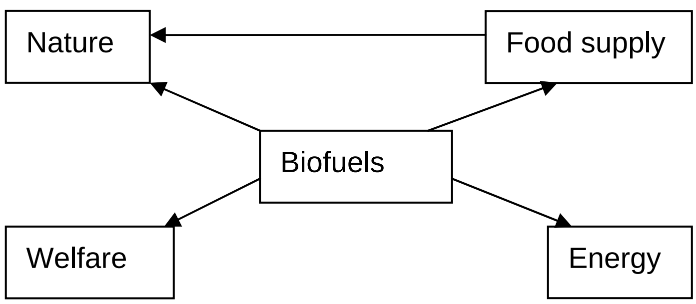
Introduction
Many national and state governments in Europe and the United States are expanding their support for biofuels for transportation. This may have significant impact on the food sector, since most of the current sources for biofuels are also raw materials for this sector. Crops like rapeseed and oil palm are purchased more and more by biofuel companies. This increasing competition causes significant market distortions, causing unforeseen and potentially unwanted effects. At the same time, the increase in demand and market prices of rape oil, palm oil and, in the America's, sugar cane, soy oil and corn for biofuel production adds extra pressure on natural habitats. Stimulation of biofuels will probably result in increased conversion and clearing of these natural habitats for the creation of extra agricultural area's for cultivation of these crops.

Seeing the increasing impact of biofuel policies on the market for vegetable oils, Unilever commissioned CE Delft to make a script for a strategic study to provide insight in the effects of the various competing sectors, and in the limitations of land availability.

The fundamental system approach: energy, food and nature
The increase of the global population and changes in diets of people causes a continuing growth of the global demand and supply of food, both in the past and in the future. At the same time, the demand for biomass is increasing since an increasing number of countries is implementing policies to promote biofuels for electricity and transport, and increasingly ambitious goals and targets are set for the future. Both developments result in a considerable extra demand for agricultural produce and land. Furthermore, the food and biofuels sectors are competing for both biomass (such as vegetable oils) and agricultural land.

Biofuel policies therefore have an effect on the current balance between area for nature and agriculture for food, they also affect the markets for the raw materials used. Furthermore, biofuels may have an effect on human welfare, for example because of higher food prices.

Figure 1 The main values related to biofuels



Various studies have analysed the potential availability of biomass for energy and transport, but the ranges in the results are large. Key elements in the studies that predict large possibilities for biofuels worldwide are the following factors:

1 Intensification of world agriculture (to the European level, in some studies).
2 A drastic reduction of the global meat consumption by a change to other protein sources.

Without these options the studies conclude that there is only limited room for biofuels and bio energy, if the worlds biodiversity and nature are to be preserved to a large extent.

Biofuels policies and discussions worldwide

Biofuel policies are being implemented rapidly, on almost a global scale. In the EU, the biofuels directive has stimulated many Member States to set ambitious targets and provide incentives for biofuels. The USA has implemented the '2005 Energy Policy Act', that also sets targets and provides incentives for biofuels.

Most discussions on biofuels are about improving efficiency by changing to other technologies and sources, mainly by introducing so-called second generation biofuels. This will reduce costs, improve both GHG reduction and energy security, and reduce the direct competition with the food sector for raw material. In various member states of the EU there is also increasing concern about the potential negative effect of biofuels on biodiversity in countries like Indonesia and Brazil.

Relevant research

In the report, an overview is provided of the most relevant recent studies on land availability, biofuels and biodiversity. However, most studies contain regional assessments (EU, USA), and there are only a few studies that aim to quantify the global land availability, and the global potential for biofuels. Key factors in all of the studies are the assumptions on the development and intensification of agriculture in the world, and on the level of sustainability (e.g., biodiversity) that is assumed.

Macro figures

Forecasts for both food and (bio)energy/biofuel demand illustrate that both competition between food and biofuels and increased pressure on nature and biodiversity are inevitable, if the current growth in biofuel demand continues. Especially developments in agricultural land use and yield improvements are crucial for the intensity of this competition.

The following example can illustrate this. The worldwide prediction for energy use in 2020 is about 600EJ/yr. Of this, around 105 EJ is oil for transport use. Producing 20% of the total energy (120 EJ) from biomass would require 0,5 to 1 billion hectares for biomass cultivation. For comparison, the world agricultural land is now about 1,5 billion hectares for direct agriculture and 3,5 billion hectares for cattle grazing land.

Focus of further study

We recommend that the focus of further study on the topic of biofuels and land availability should be on the following issues:

a A **baseline scenario evaluation** study of land availability for food, biodiversity and climate change, assuming different biofuel percentages in the world.

b A study on the **possibilities of intensifying agriculture** worldwide and the effect on biodiversity, nature and food.

c A study on the possibilities and effects of a) **second generation biofuels**, b) **bio refineries** and c) improvements of the **efficiency of traditional biomass use**.

d A **comparison with other climate change and biodiversity policies** on effects, costs and public support

e **Two case studies** looking at the key issues of increased biofuels demand (e.g., competition with food, market distortions, effects on biodiversity). Our proposal would be to look at rapeseed and palm oil.

f An **overall report of the results** with a **clear policy advice**.

1 Introduction

1.1 Introduction

Many national and state governments in Europe and the United States are expanding their support for biofuels for transportation purposes. This has significant impact on the food sector, including Unilever, since most of the current sources for biofuels are also raw materials for this sector. Crops like rapeseed and oil palm, that are particularly important for Unilever, are purchased more and more by biofuel companies. These biofuel policies thus cause increasing competition and significant market distortion, thereby causing unforeseen and unwanted effects. Effects already clearly detectable now are increasing market prices for especially rape oil and to a lesser extent palm oil. Contrary to this, glycerine prices are sharply decreasing, glycerine being offered to the market at volumes far larger than before this biofuel increase. Food industries are thus faced with higher raw material prices and lower by-products income.

At the same time, this increase in demand and market prices of rape oil, palm oil and, in the America's, soy oil for biodiesel production adds extra pressure on natural habitats. Stimulation of biofuels will probably result in increased conversion and clearing of these natural habitats for the creation of extra agricultural area's for cultivation of these crops. This land change will come on top of the conversion already occurring in especially Indonesia and Brazil/Argentina for extra oil palm and soy area for application in food and feed industries. Demands on biofuels regarding sustainability may alleviate this in the future, but may also result in a shift toward less sustainable production chains for food crops.

Unilever is therefore interested in starting the debate in both Europe and the United States on this global competition for land. Is there enough land available to accommodate all current and future demands for land, including food and fodder production, bioproducts, biofuels and bio-energy, but also nature conservation, biodiversity, etc? What is the potential effect of this competition for land, in terms of deforestation, high food prices for poor people and displacement of problems from the transport sector to the food sector? And how can potential problems be prevented, for example by changing biofuels policies or other actions?

Unilever therefore asked CE to make a script for a strategic study to provide insight in the effects of the various competing sectors, and in the limitations of land availability. Furthermore, this strategic study should provide recommendations on how to proceed on these issues, aimed at governments and other stakeholders in the EU and the USA. This report is the result of this preliminary study, and provides the necessary background information and the script for further work.

1.2 Structure of this report

This report is build up along the following lines:

Chapter 2: An overview of the main biofuel market developments, including biofuel policies and drivers, with a focus on the EU and the USA.

Chapter 3: A discussion of the main issues and developments regarding the competition between biofuels, the food industry and biodiversity

Chapter 4: Overview of the relevant literature regarding the potential availability of biomass, the competition with the food sector and potential effects of increased use of biofuels on biodiversity.

Chapter 5: Conclusions and recommendations for further studies, the script for further work

Chapter 6: Draft policy suggestions

A more extensive literature overview can be found in Annex A, the main actors in the biofuels land availability discussions are listed in Annex B. Annex C provides an overview of the global vegetable oil and oilseed markets.

2 Biofuel market developments

2.1 Introduction

In the 1970's, Brazil was the first country to implement significant biofuels policies, providing strong financial support to their national bioethanol production (i.e. sugarcane cultivation) sector. In recent years, an increasing number of other countries worldwide has implemented biofuels policies and incentives. These developments have led to a strong increase of biofuel production and use, as can be seen in the following figures that show the development of the global bioethanol and biodiesel production since 1975 and 1991 respectively.

Figure 2 Development of global fuel ethanol production, 1975-2005 (from WWI, 2006)

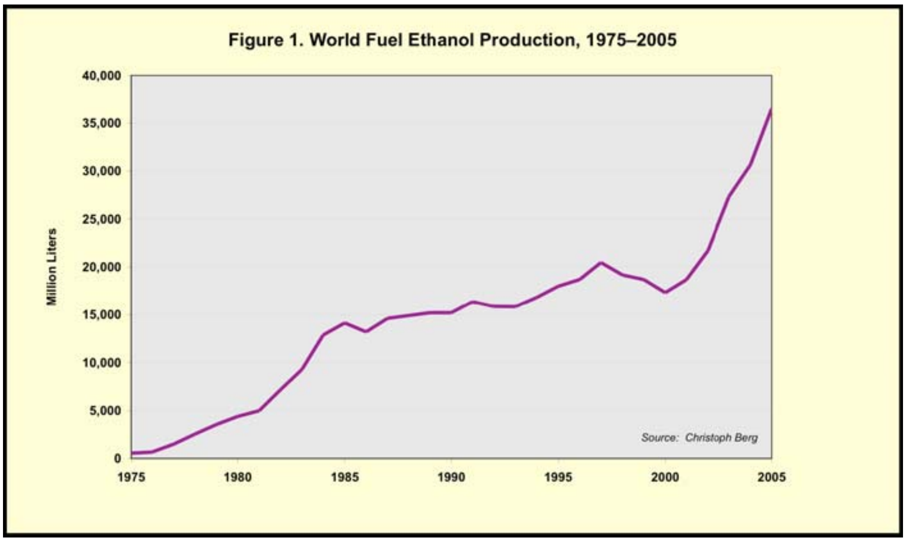
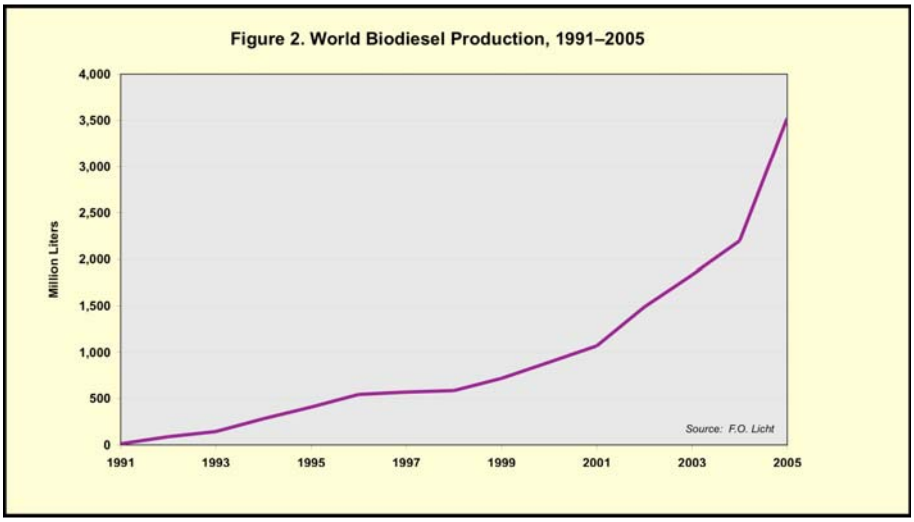


Figure 3 Development of global biodiesel production, 1991-2005 (from WWI, 2006)



Since even at current high oil prices most biofuels can currently not compete with diesel or gasoline, biofuels production and use is strongly dependant on government policies. The developments shown in the graphs are thus directly related to developments in biofuel policies, in Brazil, the EU, USA and other countries.

2.2 Drivers for biofuels policies

In the past years, an increasing number of countries worldwide has implemented biofuel policies. In most countries, the main drivers of these policies are concerns about security of oil supply and high oil price. Support for agricultural regions and climate policy are other drivers for biofuel policies.

To understand the current discussion about biofuels policies is it important to make a distinction between the traditional approach of biofuels in politics and a more realistic approach based on recent studies and discussions.

Traditional approach

The starting points and assumptions of the traditional policy approach to biofuel policies are the following:

1 Biofuels crops can be planted on set aside land and help farmers.
2 Biofuels will be planted and bought in the region.
3 Biofuels replace fossil fuels and help energy security.
4 Biofuels emit no greenhouse gas and contribute to reach the Kyoto protocol.
5 The greenhouse gas emissions of traffic are growing fast and biofuels are almost the only way these emissions can be reduced in the short term.
6 Biofuels are green and therefore beneficial for the environment.

Realistic approach

In the past years, it was found that these 6 propositions to support biofuels are not (completely) true, especially when we consider large scale biofuel use for transport in the EU, USA, China, Brazil and India. The biodiversity study of MNP (MNP, 2006) but also other research (such as (WWI, 2006)(EEA, 2006)(Concawe, 2006)) show that biofuels on a larger scale are influencing different policy goals in a complex way.

Regarding these 6 statements, the following can be said:

- Even optimistic studies about bio-energy and biofuels (like the Grain study of Faaij) conclude that worldwide set aside land is not enough to produce a substantial amount of biofuels. In the EU, the cultivation of oilseeds for biodiesel on set aside land has been limited in the Blair House Agreement (which limits oilseed production on setaside land to 1 mio t of soybean meal equivalent) (DG Agri, 2005). Furthermore NGO’s like Birdlife International claim that set aside land has a high nature value and production on this area is harmful for birds and biodiversity[1].

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[1] http://www.birdlife.org/news/features/2006/06/biofuels.html

- Biofuel crops and biofuels themselves are imported and exported all over the globe. Most of Swedish ethanol comes from Brazil and the UK and the Netherlands use Indonesian palm oil for bioenergy. Even rice husk in Thailand is interesting for energy companies in Europe.
- Especially in the USA there is a lot of discussion about the fossil fuel replacement ratio of ethanol from corn. Some researchers say that there is no replacement at all, others claim a ratio of 1.5. This means that 1 GJ ethanol only replaces net 0.33 GJ fossil fuel. For other biofuels this replacement ratio can be higher (see e.g., (Concawe, 2006) for an extensive overview). Especially second generation biofuels have a better performance.
- Because of fertilizer use, carbon released from the soil, energy necessary for production, etc, the greenhouse gas reduction of biofuels generally varies between 10% and 90%. The actual GHG balance may even be lower than most studies claim, since the GHG emission caused by changing nature into biofuel production area is often not included in the calculations.
- There are other options to reduce GHG gases in the transport sector. For example, the efficiency of cars can be improved (new technologies such as hybrid cars have entered the market in the past years). Alternatively, the transport sector may contribute to GHG reductions by paying for GHG reductions in other sectors that can reduce the GHG emissions much cheaper.
- Biofuels may contribute to the reduction of GHG. However, as large scale biomass cultivation generally has a negative effect on biodiversity (as for example the study by MNP for the UNEP (MNP, 2006) concludes), in general biofuels can not be claimed to be completely green.

Greenhouse gas reduction of biofuels

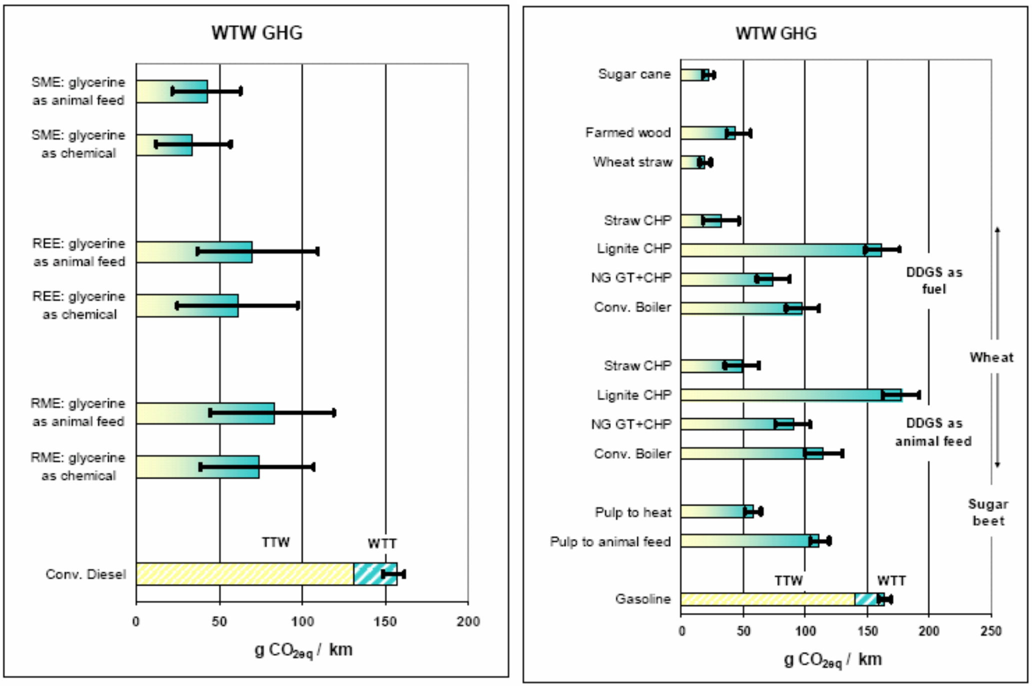
In recent years, a number of studies have been carried out in order to estimate the net greenhouse gas reduction that is achieved with biofuels. These studies use life cycle analysis (LCA) methodology, in which the whole chain of the biofuels (from plant to vehicle) is compared to the chain of the fossil fuels that are replaced (from well to vehicle). The outcome of one of various studies sometimes differ, according to the assumptions used regarding processes, agricultural practices and reference land use. Some conclusions, however, can be drawn:

- GHG emissions of different biofuels may vary significantly.
- If a feedstock is used that requires significant amounts of fertiliser (e.g., rapeseed), the

In 2006, JRC/Concawe/Eucar jointly issued an update of the ‘Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context’. Various alternative fuels were assessed in this report, including various types of biofuels. In the graphs below, the GHG emissions of biodiesel and bioethanol are shown, as calculated in that study. The figures illustrate the significant variation of GHG emissions of biofuels.

Figure left:. GHG emissions of types of biodiesel, made from sunflower (SME) and rapeseed (REE, RME), with two options for use of the byproduct glycerine

Figure right: GHG emissions of bioethanol, produced from various types of raw material (sugar cane, famed wood, wheat straw), using different processing options, and two options for use of the pulp that results in case sugar beet is used as feedstock.



Note: SME stands for sunflower methyl ester, RME stands for rapeseed methyl ester, REE stands for rapeseed ethyl ester, CHP stands for combined heat and power, NGGT stands for next generation gas turbine. DDGS stands for dried distillers grains with solids. This is a co-product of the ethanol production process that can be used as heating fuel or animal fodder.

The cost/benefit ratios, including cost of CO_2 avoidance and cost of fossil fuel substitution crucially depend on the specific pathway, by-product usage and N_2O emissions. Ethanol from cellulose could significantly increase the production potential at a cost comparable with more traditional options or lower when using low value feed-stocks such as straw. New processes are being developed to produce fuels from lignocellulosic biomass. These fuels offer lower overall GHG emissions, though still have a high energy use. Developments may be accelerated by promoting R&D of these processes, as well as their market implementation due to government incentives.
Souce: [EEA, 2006], from [Concawe, 2006]

2.3 Biofuels and their relation to policy issues

As mentioned earlier, there is a variety of reasons for different countries to establish biofuel policies and targets. Even though these may be part of an overall renewable energy programme, diversification of transport fuels has special attention world wide because of growing concerns about oil import dependence and security of supply.

In general, three main drivers of biofuel policy may be distinguished :

1 Climate change: reducing CO_2 emissions.
2 Security of supply: increasing fuel (-provenance) diversity.
3 Rural development: finding new applications for agricultural products.

