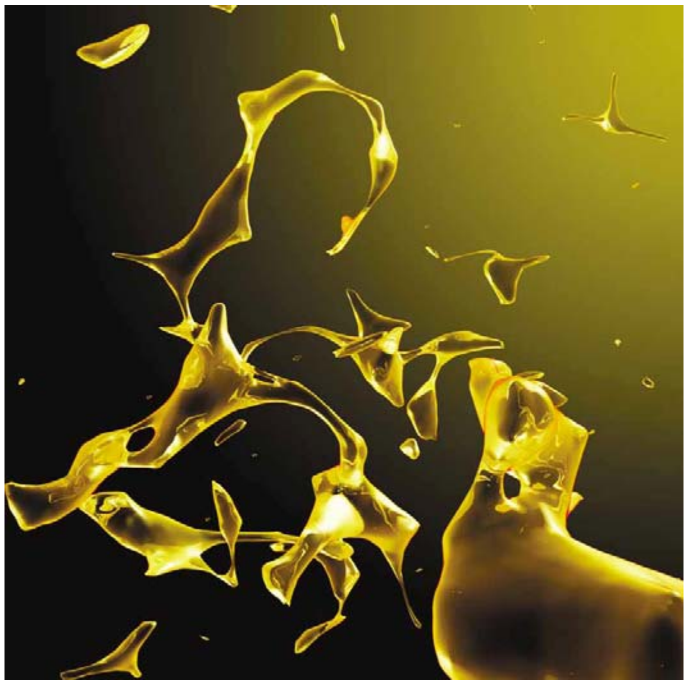
Explorative research on the transport biofuel market



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"The use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal tar products of the present time."

(The World's Fair 1896 Paris, Rudolf Diesel)

Executive summary

This thesis provides an analysis on the current situation and prospects of the biofuels market for transport purposes. The work is structured around the following main hypothesis: *"Does the biofuel market, at its current subsidized stated, have a future in the form of a self-regulated market?"* The analysis involves a desk-research by summarizing available information as-it-is