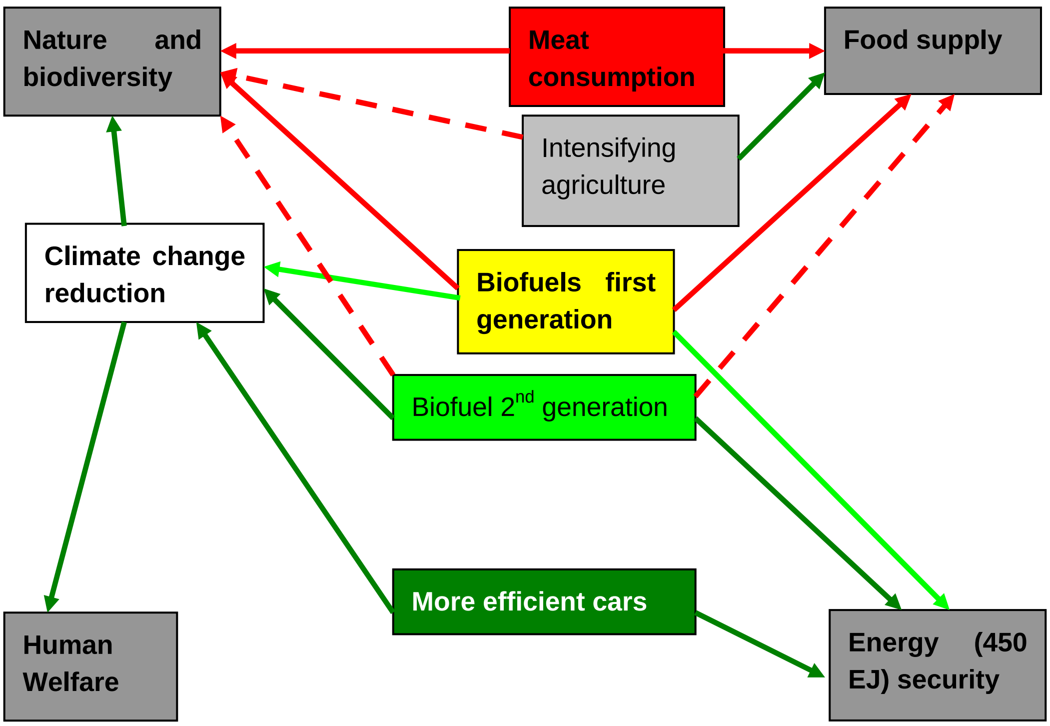
Furthermore, air quality is sometimes mentioned as a reason to promote biofuels. However, the air quality benefits (i.e. reductions of NO_x, SO_2 and other pollutant emissions) are probably very limited, and not yet well quantified.

A valid question to ask is what in turn the drivers behind those factors are, especially in the case of climate change. Climate change is thought to have potential damaging effects in several areas, such as human health and safety and economic development, but also on biodiversity. This question is relevant because the land use that is needed for biofuel production may have also effects on nature and biodiversity, as well as on food supply and rural development.

Figure 4 gives indicative relations between biofuels and these key values. The red lines mean negative effects, red dotted line smaller negative effects and the green line means positive effects (dark green large effects en light green small).

In this figure special attention has been given to meat consumption and the possibilities for intensifying agriculture. This are the key factors that determine future land use and the competition for land between biofuels and food/feed (Hoogwijk, 2003). If the meat consumption of the world population increases, the food sector requires more land for food production. Less land will be available for biofuels. However, if global agriculture can intensify (i.e. increase yields per hectare), more biofuels can be produced. Clearly, control of these factors is limited. Reducing global meat consumption (against the current trend of increasing meat consumption, e.g., in countries like China and India) will prove difficult. Regarding intensification of agriculture there are questions about water supply, fertilizer use and the effect of this on world biodiversity.

Figure 4 Policy targets concerning biofuels and their relations



The figure illustrates that first generation biofuels based on crops like corn and rapeseed have a potential direct negative influence on food supply, mainly because it uses the same crops as the food industry uses. Furthermore, these biofuels have a direct negative effect on biodiversity and nature, because set aside land is put into production again and extra nature (i.e. previously uncultivated land) is converted into agricultural land. According to (MNP, 2006) this conversion leads to a loss of 90% of the biodiversity in these area's. First generation biofuels have a moderate positive effect on climate change which is positive for human welfare and biodiversity.

The net effect of biofuels on biodiversity

The climate change effect has a negative effect on global and regional biodiversity. Therefore, reducing greenhouse gas emissions, for example by replacing fossil fuels by biofuels with significant GHG reduction, will contribute to the conservation of biodiversity. However, large scale cultivation of biomass for biofuels has a negative effect on biodiversity as well, since cultivated land has a lower biodiversity than uncultivated land. The MNP (MNP, 2006) compared both effects, and concludes that the net effect of biofuels on biodiversity is negative, at least for the first 50 years. After that period, the positive effect of reduced climate change is expected to outweigh the negative effect of the biomass cultivation.

In reality, this might even be an optimistic estimate. The model MNP used has three optimistic assumptions, we concluded from contact with MNP. First, the bio-energy scenario also includes energy savings and wind energy so the GHG reduction is not only caused by biofuels. Furthermore the GHG emission of biofuels is assumed to be zero which is also too optimistic. The third positive assumption is that GHG emissions of changing forest into agricultural land are not taken into account. On the other hand, the study assumes that biomass cultivation for biofuels is as detrimental for biodiversity as "traditional" agriculture. This may be a pessimistic assumption, especially when perennial crops are cultivated for second generation. However, it seems unlikely that this positive potential exceeds the three optimistic assumptions.

For second generation biofuels, all these effects may also occur, although some effects will be stronger and others weaker. Because second generation biofuels do not compete on crops but only on land (most use woody biomass as feedstock) the competition is less direct. Furthermore their GHG reduction effect is probably larger, and their impact on biodiversity may be lower. It is not yet clear whether the area necessary for second generation biofuels will also be lower (see section 3.5).

This positive effect on climate change and negative effect on biodiversity raises once again the question why we have climate change policies. In most countries this is not really clear. As mentioned above, human health and economic welfare as well as preventing biodiversity losses are typically mentioned. For NGO's climate change is a problem mainly because of resulting biodiversity losses. Note that in the transport sector GHG emissions can also be reduced with more efficient cars (hybrids etc). This option has positive effects on both energy security and climate change.

2.4 Biofuels policies in the EU

In the EU, the most relevant policies are the specific policies concerning biofuels and renewable energy. The biofuels policies were initiated with the Biofuels Directive, in 2003 (2003/30/EC). Indicative biofuel targets were provided in this directive, of 2% in 2005 and 5.75% in 2010, and Member States were urged to implement national targets and policies in line with this directive. In addition, a supporting directive was adopted that allowed tax reductions for biofuels (to a maximum of the additional costs of the biofuels, directive 2003/96). The biofuel directive has led to the strong increase of biofuel production and use in the EU in recent years, driven by the rapid implementation of biofuel policies and incentives in most of the EU Member States. Regarding biomass in electricity, the EU agreed in 2001 that the share of electricity from renewable energy sources in the EU consumption should reach 21% by 2010 (including hydro, wind and biomass). Since then, a number of policies have been implemented both at EU and Member State level to achieve this goal.

The main driving forces behind the biofuels and renewable energy directives are improving security of supply and climate change. The biofuels directive also aimed to support the agricultural sector.

Biofuels and bioenergy currently have a lot of attention at the EC. At the end of 2005, the EU has issued the Biomass Action Plan (COM(2005) 628), in which the main issues of biomass in its various applications are discussed. This plan was followed up with “An EU Strategy for Biofuels” (COM(2006) 34, 8.2.2006), which focussed solely on biofuels. A more general paper on energy, the Green paper “A European Strategy for Sustainable, Competitive and Secure Energy” (SEC(2006) 317) was also issued earlier this year.

The biofuels directive is currently under review, a public consultation has just been carried out. This review is part of the European Strategic Energy Review, planned for end 2006. The main conclusions drawn from the consultation were

- Biofuels still worth promoting to help achieve energy policy goals.
- 2010 targets will not be met.
- Main barriers to biofuel development.
- Investment and production costs.
- Policy uncertainty and inconsistency in national approaches.
- policy, standard and technical restrictions on high blends.
- Feedstock constraints (land use competition).
- Suggestions: mandatory targets, sustainability criteria/certification, national policy harmonisation, post 2010 targets.

To remove legal and technical barriers to the increasing use of biofuels, the standards and fuel quality directive is also being reviewed. Furthermore, the EC has announced in the Green Paper mentioned above that it will issue a Renewable Energy Roadmap early next year. This roadmap will address renewable energy in transport, electricity and heat. Furthermore, the EC is currently developing a directive for renewable heat, in line with the biofuels directive. Public consultations on the Green Paper and on the "Promotion of Heating and Cooling from Renewable Energies" are currently ongoing.

2.5 Biofuels policies in the USA

The most recent policies for biofuels are listed in the “2005 Energy Policy Act” . This act focuses on lowering the dependency on oil from the Middle East. Measures targeting biofuels are :

- Extending biodiesel tax credit; $0,50 per gallon for waste-grease diesel and $1,00 for agribiodiesel. Extra tax credit for small (agribiodiesel) producers and inclusion of production by thermal depolymerisation.
- Producer credit for small ethanol producers.
- Assessment of energy security and environmental benefits of biodiesel as a potential large-scale sustainable alternative.
- Renewable fuel standard requirement for 2006 : 2,78% volume blending.
- Alternative motor vehicle credit (may be applicable for biodiesel).

The act establishes a Renewable Fuels Standard, that requires the use of 7.5 billion gallons of ethanol and biodiesel by 2012. In the textbox below, the timeline is given.

What is the Renewable Fuels Standard Program?

Section 1501 of the Energy Policy Act of 2005 (the Act) describes the renewable fuel program, also known as the Renewable Fuel Standard (RFS) program. This provision was added to the Clean Air Act as Section 211(o), and requires EPA to establish a program to ensure that U.S. gasoline contains specific volumes of renewable fuel for each calendar year 2006 through 2012, as shown in Table II.A-1 below.

Table II.A-1.--Applicable Volumes of Renewable Fuel Under the RFS

Calendar year	Billion gallons
2006..	4.0
2007..	4.7
2008..	5.4
2009..	6.1
2010..	6.8
2011..	7.4
2012..	7.5

Starting with 2013, EPA is required to establish the applicable national volume which must require at least the same overall volume percentage of renewable fuel as was required in 2012.

In order to ensure the use of the renewable fuel volume specified for each year, the Agency must set a percentage standard for each year representing the percentage of gasoline sold or introduced into commerce which must be renewable fuel. The standard is to be set based on the renewable fuel volumes shown in Table II.A-1 and gasoline volume projections provided by the Energy Information Administration (EIA).
The standard for each year must be published in the Federal Register by November 30 of the previous year.

Renewable fuels are defined in the Act primarily on the basis of the feedstock. In general, renewable fuels must be produced from plant or animal products or wastes, as opposed to fossil fuel sources. The Act specifically identifies several types of motor vehicle fuels as being encompassed by the definition, including cellulosic biomass ethanol, waste-derived ethanol, biogas, and biodiesel.

The percentage standard is applicable to refineries, blenders, and/or importers, as appropriate. The percentage standard must be adjusted such that redundant obligations are avoided, and must take into account the fact that small refineries are exempted from the program through 2011.\1\ For liable parties, the RFS standard must be met on an annual averaging basis and does not apply on a per-gallon basis.
Source: EPA

ADVANCED ENERGY INITIATIVE (USA)
Virtually all domestically produced ethanol currently comes from corn. However, corn and other starches and sugars are only a small fraction of biomass that can be used to make ethanol. A recent DOE/USDA study suggests that, with aggressive technology developments, biofuels could supply some 60 billion gallons per year - 30% of current U.S. gasoline consumption - in an environmentally responsible manner ***without affecting future food production****.*

To achieve greater use of "homegrown" renewable fuels, ***we will need advanced technologies that will allow competitively priced ethanol to be made from cellulosic biomass****, such as agricultural and forestry residues, material in municipal solid waste, trees, and grasses. Advanced technology can break those cellulosic materials down into their component sugars and then ferment them to make fuel ethanol.*

To help reduce the costs of producing these advanced biofuels, and ready these technologies for commercialization, the President's 2007 Budget increases DOE's biomass research funding by 65%, to a total of $150 million. *The President's goal is to make cellulosic ethanol cost-competitive with corn-based ethanol by 2012, enabling greater use of this alternative fuel to help reduce future U.S. oil consumption.*

The energy bill also provides a 30% tax credit for installation of alternative fuel stations, up to a maximum of $30,000 per year. Currently only 556 public "E85" (85% ethanol) fuelling stations exist in the U.S, and many more will be needed to increase the use of renewable fuels above the 10% that can be blended into conventional gasoline.

In the "National commission on energy policy" biofuels were debated extensively on November 15, 2005[2]. This bipartite commission released earlier a document on energy policies "Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges.[3]" This commission is very critical about the poor energy ratio of bio-ethanol produced from corn. The main conclusion of this commission is that cellulosic ethanol is the most promising gasoline alternative. A program to make these fuels competitive with corn based ethanol is initiated. The policies are supported through the National Biomass Initiative[4]

2.6 Biofuels policies in the rest of the world

Brazil is currently the world's largest producer of biofuels, predominantly bioethanol from sugarcane. Brazil started an extensive programme to promote this domestically produced fuel (with considerable government support) in the 1970s. The current policies include an official blending ratio of ethanol with gasoline of 20-25% and a lower excise duty tax on ethanol. From 2007 onwards, a biodiesel obligation of 2% comes into force as well, which will increase to 5% by 2013 [OECD, 2005]. This policy measure is complemented with a support programme for the cultivation of castor-oil plants for biodiesel production.

In many other countries all over the world, biofuel policies are emerging as well. Examples are India, Thailand, some regions of China, Australia, Canada and Japan [OECD, 2005]. Most of these countries mainly promote ethanol. Driving

[2] http://www.energycommission.org/site/page.php?testimony=11

[3] http://www.energycommission.org/site/page.php?report=13

[4] http://www.biomass.govtools.us/news/DisplayRecentArticle.asp?idarticle=239

forces of these policy developments are security of supply, the high oil price, and the aim to support national agriculture.

2.7 Time line biofuels targets worldwide

In the table below, an overview of the current and future biofuel targets is provided for a number of countries, for the coming years and decades.

Table 1 Biofuel policy targets or goals, E10 indicates 10% blending ethanol, B2 a 2% blending of biodiesel, etc. Some sources give contradictory targets e.g for Japan, Thailand

		2006	2008	2010	2011	2012	2020	2030
USA	federal	2.78%				>7.5 Gallon/a (~E5)		30%
	Individual states	E10, B2						
EU	union			5.75%				
	Individual countries	E5 – B100						
India	federal				B20?		20%	
	Individual states	E10						
Brazil		25%						
Canada	federal			3.5%				
	Individual states	E5						
Japan		3%	10%	500,000ML ?				
Thailand				2%?	B2, E10			
China	federal							
	Individual states	E10						

2.8 Bio energy and bio chemistry

Besides goals for biofuels many countries also stimulate bio electricity, bio heat and sometimes bio chemistry (especially bio plastics for packaging). The main source for bio electricity in the world is wood, waste wood and waste from the wood industry. In addition, manure, sewage sludge and other biogenic waste are also significant sources for bio electricity and heat. The next ten years these sources will not compete directly with the oils and fats produced for Unilever because these are different markets and production regions.

However, in recent years electricity producers in a number of European countries have started to use palm oil as a source for bio electricity, because of its relatively low cost. This oil is also used in the food industry, leading to direct competition between the two industries. This usage of an edible oil connected with deforestation for green electricity has lead to a lot of debate especially in the Netherlands, the UK and now also in Germany. Despite this debate the usage of palm oil for bio electricity is still expanding.

2.9 Comparing biofuels policies with other policy measures

Biofuels as a policy option should be compared to alternative policies both for climate change and for energy security, which are by far the most important drivers.

Regarding energy security, projections for oil import dependence for 2020 are almost 50% for North America, about 70% for China and up to 90% for the EU, Japan, Korea and India (source: Clingendael & IEA, 2004). The capability to produce biofuels domestically, and the possibility to import fuels from a larger variety of countries are therefore some of the main advantages of biofuels.

A crucial factor for biofuels - and in fact all biomass - to be effective both in terms of climate change and security of supply is the so-called *energy ratio*. This is the ratio between the (renewable) energy delivered and the cumulative fossil energy use in the production chain of a unit of the fuel (including feedstock). For example, the energy ratio of bioethanol from corn is rather low (1,3-1,5), mainly because of fossil energy use during production of the crop and production of fertilizers. This has led to an intense debate in the USA, because this means that the contribution to energy security of this product is rather low. Brazilian bioethanol produced from sugarcane claims to achieve an energy ratio of 5.

Alternative climate change policies

Besides biofuels there are also other climate change policies. We propose to compare biofuels with the following three alternative measures:

1. More efficient cars (hybrid, etc.).
2. Energy from waste.
3. Energy form coal with CO_2 sequestration.

The first option is also in the transport domain and scores good on energy security and climate change. Drawback are the costs of the measure.

The second option is often forgotten but research from CE concluded (source: Trendwatching study CE 2005) that more than 5% of the electricity production in the EU can be produced from waste that is landfilled today. Because of the significant methane spill at landfills the greenhouse gas reduction of this option is also very large.

Worldwide the use of coal (which is still available for hundreds of years) for energy or fuels, in combination with CO_2-sequestion is also an interesting technique for comparison. This option has a better performance on many of the main policy goals than biofuels.

Comparing biodiversity policies

Very interesting in the MNP study on policy options to protect biodiversity (MNP, 2006) is the fact that also other policies were analysed that can have a positive effect on biodiversity. The study concludes that almost all policies fail, except for one: lowering the meat consumption has a very positive effect on biodiversity.

Because of the large area which is necessary for meat production this policy also has very positive effects on the food supply

Faaij (University of Utrecht) argues in the Grain study that a worldwide intensification of agricultural production up to the European level would be possible, necessary and desirable (Hoogwijk, 2004). How this would be done is not made clear in his studies. WWF reacts to this that intensifying agriculture is also bad for biodiversity. We think that this question of the potential and the pros and cons of intensifying agriculture is a key question regarding the issue of future land availability for food, energy and nature.

3 Competition between biofuels, the food industry and biodiversity

3.1 Introduction

As illustrated in the previous chapter there is a political ambition in many countries to increase biofuels production and usage as either a means to become less dependent on fuel imports, as a measure to reduce greenhouse gas emissions in the transport sector or as a measure to support the agricultural sector. Though biofuels can indeed be beneficial to achieve these goals, it was argued that increased production of biofuels can also have adverse economic, social and environmental effects.

From the literature sources on this topic (see e.g. the literature overview in Annex A), we conclude that the main potential negative impacts of increased biofuels production are related to the environmental effects of biomass cultivation, and to the availability of food and raw materials for food production:

- Environmental effects:
    - Deforestation and clearing of other natural habitats and resulting indirect impacts, e.g.:
        - biodiversity loss;
        - enhanced greenhouse gas emissions due to land use change;
    - Drought from changes in precipitation patterns, resulting from deforestation.
    - Drought from water consumption for irrigation (compare Aral sea).
    - Erosion and soil fertility loss due to over cultivation and soil exhaustion.
    - Emissions of eutrophicating and acidifying compounds
- Availability of food and raw materials:
- Substitution of crops grown for raw materials or food by biofuels feedstock (compare the substitution of rubber plantations by oil palm plantations in Malaysia).
- Scarcity on the market of raw material in case of direct competition for this raw material between biofuels production and other applications – resulting in increased prices of the raw material, etc. (see for example the effect of increased rapeseed use for biodiesel in the EU).
- Increased vulnerability of local economies in case of monoculture agricultural systems[5]

Negative impacts result partly from incorrect land management (erosion, emissions, water scarcity) but also from increased requirements for agricultural land, or intensification of existing agriculture.

Global population increase and economic growth have resulted in increased pressure on natural habitats by the increased demand for agricultural acreage for food production, resulting in loss of natural habitats and biodiversity. These adverse effects already occur within current agriculture for cash crop production

[5] The collapse of the local economy in certain regions in the Philippines after the switch of the North American beverage industry from sugar cane sugar to isoglucosis illustrates the vulnerability of agriculturally economies that are dependent on one cash crop.

in e.g. Brazil and Indonesia. This mechanism will probably intensify in the future as a result of further population increase and economic growth. Increased biofuels production on top of this mechanism requires even more land and will thus further increase the pressure on natural habitats[6].

In addition, increased demand for agricultural products or byproducts traditionally applied as food or raw material by the biofuels sector can result in scarcity and price increase for these (by-)products.

In the following paragraphs, we will look further into the issue of competition between biofuels, food production and biodiversity. We will provide a first overview of biofuel crop cultivation and its potential environmental impacts. Also, an overview of the markets for crops and their fruits that are potential raw materials for current biofuels is given.

3.2 Developments in population and economic wealth and resulting food and energy consumption

Land requirements for agriculture are related to both size of population and economic wealth, which largely determines the amount and nature of purchased foods.

As can be seen in **Fout! Verwijzingsbron niet gevonden.**, global population is expected to increase from current 6,5 billion people to approximately 7,5 billion people in 2020[7], year of focus in this study[8]. Furthermore, economic wealth as expressed in GDP, is expected to increase with 225% (OECD-FAO, 2006) compared to current level.

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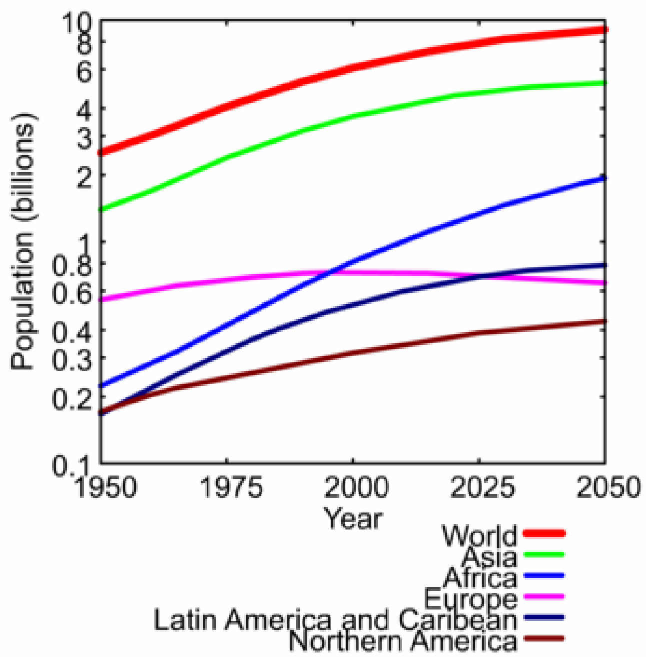
[6] Note that the demand for feedstock for bioenergy and for biobased industrial raw materials production for example natural fibres, wood, starch, etc is also likely to increase.

[7] See also WNA, 2004), (OECD-FAO 2006).

[8] In this estimation decrease in annual population growth as a result of a decreasing number of children per family was incorporated.

Figure 5	Prognoses for population growth per continent



Source: http://en.wikipedia.org/wiki/World_population, from United Nations World Population Prospects, the 2004 Revision Population Database.

The result of both mechanisms is anticipated to be an increase in food consumption with 20% - 50% and an increase in energy consumption with about 50%, compared to 2003 (see Figure 6 and Figure 7). Predictions for increases in use of construction wood, fibre crops etc have not been found. The higher increase in meat and sugar demand relative to basic requirements as cereals gives an indicates of the additional effect of increased prosperity next to increase in population[9].

Figure 6	Forecasts for food consumption growth (based on OECD-FAO, 2006)

[9] Note that forecasts as published by OECD-FAO and IEA are based on computer models, and current policies and developments.

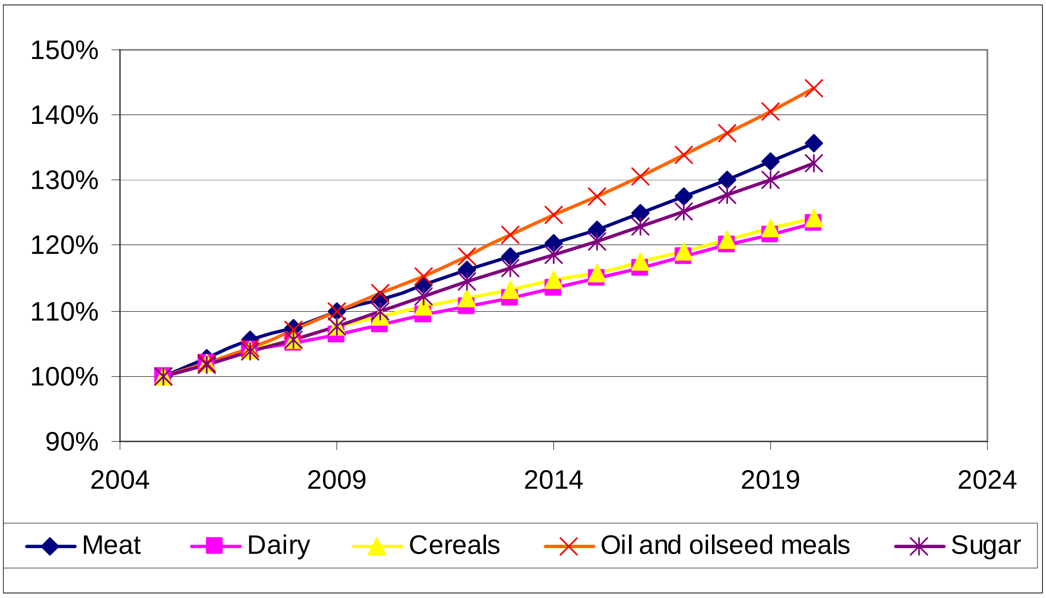
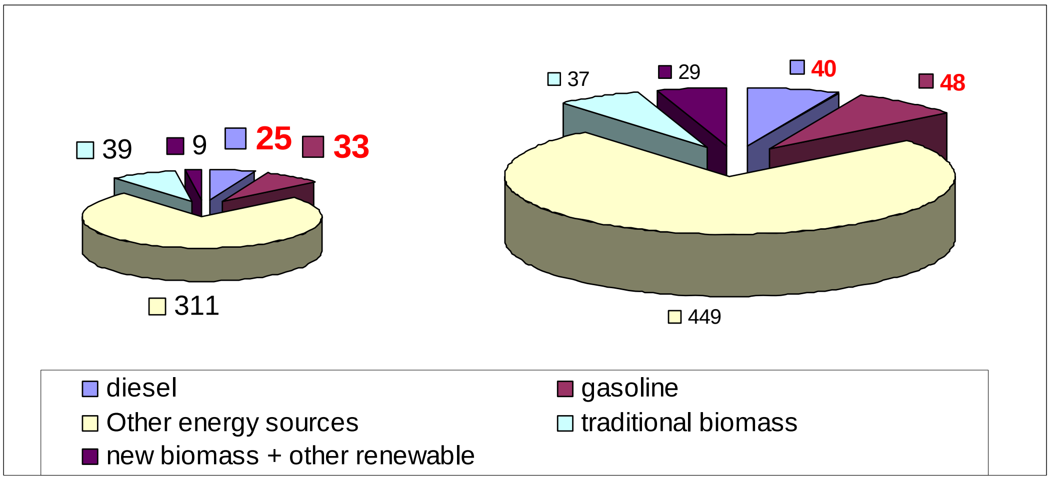


Figure 7 Forecasts for energy consumption (WEO, 2004), all figures in EJ/year



The expected increase in 'new biomass and other renewables (wind, solar) is markedly and illustrates anticipated effects of global greenhouse gas policies. The requirement for 'new biomass' partly concerns the issue considered in this report, but also refers to biomass for electricity. Production of biomass for electricity generation will further increase land requirements if the biomass feedstock is cultivated and doesn't concern residues from e.g. wood industry.

3.3 Developments in land availability and requirements

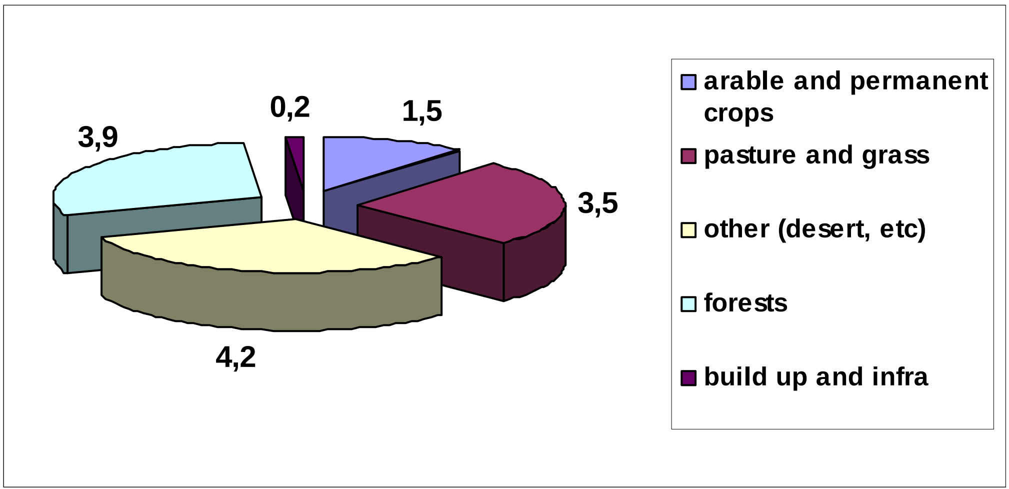
The question that comes up concerning expected increases in consumption of food and energy – especially biomass - is whether the available land area can support and produce the required amounts of food and biomass for energy and industrial appliations.

Current global land use is illustrated in Figure 8.
Out of the total of 13 billion ha, a total of approximately 5 billion hectares are used for food crops and animals and industrial crops:

- 1,5 billion hectares as arable land
- 3,5 billion hectares as pasture.

The current area of fertile soils in forests amounts to approximately 4 billion hectares (UNEP, 2002),

Figure 8 Current global land use (UNEP GEO)[10]



Indications on increase in crop land and pasture vary:

- In UNEP, 2002 expansion of arable land is forecasted to amount to approximately 0,1 billion hectares by 2030.
- However in the same source current loss of forested area amounts to an approximate gross 16 million hectares per year of which 70% is turned into arable land. This loss is partly offset by creation of 5 million hectares of forests each year in the shape of e.g. wood plantations.

About 2 billion ha of soil, equivalent to 15 per cent of the Earth's land area, have been degraded through human activities in earth's history resulting in soil with greatly reduced agricultural productivity (Table 2).

Table 2 Degenerated areas of agricultural land (UNEP, 2002)

Area degenerated (billion hectares)	
0,58	Deforestation - vast reserves of forests have been degraded by large-scale logging and clearance for farm and urban use.More than 220 million ha of tropical forests were destroyed during 1975-90, mainly for food production for an extra 1,2 billion people.
0,68	Overgrazing - about 20 per cent of the world's pasture and rangelands have been damaged. Recent losses have been most severe in Africa and Asia.

[10] UNEP GEO data portal: http://geodata.grid.unep.ch/

0,14	Fuelwood consumption - about 1,730 million m^3 of fuelwood are harvested annually from forests and plantations. Woodfuel is the primary source of energy in many developing regions.
0,55	Agricultural mismanagement - water erosion causes soil losses estimated at 25 000 million tonnes annually. Soil salinization and waterlogging affect about 40 million ha of land globally.
0,02	19.5 million ha Industry and urbanization - urban growth, road construction, mining and industry are major factors in land degradation in different regions. Valuable agricultural land is often lost.
1,97	Total

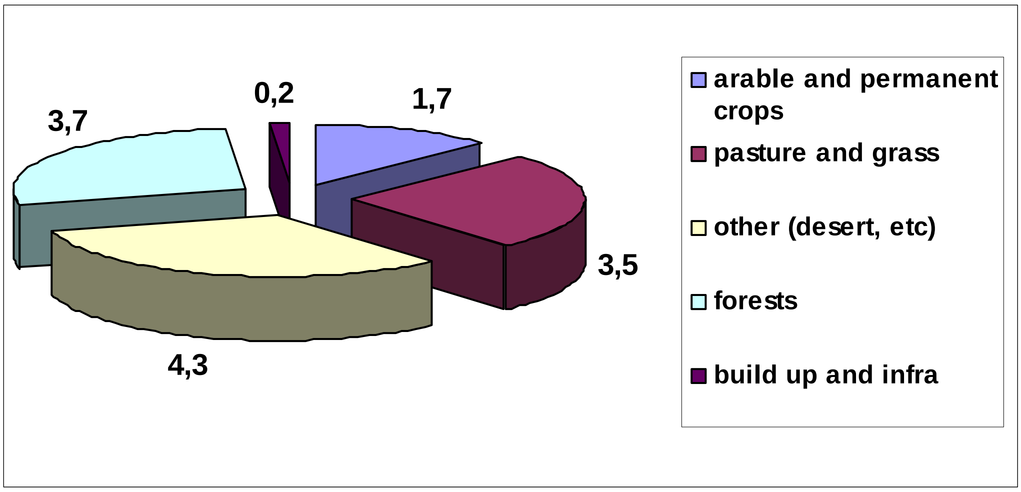
At present as a result of land degradation 6-7 million hectares of fertile soils are eliminated from the world's agriculture turnover annually[11]. These areas turned into deserts.

A projection on the basis of these indicative figures – forest conversion to arable land and pasture at a rate of 16 million hectares, degradation of 6-7 million hectares annually - results in the land use forecast given in Figure 9.

The increase in arable land and pasture land projected on the basis of the (current) indicative land degradation rate and forest conversion rate results in an increase of arable land and pasture of respectively 8% and 1%. This is clearly less than the anticipated increase in consumption of food of 20% - 50%.
For matching increase in food consumption with the projected arable land and pasture area in 2020 two strategies can be applied:

- Increased yields of crops and meat per hectare.
- Increased rate of conversion of land
- Reduction of consumption – especially meat - in the developed countries in the North.

Figure 9 Forecast for global land use in 2020



So whether currently available land will be sufficient to feed coming generations whilst preserving global and regional biodiversity remains to be seen. It depends on many aspects, and increased biofuel and bioenergy production is probably

11 http://enrin.grida.no/aral/aralsea/english/land/land.htm

only achievable by further intensification relatively to the intensification level already required for production of enough food.

The question whether agricultural land will yield enough food to feed global human population is of course strongly related to the question whether there will be agricultural land available for energy crops cultivation. Should energy crops be cultivated at agricultural land at all or should biomass for energy be extracted solely form degenerated soils, oceans and production forests? Clearly, this will probably require large efforts and investments.

3.4 Intensification of agriculture

Intensification of agriculture has since many decades been a spearhead in global agricultural policies. Examples are the Green Revolution in the sixties and seventies of past century and current efforts in integrated pest management.

Agricultural innovations have allowed increasing crop yields in the past. The potential for further yield increases may seem enormous, when looking for example at the differences in yield between developed and undeveloped countries: record yields of wheat in the Netherlands amount to 12 tonnes/hectare, compared to an average yield in Africa of just 1 tonne/hectare.

However, intensification is not that easy, given the experiences in Asia in the nineties (Environment, 1996), despite efforts with increased application of pesticides, fertilizers and adapted and genetically modified crops.

> *‘Heavy use of pesticides, for example, has turned out to be counterproductive in much of Asia's ricelands, and the practice of growing tow and even three crops of rice per year has depleted soil micronutrients. As a result, the spectacular growth of crop yields in the 1960s and 1970s has not been repeated recently. And given the difficulties with intensification, replicating that miracle will be neither easy nor automatic.’*

The potential hazards for soil fertility from intensification of agriculture is also illustrated by the fact that of 1,2 billion hectares or approximately 10% of earth’s land mass soil fertility has been degenerated because of overgrazing and agricultural mismanagement.

Next to this, intensification is also capital intensive, requiring high investments in machinery and other facilities. The question is whether farmers in developing countries can actually afford this kind of investments. Having the means doesn’t automatically mean high yields anyway. As illustrated by Dutch agricultural practices, agriculture is also a question of large efforts in management of soil - feeding the right dose of fertilizer and manure, keeping soil carbon content at a high enough level, preventing soils from compacting, allowing the right amount of water and water drainage, etc, etc. It will require much time to determine the best management practice for every region in the world, to supply farmers with the means that allow this kind of management and to teach farmers to manage soil in the optimum way.

Thirdly, potential for intensification is also limited by water availability. Effect of water availability is illustrated by for example a yield twice the yield from rainfed fields in the Sub Saharan countries in Africa.

Furthermore, research by the UNEP has shown that climate change is likely to have a negative effect on agricultural productivity, as illustrated in Table 3.

Table 3 Forecasted effects of global warming on agricultural land acreage and productivity (UNEP, 2002)

Africa	Grain yields are projected to decrease for many scenarios, diminishing food security, particularly in small food-importing countries. Desertification would be exacerbated by reductions in average annual rainfall, run-off and soil moisture, especially in Southern, Northern and Western Africa. Significant extinctions of plant and animal species are projected and would affect rural livelihoods, tourism and genetic resources.
Asia	Decreases in agricultural productivity and aquaculture due to thermal and water stress, sea-level rise, floods and droughts, and tropical cyclones would diminish food security in many countries of arid, tropical and temperate Asia; agriculture would expand and productivity would increase in northern areas. Climate change would exacerbate threats to biodiversity due to land-use and land-cover change and population pressure in Asia.
Australia, New Zealand	In Australia and New Zealand, the net impact on some temperate crops of climate and CO_2 changes may initially be beneficial but this balance is expected to become negative for some areas and crops with further climate change. Some species with restricted climatic niches and which are unable to migrate due to fragmentation of the landscape, soil differences or topography could become endangered or extinct.
Europe	There will be some positive effects on agriculture in northern Europe; productivity will decrease in southern and eastern Europe.
Latin America	Yields of important crops are projected to decrease in many locations in Latin America, even when the effects of CO_2 are taken into account; subsistence farming in some regions of Latin America could be threatened. The rate of biodiversity loss would increase.
North America	Some crops would benefit from modest warming accompanied by increasing CO_2 but effects would vary among crops and regions, including declines due to drought in some areas of Canada's Prairies and the US Great Plains, potential increased food production in areas of Canada north of current production areas and increased warm-temperate mixed forest production.
Polar region	Polar Natural systems in the polar regions are highly vulnerable to climate change and current ecosystems have low adaptive capacity; technologically developed communities are likely to adapt readily to climate change but some indigenous communities, in which traditional lifestyles are followed, have little capacity and few options for adaptation.
Small islands	The projected sea-level rise of 5 mm/year for 100 years would cause enhanced coastal erosion, loss of land and property, dislocation of people. Limited arable land and soil salinization makes agriculture of small island states, both for domestic food production and cash crop exports highly vulnerable to climate change.

3.5 Land requirements of biofuels

When looking at the major biofuels available on the market in terms of market share in 2007/2010 the focus has to be on the so-called first generation fuels: biodiesel and ethanol produced on the basis of sugars and oils derived directly from agricultural crops or residues.

An alternative we might also consider is biogas produced by anaerobic digestion of e.g. energy corn. This technology is commonly applied for decentralized power and heat production with gas engines. However in Sweden biogas is also applied as an automotive fuel and as a fuel in trains. Since biogas production from e.g. optimized corn varieties gives a higher yield of automotive fuels per hectare than even sugar cane it might be an attractive alternative to both other first generation biofuels, from an ecological point of view. Costs of biogas are, however, high, compared to other types of biofuel.

For 2020 the general opinion is that by then Fischer Tropsch and ethanol produced from ligno cellulosic feedstock will have become mature technologies. A scenario often anticipated is that these technologies will at first instance compete with first generation biofuels utilizing first-of-a-kind plants, but after having become mature will replace the first generation technology. However, it might well be possible that both types of biofuel will be used in parallel. This will depend on costs, feedstock availability and government policies (CE, 2005).

Competing alternative technologies to Fischer Tropsch and second generation ethanol production technology (i.e., outsiders in this competition) are technologies based on hydrolysis and pyrolysis, such as HTU (CE, 2004) and Thermal Conversion Plant (TCP), currently demonstrated with a commercial scale installation in Carthage (USA). These technologies receive little attention up to now, but might in the end prove a more attractive alternative

The different biofuels can be produced from the crops mentioned in Table 4 and Table 5 (for first and second generation biofuels respectively) and in the regions mentioned in this table. Furthermore, especially the 2nd generation biofuels can be produced from residues from food/fodder production and forestry, such as straw. HTU and TCP technologies can also convert wet organic waste streams.

Table 4 Crops applicable as raw material source for the current biofuels considered in this study

	Biodiesel				Ethanol					
Crops	Oil palm	Rape	Sunflower	Sopy	Sugar beet	Sugar cane	Sweet Sorghum	Cassave	Corn	Wheat
Region of cultivation (potential)										
South East Asia	X					X	X	X	X	
Latin America	X		X	X		X	X	X	X	X
Africa	X					X	X	X	X	
North America		X	X	X					X	X
EU25		X	X		X				X	X

Table 5 Crops applicable as raw material source for the future (2nd generation) biofuels considered in this study

	Fischer Tropsch			Innovative ethanol production process			HTU, CPT,….		
Crops	Wood	Stalk and blade crops and residues (e.h.g straw)	Wet biomass and residues	Wood	Stalk and blade crops and residues (e.h.g straw)	Wet biomass and residues	Wood	Stalk and blade crops and residues (e.h.g straw)	Wet biomass and residues
Region of cultivation (potential)				X	X	X		X	X
South East Asia	X			X	X	X	X	X	X
Latin America	X			X	X	X	X	X	X
Africa	X			X	X	X	X	X	X
North America	X			X	X	X	X	X	X
EU25	X			X	X	X	X	X	X

Availability of residues is limited by the size of economic activity these are generated in. Forecasts for availability of agricultural residues, forest residues, animal waste and organic waste in 2020 amount to a range of 30 - 75 EJ/year (WWI, 2006), (Hoogwijk, 2003).

Residues can be converted into biofuels with a typical efficiency of 50% applying HTU, CPT, Fischer Tropsch technology and ethanol production from ligno cellulosic feedstocks. These technologies therefore theoretically allow for an annual biofuels production from residues of 15 - 37 EJ. So in theory a maximum of 40% of global automotive fuels in 2020 could be covered by biofuels from residues.

However, there is competition with electricity and heat generation for these residues. Especially residues generated in the food industry are increasingly applied as fuels in cogeneration power plants. Forest residues are the preferred fuels for large power plants because of the attractive fuel characteristics of wood. New biomass is forecasted to supply 30 EJ/year of the global primary energy requirement in 2020. It is therefore likely that only a modest part of the generated residues will become available in 2020 for biofuels production.

An overview of current and future yields of these biomass/fuel combinations per hectare are given in Table 6. For palmoil and rape, both current and expected future (increased) crop yields are provided. Future technology for sugar cane and sugar beet refers to ethanol production from both the soluble sugars and the ligno cellulosic pulp and bagasse of both crops (i.e., 2nd generation bioethanol). The figures in Table 6 are based on world average crop yields, e.g. 2,5 tonnes/hectare for wheat.

Table 6 Biofuels yield (GJ) per hectare for different crops (Smeets, 2005), (OECD, 2006), (BIO, 2005), (Parkhomenko, 2004), (Maïs, 2005), (SGC, 2005), (EEA, 2006), (WWF, 2000)

	Biodiesel		Ethanol		FT diesel	Biogas	
	Current crop yields	Future crop yields	Current technology	Future technology	Future technology	Current technology	Future technology
Oil palm	130	260					
Rape	55	75					
Sunflower	35	35					
Soy	20	20					
Sugar beet			130	160			
Sugar cane			135	280			
Sweet Sorghum			?				
Cassave			?			300	300
Corn			80	80		200 - 250	250 – 300
Wheat			20	30		55	55
Wood				90	90		

Biogas yields can even now be as high as 200 - 300 GJ/hectare, if corn is used as feedstock. The process applied (fermentation) also has the advantage that nutrients are largely conserved and can be returned to the field. Production costs are approximately 20% - 40% higher as for ethanol from wheat and sugar beet in a West-European setting[12]. However fermentation technology is still a relatively recent technology, that is furthermore applied primarily in small scale on farms at which the process is a side step and not the main activity. This results in sub optimum operational practices with conversion efficiencies of 60% on average, while under more controlled conditions efficiencies of 80% can be realized. Innovations such as TAP (The Anaerobic Pump) – with over 90% conversion efficiency - and application of modern large scale microbiologic reactors with immobilized micro organisms may reduce biogas production costs.
Emissions of methane from fermentation would greatly reduce greenhouse gas mitigation realized by biogas, because of the high contribution of methane to global warming. However, leakage of methane are modest at maximum.

Table 6 also illustrates the advantages of second generation technologies, which can greatly reduce land area requirements per unit of biofuels.

The three OECD regions, the US, Canada and EU(15) require between 30% and 70% of their respective current crop area if they are to replace 10% of their transport fuel consumption by biofuels, assuming unchanged production technologies and crop yields, and in the absence of international trade or use of marginal or fallow land. However, only 3% would be required in Brazil due to not only the high ethanol yield per hectare of land, but also because of the relatively low per capita fuel consumption in this country [OECD, 2006].

[12] Total costs of biogas use in transport are even higher, since vehicles need to be equipped with biogas engines, and tank infrastructures would have to be adapted.

Resulting global land requirements, as a function of the desired percentage of (global) gasoline and diesel substituted by biofuels, are illustrated in Figure 10 and Figure 11.

Figure 10 Land requirements for substitution of gasoline and diesel by biofuels at current crop yields and technology, in 2020.

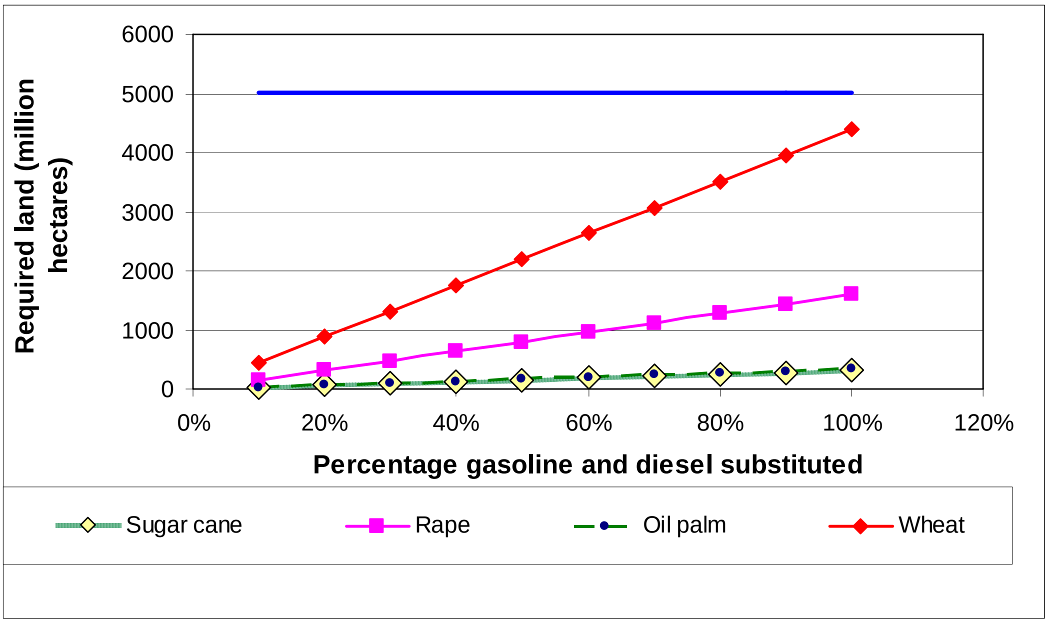
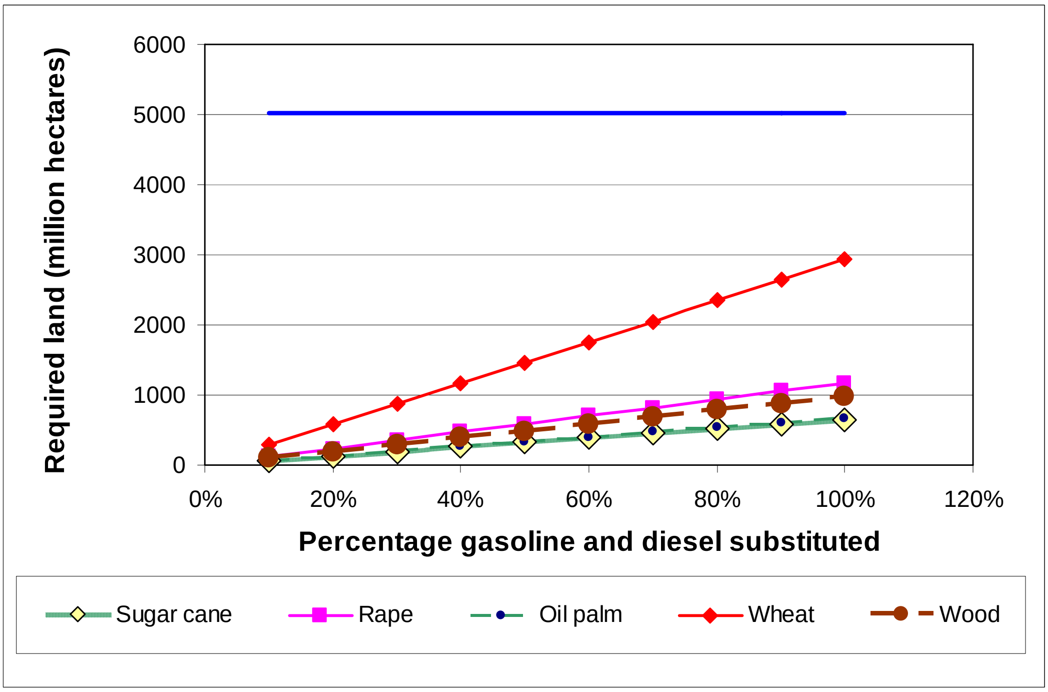


Figure 11 Land requirements for substitution of gasoline and diesel by biofuels at future crop yields and technologies, in 2020.



Both figures illustrate:

- The dark blue line represents current land use un the shape of arable land and pastures: total of 5 billion hectares.
- Land area requirement for substitution of 0% - 100% of gasoline and diesel in 2020.

Given the yields per crop for current and future technology, land area requirement will be minimal when sugar cane and palm oil are applied. With these crops, at maximum substitution of automotive fuels by biofuels, land requirement amounts to:

- approximately 650 – 700 million hectares with current cropping yields.
- Approximately 350 – 550 million hectares with improved cropping yields.

These requirements are comparable to 6% - 13% of total surface of arable land and pastures in 2020 total of (approximately 5,2 billion hectares, see Figure 9). As can be seen in the graphs, other crops may require much higher land areas, biogas might require less.

Still, even with these crops and with future technology requirements for land area are significant compared to current arable land area at high substitution percentages. Minimizing pressure on natural habitats in combination with high percentages of biofuels in automotive transportation fuel market will therefore require a high degree of intensification of agriculture around the world[13].

So-called second generation technology has advantages with respect to GHG reduction and less direct competition with the food sector. However, they also require feedstock and lack high enough efficiencies to significantly reduce land requirements. With current biogas from energy corn technology as currently demonstrated in Germany minimum land area requirements can be reached today, without requiring technology innovation (as far as efficiency is considered). However, costs must be brought down significantly in order to make this option more attractive from an economical point of view.

3.6 Market disturbances

Biofuels production from palm oil and sugar crops will not only potentially put pressure on land use and natural habitats but may also significantly disturb the markets for these commodities. For example, the amounts of palm oil and sugar crops required for a 20% coverage of automotive fuel requirements in 2020 would require amounts of approximately 470 Mtonnes of palm oil and the equivalent of 1.260 Mtonnes of sugar. Both values are approximately tenfold the current production of palm oil (see Annex C) and sugar.

Indeed even in the current situation in which biofuels consumption is limited to a few percent within the EU, the effects of production of especially rapeseed for biodiesel production are already notable (see Grains reports on USDA website):

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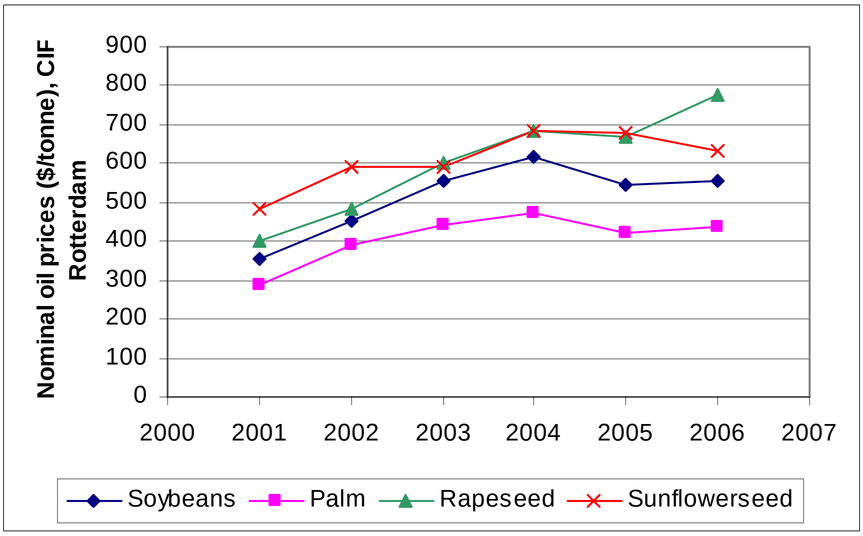
[13] We did not include a crop suitable for degenerated land (e.g. jatropha), because such crops are still under development and their potential is as yet unknown.

– As a consequence price differences between non-food and food rapeseed has almost disappeared and prices for rapeseed oil have gone up over the past 5 years with almost 100% up to almost $ 800/tonne (see Figure 12). This has resulted in substitution of rapeseed oil by sunflower oil in food applications whereas the situation used to be the other way round.
– Contrary to this prices for rapeseed have largely remained at the price level of 2002 resulting in increased margins for crushers. As a result crushers in Europe are converting from soy to rapeseed and soy meal and oil are increasingly imported, primarily from South America.
– The extra demand for rapeseed for both food industry and biofuels production has also resulted in the net import of rapeseed, while the EU used to be an exporter of rapeseed. Probably, rapeseed imports by the EU will compete with imports by China
– Increased rapeseed cultivation and processing has resulted in production of extra rapeseed meal and glycerine. In for example France livestock farmers are being persuaded to apply increased amounts of meal in the feed for their livestock, thus substituting soy meal imports from Latin America.

Figure 12 Developments of prices of plant oils on the European market in recent years (USDA, 2006)



4 Literature overview

4.1 Introduction

In recent years, various research institutes have tried to quantify the global or regional biomass potential. An overview of the most well-known studies is given in Annex A. In this chapter, we briefly summarize the main results, and describe the various approaches that were taken in these studies.

4.2 Relevant literature

In recent years, a number of scenario and impact studies were carried out that aimed to analyse the either the effects or the potential of the increasing use of biomass for biofuels and bioenergy. Some were limited to a national or regional scale (e.g., USA, EU, Brazil or Mozambique), some looked at global potential and effects.

In the following table, an overview of most relevant literature is provided. More information on these studies can be found in Annex A. This list certainly does not cover all studies that were performed. This selection, however, covers the most influential studies in current discussions in the EU and USA. Furthermore, it provides an overview of the different approaches that can be taken to analyse and asses the effects and potential of increased biomass use for non-food purposes. We have added some recent reports on sustainability certification to this list, in view of the growing call for sustainable biomass cultivation. Certification, but also demands to preserve nature and the environment on a more macro level, can severely limit the biomass potential.

Study performed by	Commissioned by	Titel	Geographic scale	Year of Publication	Main objective
OECD	OECD	Agricultural market impacts of future growth in the production of biofuels	global	2005	To look at the economics of biofuel production and the likely impacts of an expected growth in biofuel-related demand for agricultural products on commodity markets.
Copernicus Institute	OECD	Supportive study for the OECD on alternative developments in biofuel production across the world	global	2005	Provided input for OECD study above
OECD and FAO	OECD and FAO	Agricultural Outlook 2006-2015	global	2006	A medium term assessment of global commodity markets. Describes the trends in production, consumptions, stocks, trade and prices.
Oak Ridge National Laboratory	US Department of Agriculture (USDA) and the US Department of Energy (DOE)	Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply	USA	2005	To determine whether the land resources of the US are capable of producing a sustainable supply of biomass sufficient to displace 30% or more of the county's present petroleum consumption – the goal set by the Advisory Committee in their vision for biomass technologies.
Agency for Technical Cooperation (GTZ), with research support of the World Watch Institute	German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV)	Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century	global	2006	The report aims at presenting the opportunities, but also the limits, of global biofuel production and use in terms of energy, agricultural, environmental, and rural development aspects, as well as in economic terms. The report also examines the impact of globally expanded biofuel production on Germany's biofuel sector. Finally, the study presents detailed recommendations for action for decision-makers in politics, industry, and elsewhere.

FAO	FAO	Food Outlook – Global Market Analysis	global	2006	Provides a market assessment of various commodity markets, including oilseeds, oils and sugar. Furthermore, a special feature addresses the relationship between rising crude oil prices and ethanol-related demand for agricultural commodities. Main scope: 2005/06, prospects given for 2006/07.
MNP, UNEP-WCMC, UNEP-GRID Arendal, WUR-LEI	Convention on Biological Diversity	Cross-roads of Planet Earth's Life, Exploring means to meet the 2010 biodiversity target	global	2006	To explore policy options for achieving the 2010 biodiversity target at global and regional levels. One of the scenario's assessed in that report was a bio-energy intensive climate change mitigation policy option.
United Nations Development Programme (UNDP), UN Department of Economic and Social Affairs, World Energy Council	idem	World Energy Assessment: Overview 2004 Update	global	2004	The World Energy Assessment provides analytical background and scientific information for decision makers. It describes energy's fundamental relationship to sustainable development and analyses how energy can serve as an instrument to reach that goal. It was prepared in order to provide scientifically based input to the intergovernmental processes that led up to the treatment of energy in the context of the World Summit for Sustainable Development (WSSD) in Johannesburg in September 2002.
EEA and AEA Technology	EEA	How much bioenergy can Europe produce without harming the environment?	EU	2006	To assess how much biomass could technically be available in the EU for energy production without increasing pressures on the environment.

EEA and ETC/ACC	EEA	Climate change and a European low-carbon energy system	EU	2005	An assessment of possible greenhouse gas emission reduction pathways made feasible by global action and a transition to a low-carbon energy system in Europe by 2030. It analyses trends and projections for emissions of greenhouse gases and the development of underlying trends in the energy sector. It also describes the actions that could bring about a transition to a low-carbon energy system in the most cost-effective way.
Copernicus Institute	Publication in 'Biomass & Bioenergy'	Exploration of the ranges of the global potential of biomass for energy	global	2003	To gain insight in the factors that influence the potential of bioenergy in the long term. To explore the theoretical ranges of the biomass energy potential on the longer term in a comprehensive way, including all key categories and factors. To evaluate to what extent the potential of biomass supply can be influenced. Timeframe is 2050.
M. Hoogwijk, Copernicus Institute	PhD Thesis	On the global and regional potential of renewable energy sources	global	2004	Exploration of the ranges of the global potential of biomass for energy. Potential of biomass energy under four land-use scenario's. Part A: the geographical and technical potential. Part b: Exploration of regional and global cost-supply curves.
Copernicus Institute	Publication in 'Energy for Sustainable Development'	Biomass and bioenergy supply from Mozambique	Mozambique	2006	A detailed country-level study, to investigate the potential, economics and logistic options for Mozambique to produce biomass and biofuels for the export market.

Copernicus Institute	Copernicus Institute	The impact of sustainability criteria on the costs and potentials of bioenergy production	Ukraine and Brazil	2005	To analyse the impact on the potential and the costs of bioenergy that the compliance with various sustainability criteria brings along. This nature of this work is exploratory. Ukraine and Brazil are used as case studies.
Commission Cramer	Dutch Energy Transition Task Force	Criteria for sustainable biomass production, Final report of the Project group 'sustainable production of biomass' (Commission Cramer)	global	2006	To formulate sustainability criteria for the production and processing of biomass for energy, fuels and chemistry.
ECCM, IIED, ADAS, Imperial College	LowCVP	Draft Environmental Standards for Biofuels	global	2006	To describe the framework and draft standards that could operate for environmental assurance of biofuels.

Looking at these studies, we can distinguish the following types of approaches:

- Scenario studies that aim to determine the potential availability of biomass (i.e. biofuels and/or bioenergy), on a global, regional or national scale. Different scenario's are based on different assumptions regarding, for example, food demand, agricultural developments or sustainability requirements.
- Studies that aim to determine the effect of developments (typically looking at a baseline scenario and various policy options or potential global developments). The effects that are calculated are diverse, such as the agricultural commodity market and prices, biodiversity, etc.
- A third group of studies is trying to provide guidelines for certification of the sustainability of the biomass used for biofuels and/or bioenergy.

4.3 A variety of studies and scenario's, a variety of results

When looking at the studies listed above and in Annex A, we can conclude that there are only a few studies that aim to quantify the global land availability, and the potential for biofuels. These are mainly performed by the Dutch Copernicus Institute, although the OECD, FAO, CML, UNEP/MNP and the Worldwatch Institute have carried out relevant global studies on this subject as well.. Regional studies with the same objective, for example for the USA or the EU, are performed by other institutes. The various studies can not be compared easily, since they use different assumptions and models.

Nevertheless, we can conclude that the outcome of the studies and scenario's varies significantly, depending on the assumptions used. Key assumptions are related to the following issues:

- developments in food demand (determined mainly by population growth and diet)
- developments in agriculture (yield, product mix, etc.)
- potential of conversion of land that is currently not in use for agriculture (taking into account various levels of protection of nature and environment, use of abandoned and/or degraded land, etc.)

The studies that calculate biomass potential typically distinguish various types of biomass, and agricultural land. An example of the types considered is given in Table 7. The models then estimate the potential of these different categories.

Table 7 The biomass resource categories distinguished to assess the theoretically available potential of biomass for energy use

Category	Description
Category I: biomass production on surplus agricultural land	The biomass that can be produced on surplus agricultural land, after the demand for food and fodder is satis9ed
Category II: biomass production on surplus degraded land	The biomass that can be produced on deforested or otherwise degraded or marginal land that is still suitable for reforestation
Category III: agricultural residues	Residues released together with food production and processing (both primary and secondary)
Category IV: forest residues (incl. material processing residues)	Residues released together with wood production and processing (both primary and secondary)
Category V: animal manure (dung)	Biomass from animal manure
Category VI: organic wastes	Biomass released after material use, e.g. waste wood (producers), municipal solid waste
Category VII: bio-materials	Biomass directly on used as a feedstock for material end-use options like pulp and paper, but also as feedstock for the petrochemical industry

Source: Hoogwijk, 2003

To illustrate the outcome of these studies, we provide a few typical results:

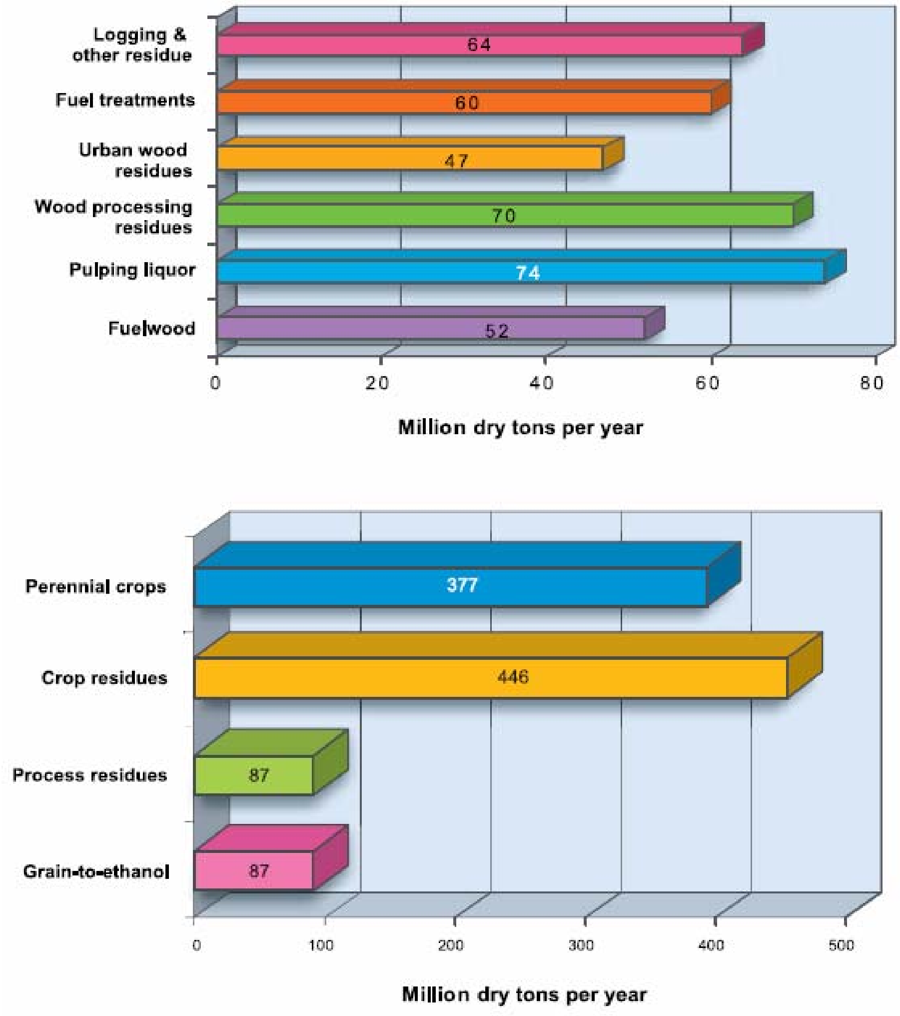
- Table 8 is a summary of the results of (Hoogwijk, 2003)
- Figure 13 is summary of the results of (ORNL, 2005)

Table 8 Contribution of each category to the global site potential

Category	Remarks	Potential bioenergy supply [EJ/y]
I: Biomass production on surplus agricultural land	Available area 0–2.6 Gha, yield energy crops 10–20 Mg $h^{-1}y^{-1}$	0–988
II: Biomass production on degraded lands	Available area 430–580 Mha, yield 1–10 Mg ha^{-1} y^{-1}	8–110
III: Agricultural residues	Estimate from various studies	10–32
IV: Forest residues	The (sustainable) energy potential of the world's forest is unclear. Part is natural forest (reserve). Range is based on estimate from various studies	10–16 (+32 from biomaterials waste)
V: Animal manure (dung)	Estimates from various studies	9–25
VI: Tertiary residue (organic waste)	Estimates from various studies	1–3
VII: Bio-materials	This depends highly on demand for biomaterials. Area 416–678 Mha. This demand should come from category I and II	Minus (0) 83–116
Total		33–1130

Source: (Hoogwijk, 2003)

Figure 13 Summary of potential forest and agricultural resources in the USA



Souce: ORNL, 2005

5 Conclusions and recommendations for further studies

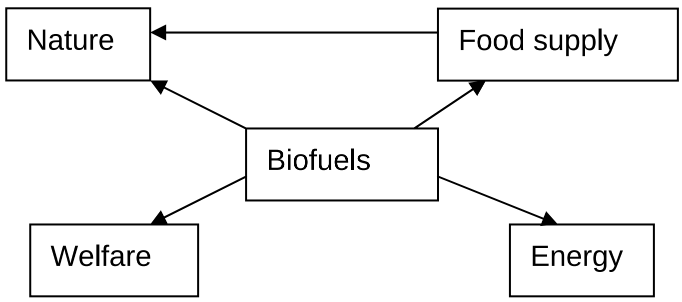
5.1 Introduction

In this chapter a script for further work is presented, based on the results and issues discussed in the other chapters of this report. First the key issues that have come up in the previous chapters are summarised in short paragraphs, then we present our recommendations for further research.

5.2 The fundamental system approach: energy, food and nature

The current and anticipated future growth of biofuels for electricity and transport results in a considerable extra demand for agricultural land. This influences the current balance between area for nature and agriculture for food, and disturbs the markets for the raw materials used. Furthermore, biofuels have an effect on the human welfare, for example because of higher food prices (see for an extended explanation chapter 3).

Figure 14 The main values connected to biofuels



In all major studies on this topic it is concluded that without changes in the system a large amount of biofuels will cause a more or less drastic reduction of nature and biodiversity[14]. This effect is amplified because of the large GHG emissions that occur when nature is converted into agriculture.

Key elements in the studies that predict large possibilities for biofuels worldwide are the following two factors:

1 Intensification of world agriculture (to the European level, in some studies).
2 A drastic reduction of the global meat consumption by a change to other protein sources.

Furthermore other, smaller efficiency options for reduction of the tension in 2020 are mentioned, such as:

3 Second generation biofuels which use wood and cellulose as feedstock.

[14] An overview of relevant literature is given in Annex A.

4 Bio refineries that produce products, biofuels and bio energy, making more efficient use of biomass.
5 Improving the efficiency of traditional biomass use (mainly cooking in developing countries).

Without these options the major studies conclude that there is only limited room for biofuels and bio energy, if the worlds biodiversity and nature are to be preserved to a large extent.

5.3 Biofuels policies and discussions worldwide

Biofuel policies are being implemented rapidly, on almost a global scale. In the EU, the biofuels directive 2003/30/EC has caused many Member States to set ambitious targets and provide incentives for biofuels. The USA has recently implemented the '2005 Energy Policy Act', that also sets targets and provides incentives for biofuels. In the EU, main driving forces are greenhouse gas reduction, concerns about security of supply and support to the agricultural sector. In the USA, the main driver is security of energy supply.

Most discussion on biofuels are about improving efficiency by changing to other technologies and sources. This will reduce costs and improve both GHG reduction and the energy security factor. In the USA the discussion is mainly about improving the energy factor, in the EU the main issue is improving the greenhouse gas reduction factor. For several biofuels these factors go hand in hand. Second generation biofuels are presented as the solution from both perspectives.

In the Netherlands, the UK and some other member states of the EU there is increasing concern especially among NGO's (Greenpeace, Friends of the Earth and somewhat more moderate WWF) about the negative effect of biofuels on biodiversity in countries like Indonesia and Brazil. In Belgium a system of sustainability certification for bio energy is in place, the Dutch and UK government are developing such a system for biofuels. The European Commission has announced in the Biomass Action Plan that she will investigate the possibility of sustainability certification of biomass. The competition with food production is also mentioned in this discussion but this factor is seen as difficult to manage. Furthermore increasing food prices are also seen as an economic opportunity for farmers and producing countries.

5.4 Relevant research

In Annex A a number of studies on land availability, biofuels and biodiversity are presented. Many of the global studies have be carried out by Faaij of the University of Utrecht/Copernicus Institute. However, the OECD, FAO, CML, UNEP/MNP and the Worldwatch Institute have carried out relevant studies on this subject as well. Key factors in all of the studies are the assumptions on the development and intensification of agriculture in the world, and on the level of sustainability (e.g., biodiversity) that is assumed. CML is currently working on an interesting study which claims that intensification of agriculture is not likely to happen and that worldwide agriculture will need twice the area in 2050. This agriculture area discussion is very important for the land availability for biofuels and should therefore be integrated in the biofuels policy debate.

5.5 Macro figures

The worldwide prediction for energy use in 2020 is 280 MBDOE = 600EJ/yr. Of this, around 105 EJ is oil for transport use. Many governments have stated goals of 20% biofuels for transport in 2020, and similar goals for electricity. Producing 20% of the total energy (120 EJ) with biofuels would need 0,5 to 1 billion hectares. For comparison, the world agricultural land is now about 1,5 billion hectares for direct agriculture and 3,5 billion hectares for cattle grazing land. Besides that area there is 4 billion hectares of forest in the world and 4 billion hectares of other nature that is not suitable for agriculture (mountains, deserts, permafrost).

These global macro figures illustrate that both competition between food and biofuels and increased pressure on nature and biodiversity are inevitable, and that especially developments in agricultural land use are crucial for the intensity of this competition.

5.6 A script for progress in knowledge and discussion

Focus of further study

Based on the various issues summarized above, we recommend that the focus of further study on the topic of biofuels and land availability should be on the following issues:

a A **baseline scenario evaluation** study of land availability for food, biodiversity and climate change, assuming different biofuels percentages in the world.
   In this baseline, it is assumed that none of the 5 major efficiency measures (see §5.2) will be implemented. This scenario evaluation study can be based on existing models presented by MNP, RUU, EEA, CML and IEA. In this calculation the use of set-aside land and residues should be included. Where necessary, the models will be corrected for optimistic assumptions. Furthermore, a prediction will be made (together with experts) regarding the food and feed consumption in the world in 2010 and 2020. The study should include a calculation of the effects of these developments on land availability for food, biodiversity and climate change.

b A study on the **possibilities of intensifying agriculture** worldwide and the effect on biodiversity, nature and food. Carried out with the help of WWF and CLM (Centre for Agriculture and Environment)

c A study on the possibilities and effects of a) **second generation biofuels** (CE), b) **bio refineries** and c) improvements of the **efficiency of traditional biomass use**.

d A **comparison with other climate change and biodiversity policies** on effects, costs and public support

For example:

- More efficient cars.
- Energy from waste in Europe and the States.
- Energy from coal with CO_2 sequestration.

e **Two case studies** looking at the key issues of increased biofuels demand (e.g., competition with food, market distortions, effects on biodiversity). Our proposal would be to look at rapeseed and palm oil.

f An **overall report of the results** with a **clear policy advice**.

In these calculations first generation biofuels will be used as the standard in 2010. In 2020 a mix of fist and second generation biofuels and bio refinery will be used.

6 Draft policy suggestions

6.1 Introduction

This scouting study on land availability concludes that there is a potentially significant problem developing in the triangle food, energy and biodiversity, caused by the increased demand for biofuels. An increasing number of governments worldwide implement biofuels policies, and set ambitious targets for these fuels. This distorts the markets for raw material of the food sector, and leads to an expansion of global agricultural area. This results in higher prices for food products, reduced availability of, in particular, vegetable oils, and an increased pressure on nature and global and regional biodiversity.

Without changing policies the problems are likely to get worse. Because of the direct connection between biofuels and government policies (without government support there would be almost no biofuels at all) it is reasonable to ask governments to act.

In this chapter a number of possible government actions are mentioned which could help to address and solve this problem:

- Sustainability criteria for biofuels and bio electricity
- Environmental Impact Assessments
- Flanking policies

In addition, we recommend that the various stakeholders involved, including governments, biofuel producers, NGO's and the food sector jointly cooperate on finding a solution to the dilemma's and threats described in this report.

6.2 Sustainability criteria for biofuels and bio electricity

Several governments react to the emerging problems by introducing sustainability criteria for biofuels. In these countries, these products are promoted for sustainability reasons and are sold as sustainable products, so this type of regulation seems to be reasonable. In the UK the LowCVP is developing sustainability criteria for biofuels, in Belgium (especially Wallonia) sustainability criteria are in place for bio electricity and in the Netherland the Commission Cramer is developing criteria as well. In Germany, where the palm oil debate has recently started, criteria development is also expected.

A number of social and environmental aspects are of will be addressed by these criteria. This means that environmental problems and social problems that are directly caused by the biofuel chain can be solved with this type of policy instrument.

When looking at the competition with food and the macro effect of biofuels on biodiversity (expansion of agricultural land, intensification of agriculture) an important question will be if also indirect effects of biofuel chain stimulation are taken into account in the sustainability criteria. Indirect effects can be very significant, especially in the GHG calculation and the biodiverisity protection index. For example if the production of palm oil for biofuels has to meet sustainability criteria, the existing plantations can be made sustainable while the new plantations in the rainforest will deliver to China and India. This displacement or leakage effect is important, but difficult to capture in a criteria system. Both the Dutch and UK governments agree on this, but they fear that this will complicate their system. The Dutch and British governments therefore propose to only monitor this displacement effects on a national and EU level, but not to integrate it in the GHG index and biodiversity protection.

For the macro competition between food, energy and biodiversity it is important that governments and biofuels producers take the responsibility for the displacement effects of biofuels. If biofuels producers and governments who support them take this responsibility this will support a more sustainable expansion of biomass cultivation, through, for example:

- yield increase on existing plantations
- production on marginal and set aside land
- a penalty for using a crop from a plantation which earlier produced for food or feed
- an integral approach of increasing demand for biofuels and intensifying agriculture aimed at increasing land availability for biofuels

When displacement effects would be integrated into the GHG-index and biodiversity protection for biofuels and support schemes would be implemented, the problem of competition between food and biofuels would be much lower and necessary developments to make space for biofuels would be directly coupled to biofuels policies.

It remains to be seen if national monitoring of displacement may have the same effect as sustainability certification. In theory this is possible but it depends on the response of governments to the results of the monitoring.

6.3 Environmental Impact Assessments

For large programmes and plans, the EU and its member states are obliged to carry out an environmental impact assessment according to European law. Some member states and many NGO's are stressing that the EC has to carry out such an assessment for biofuels. If done correctly this would give a lot of useful information about the likely impact on food and biodiversity, which may help to improve biofuel policies.

6.4 Flanking policies

Besides policies directly coupled to biofuels also other flanking policies are possible to make the competition between biofuels food and biodiversity less problematic. Some of these are:

- stimulation of the use of set aside land and marginal lands for food and biofuels

- stimulation of maximising yields per ha for biofuels and food
- stimulation of developing new crops for biofuels with high yields and low biodiversity effects
- ...

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Biofuels and their global influence on agriculture and the food market

A first evaluation and a proposal for further fact finding
Annexes

DRAFT

Working document II

Delft, December, 2006

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A Literature overview

A.1 Literature overview

In the recent past, various studies were carried out that analysed the effects on increased biofuels production. These studies have various scopes (EU, global, etc), and addressed various topics (land availability, effects on biodiversity, etc.). In the following, we provide an overview of a selection of this literature. Only those studies are included here that are:

- Relatively recent (i.e. include recent developments of biofuel and bio-energy policies).
- Cover a large area (i.e. at least a large region such as the EU or the USA).
- Address the issues relevant to this study, and
- That we judge to be 'credible' (i.e. performed or commissioned by a well known institution).

In this overview, we provide a brief outline of the various studies and their conclusions.

A.2 OECD reports

Agricultural market impacts of future growth in the production of biofuels AGR/CA/APM(2005)24/FINAL

Main objective of the study:

To look at the economics of biofuel production and the likely impacts of an expected growth in biofuel-related demand for agricultural products on commodity markets.

Models used:

- Aglink, the OECD partial equilibrium model for temperate zone agricultural commodities.
- Cosimo, the FOA counterpart.
- OECD World Sugar Model.

Main conclusions (with respect to land use, land availability, competition and other effects):

The results of these calculations suggest that the three OECD regions, the US, Canada and EU (15) would require between 30% and 70% of their respective current crop area if they are to replace 10% of their transport fuel consumption by biofuels, assuming unchanged production technologies, feedstock shares and crop yields, and in the absence of international trade in biofuels or use of marginal or fallow land. However, only 3% would be required in Brazil. While technical progress in agriculture and biofuel production as well as land use changes are likely to improve efficiencies of biofuel production processes, both production costs and area requirements suggest a substantial comparative advantage of Brazil relative to OECD countries.

The additional demand for agricultural commodities resulting from increased biofuel production is likely to substantially affect the outlook for their markets. The major producers of biofuels – Brazil, the US, the EU and Canada are covered explicitly in this analysis – are expected to significantly reduce their exports of the respective feedstock commodities or to increase their imports. Compared to a situation with unchanged biofuel quantities at their 2004 levels, crop prices in 2014 could increase by between 2% in the case of oilseeds and almost 60% in the case of sugar.
The analysis also shows that commodity markets are strongly influenced by crude oil prices. Higher
oil prices as currently observed increase production costs in agriculture, but also create higher incentives for biofuel production, thus stimulating demand for feedstock products. The degree to which biofuel quantities would increase strongly depends on parameters that are yet unobserved. Nevertheless, the results of this analysis suggest that the impacts of high oil prices on agricultural markets may well be dominated by their direct effects on agricultural production costs rather than by the increased demand for agricultural commodities.
The impact of biofuel production on agricultural markets is expected to change significantly once “advanced” biofuels become competitive. Technologies to produce ethanol from cellulosic and lignocellulosic material are being developed in pilot plants and are expected to allow production costs to fall substantially below those of commodity-based fuels within the next two decades – developments that have not been considered in this analysis. In addition to the cost advantage, area requirements for a given quantity of ethanol would be much lower as the fuels could be produced either from waste materials or from designated fuel crops with a much higher ethanol yield per hectare of land. Due to the possible strong increase in biofuel production as costs fall, however, it is impossible to make an a priori assessment on whether the lower land requirements per unit of biofuel energy would be under- or overcompensated by the overall change in biofuel production, and hence whether the eventual market implications would be smaller or larger than those shown in this study.

Comments (by CE Delft):
Oil prices assumed in the baseline scenario are relatively (unrealistically) low (p. 23). The high oil price scenario seems to be more relevant.

Relevant data provided:
Yield data: p.37, yields given for USA, CAN, EU-15, POL, BRA, for various crops.

Smeets, Junginger and Faaij, 2005 (Copernicus Institute, commissioned by the OECD)
Supportive study for the OECD on alternative developments in biofuel production across the world
Interesting for this part of our study:
- An overview of biofuels policies and incentives in various countries (global scope).
- P. 47 ff: Biofuels production outlooks. Including a rather extensive description of the global ethanol production outlook, based on Berg, C. World fuel ethanol

analysis and outlook, April 2004, www.distill.com/World-Fuel-Ethanol-A&O-2004.html.

- Lots of detailed technical data (incl. detailed costs) of production of various biofuels. These were the input data for the OECD report *Agricultural market impacts of future growth in the production of biofuels.*

OECD-FAO Agricultural Outlook 2006-2015

Main objective of the study:

A medium term assessment of global commodity markets. Describes the trends in production, consumptions, stocks, trade and prices.

Main conclusions (with respect to land use, land availability, competition and other effects):

World agricultural production is projected to expand steadily over the next decade, but at a slower rate than during the previous ten years. Per capita food consumption is increasing with rising incomes and growing trade. Increasing local production and lower costs from more efficient transport and product distribution systems as well as consumption shifts due to urbanisation and dietary changes are factors that add to this evolution in developing countries. In these countries, there is an increased emphasis on livestock products and animal feedstuffs compared to food grains. In the more developed markets, concerns with the availability of food have been replaced by those for food attributes and quality.

- The location of world agricultural market expansion is shifting increasingly towards developing countries. This tendency is expected to accelerate over the outlook period, as investment in production capacity and infrastructure are shifting the location of production, particularly for bulk agricultural products, towards the developing world and away from the developed countries. Policy reforms in the latter are slowly changing the nature of support to agricultural production, with impacts on the level and location of production.
- While the overall rate of expansion in production in the developing and former transition countries outpaces that of the developed countries, for the Least Developed Countries, the projection is marked by growing net imports of basic food commodities. In these countries, productivity growth is lagging behind the expansion of population, leading to greater reliance on world markets for their food security and greater exposure to international market price fluctuations.
- Strong competition from several developing and former transition country exporters reflects their comparative advantage in many agricultural commodities. At the same time, new technologies in tandem with continuing globalisation and integration of the agri-business supply chain will continue to alter trade flows towards more processed products. However, projected growth in agricultural commodity trade is expected to lag behind its potential, due to the persistence of high trade barriers as well as regulatory controls related to food safety and environmental concerns.
- Global trade for wheat and coarse grain is expected to grow moderately while world rice trade is to maintain a faster pace of expansion over the Outlook. Trade in coarse grains remains closely tied to expansion in domestic livestock production, particularly in countries unable to meet their own needs for

feedstuffs. Strong demand for vegetable oil for food consumption and protein meals used in livestock feeding is expected to sustain the shares of global trade in world production of oilseeds and oilseed products at level well above those of wheat and coarse grains.

- Energy prices over the Outlook are expected to remain strong, favouring agricultural production of less energy-intensive commodities and capital investment in bio-fuel production facilities. Consequently, expanding maize-based ethanol production in the United States will moderate the export growth of maize. Despite strong growth in Brazil's sugarcane-based ethanol sector it is not expected to prevent it from increasing its world sugar market share.
- Prospects for world meat trade, driven by rising per capita incomes in a broad range of importing countries risk being dampened by a recurrence of animal disease outbreaks and their likely aftereffects. World dairy prices are expected to stay firm over the outlook period, as rising demand in developing countries, particularly in East Asia, North Africa and the Middle East, is combined with limited anticipated growth of exports from traditional suppliers from Oceania and Europe.
- Weather-related production shocks, energy price trends, investment in bio-fuel capacity, economic growth prospects and future agricultural policy developments are among the main uncertainties affecting the prospects for world agricultural markets. A major uncertainty for the Outlook is the outcome of the Doha Development Agenda of multilateral trade negotiations. The prospects for world agricultural markets are highly dependent on economic developments in Brazil, China and India, three of the world's agricultural giants.

Comments
Some comments in the report: Based on assumptions regarding key macroeconomic variables as well as agricultural and trade policies. Projections do not take account of weather shocks and related impacts or additional outbreaks of anamal diseases. on crop yields and livestock production.
CE comments: this report provides a very useful background data on the main developments in global agriculture (demand and supply) until 2015. Includes demographic and economic developments.
Note that we do not have the full report, only the highlights.

Relevant data provided:
Lots of data and assumptions used for the projections, of prices,
trade volume (distinguishing world/OECD/developing/least developed countries), policy assumptions (subsidies, taxes, import tariffs, set-aside rate and payment, etc.) for various countries and commodities (incl. oilseed) production, consumption and price of e.g., oilseed and vegetable oils (OECD, non-OECD, world).

A.3 US reports

Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply
Prepared by the Oak Ridge National Laboratory, for the (US Department of Agriculture) USDA and the US Department of Energy (DOE), April 2005

Main objective of the study:
To determine whether the land resources of the US are capable of producing a sustainable supply of biomass sufficient to displace 30% or more of the county's present petroleum consumption – the goal set by the Advisory Committee in their vision for biomass technologies. Accomplishing this goal would require appr. 1 billion dry tons of biomass feedstock per year.

Main conclusions (selected):
The short answer to the question of whether that much biomass feedstock can be produced is yes. Looking at just forestland and agricultural land, the two largest potential biomass sources, this study found over 1.3 billion dry tons per year of biomass potential — enough to produce biofuels to meet more than one-third of the current demand for transportation fuels. The full resource potential could be available roughly around mid-21st century when large-scale bioenergy and biorefinery industries are likely to exist. This annual potential is based on a more than seven-fold increase in production from the amount of biomass currently consumed for bioenergy and biobased products. About 368 million dry tons of sustainably removable biomass could be produced on forestlands, and about 998 million dry tons could come from agricultural lands.
Forestlands in the contiguous United States can produce 368 million dry tons annually. This projection includes 52 million dry tons of fuelwood harvested from forests, 145 million dry tons of residues from wood processing mills and pulp and paper mills, 47 million dry tons of urban wood residues including construction and demolition debris, 64 million dry tons of residues from logging and site clearing operations, and 60 million dry tons of biomass from fuel treatment operations to reduce fire hazards. All of these forest resources are sustainably available on an annual basis. For estimating the residue tonnage from logging and site clearing operations and fuel treatment thinnings, a number of important assumptions were made:

- All forestland areas not currently accessible by roads were excluded.
- All environmentally sensitive areas were excluded.
- Equipment recovery limitations were considered, and
- Recoverable biomass was allocated into two utilization groups – conventional forest products and biomass for bioenergy and biobased products.

From agricultural lands, the United States can produce nearly 1 billion dry tons of biomass annually and still continue to meet food, feed, and export demands. This projection includes 428 million dry tons of annual crop residues, 377 million dry tons of perennial crops, 87 million dry tons of grains used for biofuels, and 106 million dry tons of animal manures, process residues, and other miscellaneous feedstocks. Important assumptions that were made include the following:

- Yields of corn, wheat, and other small grains were increased by 50 percent.
- The residue-to-grain ratio for soybeans was increased to 2:1.

- Harvest technology was capable of recovering 75 percent of annual crop residues (when removal is sustainable).
- All cropland was managed with no-till methods.
- 55 million acres of cropland, idle cropland, and cropland pasture were dedicated to the production of perennial bioenergy crops.
- All manure in excess of that which can applied on-farm for soil improvement under anticipated EPA restrictions was used for biofuel, and
- All other available residues were utilized.

The biomass resource potential identified in this report can be produced with relatively modest changes in land use, and agricultural and forestry practices. This potential, however, should not be thought of as an upper limit. It is just one scenario based on a set of reasonable assumptions. Scientists in the Departments of Energy and Agriculture will explore more advanced scenarios that could further increase the amount of biomass available for bioenergy and biobased products.

Comments (by CE Delft):
Does not look at application of this dry biomass feedstock (transport, energy, chemicals?)

Relevant data provided:
Lots of US data.

A.4 World Watch Institute

Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century
Agency for Technical Cooperation (GTZ), with research support of the World Watch Institute
Commissioned by the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV)

Main objective of the study:
The report aims at presenting the opportunities, but also the limits, of global biofuel production and use in terms of energy, agricultural, environmental, and rural development aspects, as well as in economic terms. The report also examines the impact of globally expanded biofuel production on Germany's biofuel sector. Finally, the study presents detailed recommendations for action for decision-makers in politics, industry, and elsewhere.
Central elements of the study include:
- Consolidation of previous German studies and experience.
- Regional studies and workshops in Brazil, China, India, Tanzania, as well as the United States.
- Global analysis and derivation of recommendations for action; and
- Incorporation of the results into the international debate.

Models used:
No modelling is performed, the report is based on existing studies.

Main conclusions (with respect to land use, land availability, competition and other effects):
The conclusions provide a good overview of the developments in the biofuels industry and policies, including the problems that are likely to occur. It addresses competition and changing commodity markets, security of energy and trade. It also looks at the effects on poor countries. A number of policy recommendations are provided, incl. sustainability issues.

Regional studies that analyze the current market usage of liquid biofuels, new technologies, land availability, relevant trade issues, environmental risks and opportunities, social aspects etc. can be found at:
http://www.gtz.de/en/themen/laendliche-entwicklung/14071.htm
Regional studies are provided for the following countries: Brazil, China, India, Tansania, Germany&Europe

Comments (CE Delft)
- The full report has not yet been issued. So far, only the summary (extended and short) and the regional reports are available.
- Bioenergy production potentials for selected biomass types in 2050 are provided by Faaij.
- Fossil Energy Balances are also provided for selected fuel types, based on various sources.
- Many (potential) sustainability issues are mentioned and described, and policy recommendations are provided..

A.5 Food and Agriculture Organisation (FAO) reports

Food Outlook – Global Market Analysis
No. 1, June 2006
Main objective of the study:
Provides a market assessment of various commodity markets, including oilseeds, oils and sugar. Furthermore, a special feature addresses the relationship between rising crude oil prices and ethanol-related demand for agricultural commodities.
The main scope is 2005/06, and prospects are given for 2006/07.

Main conclusions:
This report provides some general insight in global demand and supply of these commodities, and also addresses demand generated by the biofuels policies. Apart from that, however, the relevance to our study seems to be limited.

A.6 UN reports

Cross-roads of Planet Earth's Life, Exploring means to meet the 2010 biodiversity target

Study performed for the Global Biodiversity Outlook 2. Chapter solutions-oriented scenario's

Netherlands Environmental Assessment Agency (MNP), UNEP-WCMC, UNEP-GRID Arendal, WUR-LEI.

Main objective of the study:

To explore policy options for achieving the 2010 biodiversity target at global and regional levels. The finding were expressed in terms of indicators.

Main conclusions (selected):

A baseline scenario was assessed, as well as six policy options which potentially reduce the rate of biodiversity loss. In the baseline scenario, it is concluded to be unlikely that the 2010 CBD (Convention on Biological Diversity) target of 'a significant reduction in the current rate of loss of biological diversity' will be met for terrestrial biomes at the global and regional levels.

Six policy options which potentially reducing the rate of biodiversity loss have been analysed separately for their impact. *Protection of areas* and *sustainable meat production* contribute to bringing the 2010 target closer, and may potentially reduce the rate of loss before 2050. Measures for *limiting climate change* (bio-fuels), and realising *sustainable forest management* (wood plantations) and *poverty alleviation* (increasing GDP) seem inevitably to lead to losses of biodiversity in the medium term (2010 -2050. *Full trade liberalisation in agriculture* will lead to loss of biodiversity by ongoing land conversion in low-cost areas.

Implementation of an ambitious and bio-energy intensive climate change mitigation policy option[15], stabilising CO2-equivalent concentrations at a level of 450 ppmv in line with the goal of keeping the global temperature increase below 2 oC will require substantial changes in the world energy system. One of the more promising options for reducing emissions (in particular in transport and electric power) is the use of bio-energy. A scenario has been explored in which bio-energy plays an important role in reducing emissions. In this scenario major energy consumption savings are achieved and 23% of the remaining global energy supply is produced from bio-fuels in 2050. By 2050 the biodiversity gain (+1%) from less climate change and reduced nitrogen deposition due to less fossil-fuel burning does not compensate for the natural habitat loss (-2%) for producing bio-fuels crops in about 10% of the global agricultural area. This leads to an additional biodiversity loss of around 1%.

Models used:

See page 16 ff: To analyse the economic and environmental consequences of changes in global drivers and policies, a global economic-biophysical framework

[15] Biofuels (or bio-energy) are assumed to be produced on the basis of both bio-energy crops and agricultural residues. In this study we assumed that around 50-100 EJ bio-energy can be produced from agricultural residues. The remainder is produced from bio-energy crops. Only the latter leads to additional use of land; it is discussed in this report.

was developed, by combining the extended GTAP model with the IMAGE model. GTAP: demand on and trade in agricultural products; IMAGE: Land use and environmental development, and both models interact. FAO data on yield were used (‘Agriculture towards 2030), and, e.g., effects of climate change on agriculture were included. IEA scenario was used for a world energy and climate change outlook The GLOBIO 3 model was used (among others) to estimate habitat integrity through remaining species-level diversity.

Comments (by CE Delft):
Results are provided for planet Earth + 9 regions with up to date models for agriculture. There is still discussion about the biodiversity model. The scenario study for biofuels has three positive assumptions for biofuels in it:
- The CO_2 emissions of biofuels is assumed to be zero (in practice around 50%).
- The CO_2 emissions of deforestation caused by extra plantation is assumed to be zero (in practice not negletable to very important).
- The bio-energy has also a substantial part of energy saving in the scenario which makes the climate effect much stronger.

The conclusion that biofuels have a negative biodiversity effect the first 50 years and a positive after that is very dependent of this assumptions. If these factors are corrected the 50 years may become 70 to 100 years.
The model is in principle very suitable for further research. In 2007 new results are expected from the MNP.

World Energy Assessment: Overview 2004 Update
United Nations Development Programme (UNDP), United Nations Department of Economic and Social Affairs, World Energy Council, 2004.

Objectives:
The World Energy Assessment provides analytical background and scientific information for decision makers, in language relevant to all stakeholders. It describes energy’s fundamental relationship to sustainable development and analyses how energy can serve as an instrument to reach that goal. It was prepared in order to provide scientifically based input to the intergovernmental processes that led up to the treatment of energy in the context of the World Summit for Sustainable Development (WSSD) in Johannesburg in September 2002. This is an update the Overview of the report *World Energy Assessment: Energy and the Challenge of Sustainability.*

Main conclusions (selected)
Energy Resources and Technological Options Physical resources and adequate technologies are available to meet the challenges of sustainable development. Without policy changes, cost differentials will favour conventional fuels for decades to come. Options for using energy in ways that support sustainable development, which requires a consistent focus on social, economic, and environmental processes, include:
- More efficient use of energy, especially at the point of end use in buildings, transportation, and production processes.

- Increased reliance on renewable energy sources.
- Accelerated development and deployment of new energy technologies – particularly next-generation fossil fuel technologies that produce near-zero harmful emissions, but also nuclear technologies if the issues surrounding their use can be resolved.

All three options have considerable potential; however, realising this potential will require removing obstacles to their wider diffusion – including developing market signals that reflect environmental and other costs to society not already internalised in market prices – and encouraging technological innovation. The relative importance of these options depends on the availability of natural resources. Irrespective of that, a more efficient use of energy is always essential, even in developing countries where increased access to modern energy carriers is top priority. The analysis presented here identifies key strategies and policies for globally achieving both economic growth and sustainable development.

Models used:
N.A.

Relevant data provided:

TABLE 1. WORLD PRIMARY ENERGY USE AND RESERVES, 2001

Source	Primary energy (exajoules, EJ)	Primary energy (10^9 tonnes of oil equivalent, Gtoe*)	Percentage of total (%)	Proved reserves (10^9 tonnes of oil equivalent, Gtoe*)	Static reserve-production ratio (years)[a]	Static resource base–production ratio (years)[b]	Dynamic resource base–production ratio (years)[c]
Fossil fuels	332	7.93	79.4	778			
Oil	147	3.51	35.1	143	41	~ 200	125
Natural gas	91	2.16	21.7	138	64	~ 400	210
Coal	94	2.26	22.6	566	251	~ 700	360
Renewables	57	1.37	13.7				
Large hydro	9	0.23	2.3		Renewable		
Traditional biomass	39	0.93	9.3		Renewable		
'New' renewables[d]	9	0.21	2.2		Renewable		
Nuclear	29	0.69	6.9	55			
Nuclear[e]	29	0.69	6.9	55	82[f]	~300 to >10,000[f]	
Total[f]	418	9.99	100.0				

* 1 toe = 42GJ. a. Based on constant production and static reserves. b. Includes both conventional and unconventional reserves and resources. c. Data refer to the energy use of a business-as-usual scenario—that is, production is dynamic and a function of demand. Thus these ratios are subject to change under different scenarios. Dynamic resource base – production was calculated based on a 2 percent growth rate per year from 2000 to peak production (oil 6.1 Gtoe, gas 6.3 Gtoe, and coal 8.9 Gtoe), followed by a 2 percent decline per year until the resource base is exhausted. d. Includes modern biomass, small hydropower, geothermal energy, wind energy, solar energy, and marine energy. Modern biomass accounts for 6.0 exajoules; 2.9 exajoules comes from all other renewables. "Modern biomass" refers to biomass produced in a sustainable way and used for electricity generation, heat production, and transportation (liquid fuels). It includes wood/forest residues from reforestation and/or sustainable management, rural (animal and agricultural) and urban residues (including solid waste and liquid effluents); it does not include traditional uses of fuelwood in inefficient and pollutant conversion systems. e. Converted from electricity produced to fuels consumed assuming a 33 percent thermal efficiency of power plants. f. Based on once-through uranium fuel cycles excluding thorium and low-concentration uranium from seawater. The uranium resource base is theoretically 60 times larger if fast breeder reactors are used.

Also of interest Table 7: Status of renewable energy technologies, end 2001, incl. various data on biomass for electricity, heat and transportation (for 2001).

Comments (by CE Delft):
Good overview of global energy situation and development, with 3P approach. Strong focus on access to energy in developing countries. However, no specific prognosis or quantitative analysis of biomass potential.

A.7 European Environmental Agency (EEA) reports

How much bioenergy can Europe produce without harming the environment?
EEA Report No. 7/2006

Main objective of the study:
To assess how much biomass could technically be available in the EU for energy production without increasing pressures on the environment.

Main conclusions (selected):
The study concludes that significant amounts of biomass can technically be available to support ambitious renewable energy targets, even if strict environmental constraints are applied.
Quantitative results are provided (in MtOE/year, for 2010-2030)
The bioenergy potential in 2030 represents around 15-16% of the projected primary energy requirements of the EU-25 in 2030, and 17% of the current energy consumption, compared to a 4% share of bioenergy in 2003.
The main factors driving the increase in bioenergy potential are productivity increases and the assumed liberalisation of the agricultural sector, which results in additional area available for dedicated bioenergy farming. Furthermore, with an (assumed) increase in carbon prices together with high fossil fuel prices, bioenergy feedstock becomes competitive over time compared with traditional wood industries or food crops.
Nevertheless, this study made some value judgements which limit the available potential, including the assumption that bioenergy crops should not be grown at the expense of food crops for domestic food supply. Many of the strict environmental assumptions also act to reduce the available potential. Overall, the outcome of this study can therefore be seen as a conservative estimate.

Models used:
Bioenergy from agriculture:
Modelling of released and set-aside land area was base don the CAPSIM model (for individual MS, taking into account policy developments. The competition effect between bioenergy and food production was taken into account in a parallel approach, based on the bottom-up HEKTOR model for Germany and France. It was assumed that food and fodder production for domestic demand were constant, while direct and indirect subsidised exports are gradually phased out.

Bioenergy from forestry:
The European Forest Information Scenario (EFISCEN) model was used to project the possible future development of forest resources in the EU. The competitive effect of increasing fossil fuel prices was estimated with the EFI-GTM model.

Bioenergy from waste:
A number of spreadsheet models were developed to estimate resource potentials. Main models underpinning key data were:
- Agricultural models such as CAPSIM.
- Models developed by the EEA's Topic Centre on Resource and Waste Managements.

Climate change and a European low-carbon energy system
EEA Report No. 1/2005

Main objective:
This report presents an assessment of possible greenhouse gas emission reduction pathways made feasible by global action and a transition to a low-carbon energy system in Europe by 2030. It analyses trends and projections for emissions of greenhouse gases and the development of underlying trends in the energy sector. It also describes the actions that could bring about a transition to a low-carbon energy system in the most cost-effective way.
This report addresses the need for a transition to a European society with substantially lower emissions of GHGs and the possible shape of a more sustainable European energy system. A 'climate action' scenario with several variants has been developed by the European Topic Centre on Air and Climate Change (ETC/ACC) for EEA (see Box 1.2). The time horizon of these scenarios is 2030. Also additional global energy and CO_2 emission scenarios were developed with a time horizon of 2050. In line with the targets mentioned by the Environment Council and the Spring Council of March 2005, the report analyses scenarios that could achieve an EU GHG emission reduction target of 40 % below the 1990 level by 2030.

Conclusions (selection)
- The climate action scenario shows that by domestic actions alone, based on a carbon permit price of EUR 65/t CO2, the EU could reduce its greenhouse gas emissions to 16-25 % below the 1990 level by 2030. Thus a substantial share of the reductions needed to achieve the assumed target of 40 % by 2030 could be achieved by actions inside the EU, with international emissions trading providing the remaining reductions.
- Substantial low-cost emission reductions are projected in the climate action scenario for nitrous oxide and methane emissions from industry, waste management and agriculture. However these options will have been almost fully exploited by 2030.
- In the climate action scenario, substantial changes in the EU energy system are projected, leading to energyrelated emissions of CO2 (the most important greenhouse gas) in 2030 that are 11 % below the 1990 level, compared with 14 % above in the baseline scenario. The baseline scenario assumes modestly optimistic economic growth with a diverse development of the European energy system. Larger domestic emission reductions would lead to increasing marginal abatement costs, for example a reduction to 21 % below 1990 levels would require the permit price to more than double by 2030.

- Reductions in the energy intensity of the economy are expected to account for almost half of the emission reduction in 2010. Towards 2030, their contribution will decrease, requiring a shift of effort to further long-term changes in fuel mix, mostly in the power generation sector.
- Towards 2030 more than 70 % of the CO2 emission reductions (in the climate action scenario compared with the baseline) are expected to be realised in the power generation sector, mostly as a result of a shift to low or non-carbon fuels.
- The use of solid fuels is projected to decline substantially and of natural gas to increase rapidly. Renewable energy (mainly wind power and biomass use) shows the largest increase of all primary energy sources (42 % higher than in the baseline). Combined heat and power will increase its share of electricity production.

Models used:
Various models were used in the calculations, e.g.,
- PRIMES is a partial equilibrium model for the EU energy system developed by, and maintained at, the National Technical University of Athens.
- LREM projections.
- IMAGE: Integrated model to assess the global environment.
- TIMER: Targets IMage Energy Regional model.
- FAIR 2.0: a decision-support model to assess the environmental and economic consequences of future climate regimes.

A.8 University of Utrecht

Exploration of the ranges of the global potential of biomass for energy
M. Hoogwijk, A. Faaij, R. v.d. Broek, R. Berndes, D. Gielen, W. Turkenburg

Main objective of the study:
1. To gain insight in the factors that influence the potential of bioenergy in the long term.
2. To explore the theoretical ranges of the biomass energy potential on the longer term in a comprehensive way, including all key categories and factors.
3. To evaluate to what extent the potential of biomass supply can be influenced.

The analysis focuses on a global scale, timeframe is 2050.

Main conclusions (selected):
The future geographical potential of biomass energy supply ranges from 35 to 1135 EJ/y. This result is mainly determined by the potential of energy farming that is the result of land availability and biomass productivity. However, the upper limit requires high energy inputs.
The land availability is determined by the land requirements for food demand. This is a function of future diet, population growth, but most important, the food production system (e.g.,. HEI vs. LEI system, meat and dairy production methods). In order to achieve high biomass energy potentials, considerable transitions are required in the agricultural system, especially in the way meat and dairy products are being produced.

As indicated by the range, a shortage of agricultural land may also occur e.g. when the world population and food intake increase sharply and agri development stagnates. Due to interactions between food/forest products supply systems and energy, a high demand for food/forestry products results in less available land for energy farming. However, more residues are becoming available. Nevertheless, the net impact is a significant reduction of the bio-energy potential.
Large-scale implementation of biomass could only be possible under affluent diet consumption if the global average productivity per hectare increases. Hence, sustainable development policies could on the one hand meet economic development policies in improving the efficiency of the food production system. On the other hand they could diverge if extensive food production systems nd biomass for energy are both pushed on a large scale.
NB. The study is explorative.

Models used:
The potential biomass supply of various categories is assessed using the results of existing studies.

Comments (by CE Delft):
Contains extensive literature overview of future biomass energy potential studies. Good overview of existing studies.

Relevant data provided:
Global average daily consumption per adult for three different diets (MJ/day, and kg dry weight grain equivalents/day)
Population projections
Potential area, yield and food production,

On the global and regional potential of renewable energy sources
M. Hoogwijk, PhD Thesis

Objectives:
PhD-Thesis, thorough research into the following topics (=chapters of the thesis, selection)
- Exploration of the ranges of the global potential of biomass for energy.
- Potential of biomass energy under four land-use scenario's. Part A: the geographical and technical potential.
- Part b: Exploration of regional and global cost-supply curves.

Main conclusions (selected)
6 biomass resource categories are identified: energy crops on surplus cropland, e.c. on degraded land, agricultural residues, forest residues, animal manure and organic wastes.
The range of the global potential of primary biomass (in about 50 years) is anything between nil and 1150 EJ/yr. Energy crops from surplus agricultural land have the largest potential contribution at about nil-1000 EJ/yr. The biomass productivity is mainly determined by local factors (soil quality, climate, water

availability and management). Land availability is amongst others determined by land requirements for food demand.
In order to achieve high biomass potentials, considerable transitions are required in the agricultural system, especially in the way meat and dairy products are being produced and consumed. As indicated by the range, a shortage of agricultural land may also occur, e.g., when the world population and food intake increase sharply and the agricultural development stagnates.
Large amounts of biomass grown at abandoned agricultural land and rest land (130-270 EJ/yr, about 40-70% of the present primary world energy consumption) may be produced at costs below 2 $/GJ by 2050. Interesting regions because of low costs and significant potentials are the former USSR, Oceania, East and Western Africa, East Asia. Assumptions: significant land productivity improvements over time and cost reductions due to learning and capital-labour substitution. Liquid biofuel costs: about twice present diesel production costs.

Models used:
IMAGE/TIMER 1.0, a system-dynamic simulation model of the global energy system at an intermediate level of aggregation.

Comments (by CE Delft)
Lots of (global) data and assumptions that lead to the large range of potentials from the UU/Copernicus Institute.

Biomass and bioenergy supply from Mozambique
B. Batidzirai, A. Faaij and E. Smeets

Main objective
A detailed country-level study, to investigate the potential, economics and logistic options for Mozambique to produce biomass and biofuels for the export market. In an earlier global bioenergy production potential assessment, Mozambique was identified as one of the promising biomass production regions in tropical Africa.

Main conclusions (selected)
Mozambique has capacity to produce up to 6.7 EJ of bioenergy annually, using surplus land under moderate agricultural technological inputs and using strict sustainability criteria (i.e., protecting forests and meeting growing food demand). Essential for realising this potential is rationalisation in agriculture and livestock-raising, and potential increases of up to 7 times current productivities can be achieved with moderate technology introduction. Efficient logistics are also essential to ensure competitive biomass supply to the international market. Using six regions of Mozambique as potential sites for biomass production, the study analysed and compared the cost and energy use of supplying pellets, pyrolysis oil and Fischer-Tropsch (FT) fuels to the international market. Some of the conclusions: costs vary with climate of the region (arid vs. productive), pellets are the cheapest option.

Models used:
Various parameters are modelled (i.e. estimated), such as the demand for food, feed and land use, and crops and land use.

The impact of sustainability criteria on the costs and potentials of bioenergy production
An exploration of the impact of the implementation of sustainability criteria on the costs and potential of bioenergy production, applied for case studies in Brazil and Ukraine Edward Smeets, André Faaij and Iris Lewandowski, Copernicus Institute, Utrecht University, May 2005.

Objectives:
The goal of this study is to make a first attempt to analyse the impact on the potential (quantity) and the costs (per unit) of bioenergy that the compliance with various sustainability criteria brings along. This nature of this work is exploratory, because of the broad set of issues covered very little work has been published on which we could build. Ukraine and Brazil are used as case studies, because both regions are identified as promising bioenergy producers

Main conclusions (selected):
Out of 127 criteria, a selection of 12 criteria are included in this study (environmental and social), because not all criteria could reasonably be translated into practically measurable indicators and/or measures and many criteria are related and/or overlap. Because there is no generally accepted definition of sustainability, a strict and loose set of criteria and indicators is defined, to represent the difference in individual perceptions of sustainability.
Overall, the results of this study indicate that:

- In several key world regions biomass production potentials can be very significant on foreseeable term (10-20 years from now). Feasible efficiency improvements in conventional agricultural management (up to moderate intensity in the case regions studied) can allow for production of large volumes of biomass for energy, without competing with food production, forest or nature conservation. The key pre-condition for such a development are improvements in the efficiency of agricultural management.
- it seems feasible to produce biomass for energy purposes at reasonable cost levels and meeting strict sustainability criteria at the same time. Setting, strict, criteria that generally demand that socio-economic and ecological impacts should improve compared to the current situation will make biomass production more expensive and will limit potential production levels (both crop yield and land surface) compared to a situation that no criteria are set. However, the estimated impact on biomass production costs and potential is far from prohibitive. For the case studied (SE Brazil and Ukraine) estimated biomass production costs under strict conditions are still attractive and in the range of 2 Euro/GJ for the largest part of the identified potentials.
- It should be noted that such improvements, when achieved, also represent an economic value, which could be considerable (e.g value of jobs, improvement of soil quality, etc.). Such ‘co-benefits’ could especially be relevant for the

less productive, marginal lands. Such a valuation has however not been part of this study.
- The results are indicative, based on a desktop approach (and not on field research) and pay limited attention to macro-effects as indirect employment and both potential negative and positive impacts on conventional agriculture. More work to verify and refine the methodological framework developed is therefore needed, preferably involving specific regional studies and including regional/national stakeholders.

A.9 Sustainability criteria or standards for biomass

Criteria for sustainable biomass production, Final report of the Project group 'sustainable production of biomass' (Commission Cramer)
Energy Transition Task Force
July 2006

Main objective of the study:
To formulate sustainability criteria for the production and processing of biomass for energy, fuels and chemistry.

Main conclusions (selected):
In the system that was developed sustainability criteria for 2007 are distinguished from those for 2011. In the criteria for 2007 minimum requirements have been formulated to prevent unacceptable biomass flows from being used. The criteria for 2011 have been tightened and are aimed at providing an active protection of nature and the environment and of the economic and social circumstances.
The criteria and indicators have been divided into six themes. The first three themes are specific themes, relevant for biomass. The last three themes relate to the triple P approach (people, planet, profit), which are the starting points for corporate social responsibility. The six themes are the following:
- Greenhouse gas balance.
- Competition with food, local energy supply, medicines and building materials.
- Biodiversity.
- Economic prosperity.
- Social well-being.
- Environment.

To make testing for sustainability possible the origin of the physical biomass flow must be known. A certification system must preferably be based on a track-and-trace system, in which the traceability of the biomass is guaranteed. A point of attention here is that in the short term this is not completely feasible. Therefore a transition period will be necessary, in which an increasing percentage of traced biomass is required for inclusion for subsidy or obligations. An internationally watertight monitoring and registration system will be needed. In the longer term it may be considered if a system in which the sustainability certificate is separated from the physical flow would offer any advantages.

Comments (by CE Delft):
Broad, Triple-P approach. No scenario's studies, no quantification of costs.

Draft Environmental Standards for Biofuels, A report commissioned by the LowCVP
ECCM, IIED, ADAS, Imperial College,
July 2006

Main objective of the study:
To describe the framework and draft standards that could operate for environmental assurance of biofuels.

Main conclusions (selected):
Environmental assurance schemes can be effective at ensuring products are sourced from landholdings where responsible agricultural or forest management practices are employed, thereby reducing the risk of harm to ecosystems and natural resources. Experience of environmental assurance in forestry has shown that assurance schemes have limited impacts on land use decisions (e.g. deforestation processes) outside the certified areas. Environmental assurance schemes are not, therefore, an effective substitute for good governance and regulation of natural resources but can complement these systems.

The draft standards for production of biofuel crops comprise the following "Principles":
- Conservation of carbon stocks.
- Conservation of biodiversity.
- Sustainable use of water resources.
- Maintenance of soil fertility.
- Good agricultural practice.
- Waste management.

These are complemented by specific indicators that are identified as either "Basic Criteria" that are required for compliance with the standard; or, "Enhanced Criteria" that could be used as a basis for a higher level "green label" biofuel product. Draft Standards for Storage, Transportation and Processing are also provided, covering issues of waste management and safety.
The recommended structure for the scheme (that complies with the good practice guidelines agreed in the Uruguay Round of WTO1) is to develop a "Meta-Standard" building upon existing assurance schemes in the UK and internationally (notably, the ACCS and LEAF, EurepGAP, RSPO and other round-table initiatives). The metastandard would work through a benchmarking (cross-compliance) framework which compares the requirement of the draft standard with the requirements of existing agrienvironmental assurance schemes. Criteria not covered by these schemes could be encompassed within the proposed scheme through the development of "Supplementary Checks".

Comments (by CE Delft):
Thorough analysis and recommendations, based on existing certification practices, with consideration of practical issues and stakeholder involvement. Limited to environmental issues (i.e., social issues not covered) and to biofuels. No scenario's studied, no quantification of cost.

B Main actors in the biofuels land availability discussions

B.1 Intro

The land availability discussion is rather new in the biofuels discussion. The following actors are active in the discussion.

B.2 Main actors in the EU

DGTREN
This DG is responsible for the biofuels directive and the revision of this directive. Therefore a stakeholder consultation has been done and a study is tendered. Especially Mr Maniatis is outspoken and important in the field. He is in favour of differentiation between GHG reductions and in favour of second generation biofuels but not convinced that competition with food and social sustainability is a problem.

DGENV
This DG of the EU seems not so active in the discussion but is also responsible for biodiversity and climate change so it is a natural partner for the land availability discussion.

DGAGRI
This DG support biofuels because of the farmers wishes in countries like Germany and France. Following the publication of the Biomass Action Plan, DG-Agri published in February 2006 a communication on an EU Strategy for Biofuels. This paper outlines the Commissions intention to stimulate demand of biofuels in the transport sector by further developing the production and distribution of biofuels and enhancing trade and supply.

WWF
WWF is very active in the discussion in Brussels and respected very much. Compared to other NGO's they are moderate and have an optimistic view on the possibilities for combining food, biofuels and biodiversity. They hope that certification will prevent problems.

EEB, T&E, Friends of the Earth, Greenpeace
Although not so active in the debate also other NGO's are concerned about the sustainability of biofuels. This NGO's in general support stopping imports of Indonesian palm oil and Brazilian ethanol because of risks for biodiversity and social scandals (land rights). Greenpeace is also very concerned about GMO's.

Farmers: NFU and other farmer associations
In many European countries national farmer organisations promote the use, stimulation and production of especially first generation biofuels with arguments of rural development and energy security.

EU industry
The European industry seems quiet in their statements on the land availability issues. Some industries like the European petrol industry Europia **(www.europia.com)** argue that the climate effect of biofuels is smaller than claimed and expensive but land availability seems a new item in the arguments. Also in the questionnaire for the Review of the biofuels directive Unilever seems the only major company which raises the question of land availability. On the other hand many companies support sustainability certification of biofuels.

B.3 Main Actors in the USA

In the United States there is a lot of discussion which have to be further explored with the World Watch institute. Important organisations are:

World Watch Institute
Which has published and distributed to high levels a world wide fact finding study on biofuels which seems rather optimistic on land availability.

The national Commission on energy policy (NCEP) (www.energycommission.org)
This commission with direct links to government and both houses has recently published a number of statements on biofuels which emphasis the need to go to second generation biofuels. A discussion about land availability could be interesting with this commission.

C Vegetable oils and biofuels

C.1 Introduction

In the following, an overview is provided of the global oil and oilseed markets. Subsequently, section C.3 contains a more detailed analysis of the recent development of the rapeseed oil market, in relation to the biodiesel policies.

C.2 Oil and oilseeds

Plant oil or vegetable oil, a potential source of raw materials for biofuels, stem from a variety of crops. All crops produce a fruit (palmoil) or a seed containing 20% - 50% of oil (Parkhomenko, 2004). The other part of the fruit or seed is in general a protein riche meal. The market volume for vegetable oils is dominated by 4 oils, together making up approximately 85% of the total market. Given the broad nature of this project, we focussed on these four.

Table 9 Overview of the main vegetable oils produced and consumed worldwide.

Oil source	**World consumption 2006/2007 (crude oil)**		**Notes**
	Mtonnes/year		
Soybeans	34,94	29%	Accounts for about half of worldwide edible oil production.
Palm	37,37	31%	The most widely produced tropical oil. Also used to make biofuel.
Rapeseed	17,61	15%	One of the most widely used cooking oils, Canola is a (trademarked) variety (cultivar) of rapeseed.
Sunflowerseed	10,10	8%	A common cooking oil, also used to make biodiesel.
Peanut	5,00	4%	Mild-flavored cooking oil.
Cottonseed	4,74	4%	A major food oil, often used in industrial food processing.
Palm Kernel	4,48	4%	From the seed of the African palm tree
Coconut/Copra	3,26	3%	
Olive	2,85	2%	Used in cooking, cosmetics, soaps and as a fuel for traditional oil lamps
	120,35	100%	

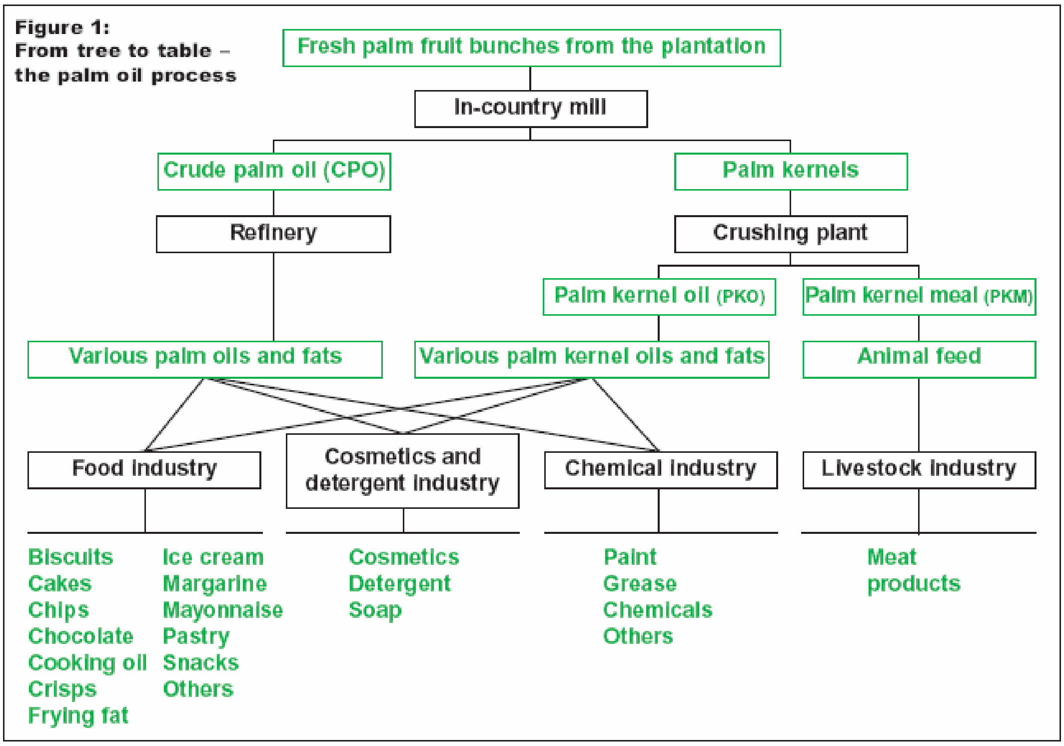
Sources: http://www.fas.usda.gov/psd/intro.asp?circ_id=2 and http://en.wikipedia.org/wiki/Vegetable_oil

Globally application of vegetable oil is until now predominantly in the food industry and in food products. Depending on the type of oil 80% - 90% is utilized in various food industry branches. The other 10% - 20% is applied as a raw material in the chemical industry. This fraction consists to a significant percentage (5% of crude plant oil) of the free fatty acids, distilled off in the vegetable oil refinery.

The meal is often applied as fodder for livestock, sometimes as a fertilizer.

As an illustration Figure 15 gives the structure of the palm oil and palm kernel cultivation and processing chain.

Figure 15 Production chain for palm oil, palm kernel oil and palm kernel meal



Source: Greasy Palms, Friends of the Earth.

Obviously production volume and market volume of oil containing seeds and fruits is influenced by:

- Demand for and market prices of oil product.
- Demand for and market prices of meal product.
- Specifications and qualities of these products.
- Crop yield, determined naturally by growing conditions (wheather).
- Relative costs for cultivation and processing.

in Table 10, diversity in crop yields between countries and from one year to another is illustrated by some up to date and preliminary figures for the four most important oils considered in this study.

Table 10 Total cultivation area and average yield of four vegetable oils in various countries, for various years

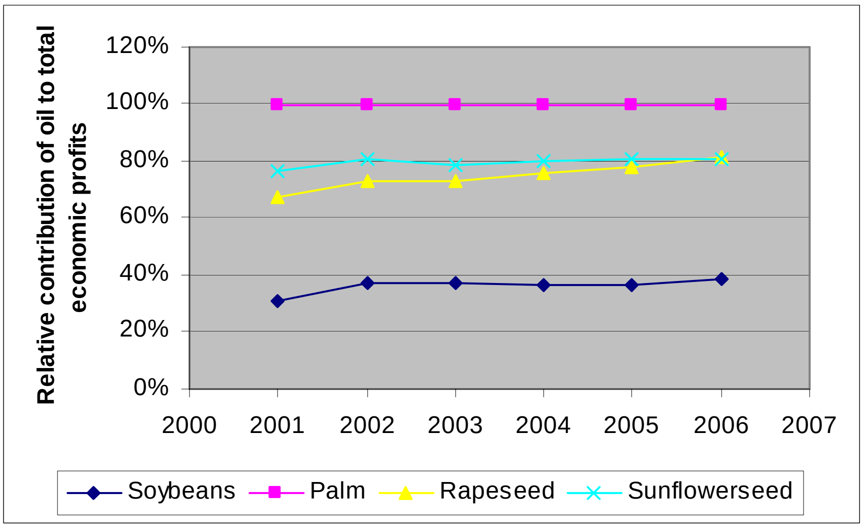
	Average 2000-2005		Preliminair 2005/2006		Forecast 2006/2007	
	Area (10^6 hectares)	Yield (tonne/ha)	Area (10^6 hectares)	Yield (tonne/ha)	Area (10^6 hectares)	Yield (tonne/ha)
Soybeans						
- US	29,5	2,6	28,9	2,9	29,9	2,7
- Brazil	18,6	2,6	22,0	2,5	21,0	2,7
- Argentina	12,6	2,6	15,2	2,7	15,4	2,7
- China	9,3	1,7	9,5	1,8	9,3	1,8
- India	6,4	0,9	7,7	0,8	7,8	0,8
- Other	7,4	1,7	9,0	1,7	9,4	1,8
Crude palm oil						
- Indonesia	3,2		3,6			
- Malaysia	3,3		3,6			
- Others	0,8		0,9			
Rapeseed						
- EU	4,2	2,9	4,7	3,3	4,9	3,0
- China	7,2	1,6	7,3	1,8	7,2	1,7
- Canada	4,3	1,4	5,3	1,8	5,1	1,6
- India	5,7	0,9	7,3	0,9	7,1	0,9
- Other	3,0	1,1	2,8	1,3	3,1	1,2
Sunflowerseed						
- Russia	4,2	1,0	5,4	1,2	5,8	1,1
- Ukraine	3,0	1,1	3,7	1,3	3,8	1,1
- EU	2,3	1,7	2,0	1,8	2,2	1,9
- Argentina	2,0	1,8	2,2	1,7	2,3	1,7
- Other	9,0	1,1	9,4	1,2	9,2	1,1

Oils and meals from different crops compete with each other, in addition oils or derived platform chemicals in specific applications in the chemical industry also compete with petrochemically based raw materials.

The relative importance of meal and oil in crop profitability and hence area under crop varies largely for the different crops (see also Figure 16):

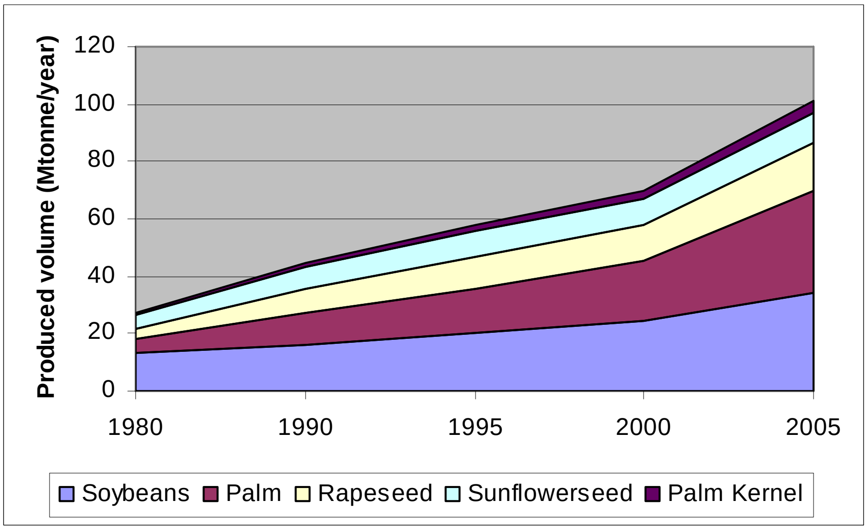
- Soy is cultivated predominantly for its meal, the oil being a valuable byproduct.
- Oil palms are cultivated exclusively for their oil, both the palm oil and the oil extracted from the nut (palm kernel oil) of the palm fruits.
- Sunflower and rapeseed are cultivated primarily for their oil and the produced meal contributes a modest 20% to total crop gross profits.

Figure 16 Relative contribution of oil to the total economic profits of the crops



Production of all three oilseeds and palmoil and the subsequently produced oil considered in this project has increased in recent years and has increased by more than 300% during the last 25 years, as can be seen in Figure 17.

Figure 17 Development of the produced volume of the oils considered here, between 1980 and 2005



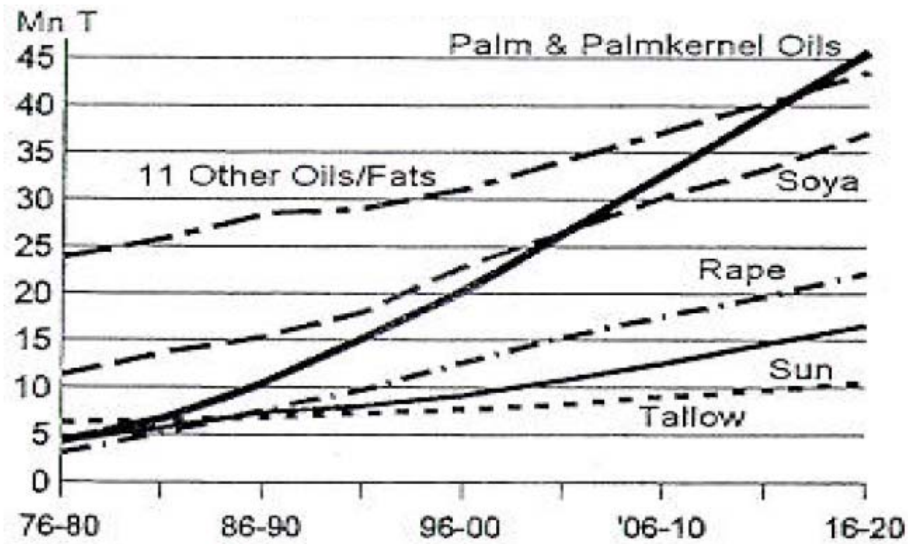
Increased production/consumption is related to population increase and to income growth around the world:

– Soy is cultivated primarily for meal for cattle with USA, Argentina and Brazil being responsible for 80% and China for another ±8% of total global production. Main increase in production takes place in Latin America and main growth in consumption in China. Soybean is the most important oilseed and prices for soybeans have a large influence on the prices of other oilseeds. Soy oil requires little processing is considered a good quality oil for food. The meal is considered the premium oil meal with high protein content and good palatibility.

- Rapeseed oil is a premium quality vegetable oil, mainly produced in EU, China, Canada and India. Rapeseed is partly exported from Canada to China.
- The popularity of palm oil is related to its structurally low price. Its price is low due to cheap labour costs and to the high yield per hectare. Malaysia and Indonesia produce over 80% of total palm oil production. Increase in production in Indonesia has been 80% during the last 5 years and increase in production in Malaysia approximately 30%. Major importers are China, India, Pakistan and the EU25.
- Sunflower oil is mainly produced in Russia, Ukraine, EU-25 and Argentina. The sunflower market is primarily a regional affair, with major producers also being major consumers. The exception is production in Argentina, approximately 1 Mtonne/year of its total production is annually shipped to the EU-25.
- Overall USA, China and EU-25 consume respectively 10%, 20% and 30% of total vegetable oil production USA;
- Meals from soybeans, sunflower and are also consumed predominantly in USA (15%), China (20%) and EU-25 (25%).

It is expected that demand for oil and meal of these four most important oil crops will continue to increase autonomously as a result of increased wealth in particular in China and the rest of Asia (see Figure 18).

Figure 18 Oil production: historic development and prognosis for the future



As illustrated by the current market situation in Europe demand for oil could be significantly increased further by government policies that promote biofuels based on vegetable oil.

The (indicative) target defined by the EU to substitute up to 5,75% of automotive fuel by 2010 by biofuels has resulted in a strongly increased demand for rapeseed oil for biodiesel production. This has led in return to a sharp increase in rapeseed oil price over the past 5 years. Rapeseed, previously being prime choice because of its lower price compared to sunflower oil is now being replaced by sunflower oil, despite the increase in sunflower oil commodity price with approximately $100/tonne.

There are also fears that this EU target will mean extended pressure on natural habitats within and outside the EU. Within the EU increased production of biofuels is anticipated to result in conversion of naturally valuable areas such as set aside land and olive groves into arable land for energy crops. Furthermore, it is expected that at elevated targets (5-10% or more of automotive fuels) the EU cannot cover its demand for biofuels with available agricultural area within the EU and will therefore have to import oilseeds, oils or biofuels. One assumption is that imports may be based primarily on palm oil, given the low price of palm oil. Increased demand for palm oil for biofuels production will have significant impact on the rain forests in Malaysia and especially Indonesia as production of palm oil for food industry has allegedly already resulted in the devastation of large tropical rain forest areas on Sumatra and Borneo.

We will investigate these items for rapeseed and palm oil into more detail in the next two paragraphs. Rapeseed is considered here because of its important role on the existing EU biofuels market. Palm oil is considered because of its potential role on this market and because of the environmental impact related to palm oil production.

C.3 Rapeseed

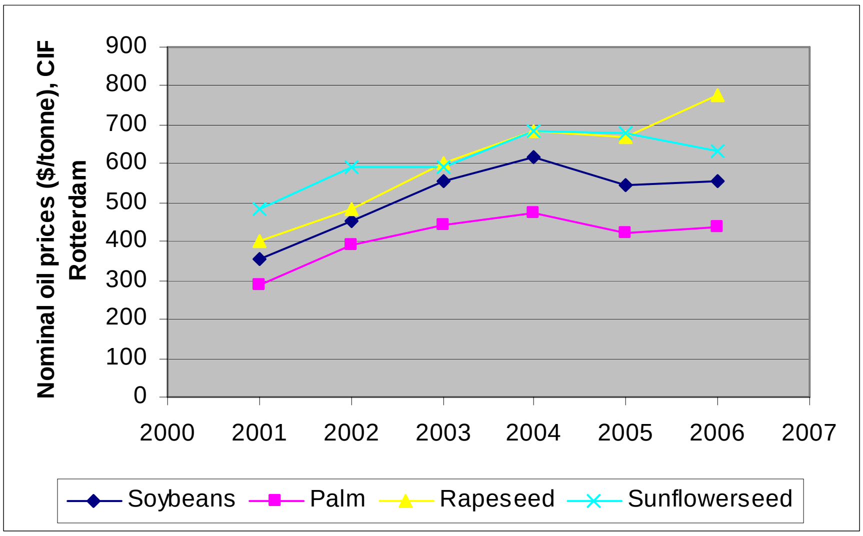
Since 2002 the biofuels production capacity has increased by about 35 percent in the EU and experts estimate that around 2.2 million tons of biodiesel are produced. The share of biodiesel use, in total usable rapeseed production, increased from 23 percent in 2002 to an estimated 40 percent in 2005. The crushing of rapeseed in the EU was estimated to

- 2.7 million tons in 2002.
- 4.6 million tons in 2004.
- 5.2 million tons in 2005.

The annual production of non-food rapeseed on set-aside area contributes to around 2.0 million tons of rapeseed.

As a consequence price differences between non-food and food rapeseed has almost disappeared and prices for rapeseed oil have gone up over the past 5 years with almost 100% up to almost $800/tonne. This has resulted in substitution of rapeseed oil by sunflower oil in food applications whereas the situation used to be the other side around.

Figure 19 Oil price development ($/tonne, CIF Rotterdam)



Contrary to this prices for rapeseed have largely remained at the price level of 2002/2002 resulting in increased margins for crushers. As a result crushers in Europe are converting from soy to rapeseed and soy meal and oil are increasingly imported, primarily from South America.

The extra demand for rapeseed for both food industry and biofuels production has also resulted in the net import of rapeseed, while EU used to be an exporter of rapeseed. Probably, rapeseed imports by the EU will compete with imports by China.

Biodiesel production currently uses around 1.4 million hectares of arable land in the European Union. The most important biodiesel producer is Germany (with about 40 percent of the production). There are approximately 40 plants in the EU, however the number of plants and the crushing capacity is growing quite fast. The plants are mainly located in Germany, Italy, Austria, the Czech Republic, France and Sweden.

In the New Member States only the Czech Republic has a significant production volume of biodiesel. Poland and Hungary also have some production, however it is still insignificant, and not yet on a commercial level. Expectations are that the biodiesel production might be quite important in Poland in the future since Poland is a member state where an important amount of rapeseed is grown, and with better availability to newer technology and better genetics, harvests are expected to increase considerably.

Total land requirement for realizing the EU biofuels 2010 target with rapeseed will require approximately 8,5% - 9,5% of all arable land within the EU-25. This is approximately 15 million hectares. At this moment 1,4 million hectare or ±1% of all arable land is used for rapeseed production for biofuels production. The Blair House Agreement between USA and EU-25 restricts the maximum EU oilseed area for food use to 5,0 million ha, and the annual output of oilmeal from oilseeds

planted on set-aside land for industrial use to 1 million MT of soybean meal equivalent. Acreage for rapeseed for biofuels production is anticipated to growth with another 1,5 million hectares in Poland and France in the next years, but these increases will be insufficient to reach the 5,75% biofuels target.
All this means that the EU-25 will eventually have to import oilseeds or oil in order to reach the target.

Thus far there is no sign of competition with palm oil or sunflower oil. Sunflower oil is applied predominantly in the southern European member states because the climate is unsuited for rapeseed. There might develop a competition with palm oil since Malaysian producers are constructing a biodiesel plant based on palm oil. However current fuel specification requirements for biodiesel (DIN EN 14214) allows only addition of approximately 10%, so that market opportunities are very much entwined with the rapeseed biodiesel market.

Increased rapeseed cultivation and processing has resulted in production of extra rapeseed meal and glycerine. In for example France livestock farmers are being persuaded to apply increased amounts of meal in the feed for their livestock, thus substituting soy meal imports from Latin America.

Our conclusion is that at this moment biofuels policy in Europe has a significant influence on the structure of regional oilseed and oilseed products market. However there is no clear evidence that increased production and utilization of biofuels results in increased environmental impact due to e.g. intensified cultivation of palm oil. Things might change, now that acreage for oilseeds in Europe has been utilized almost completely.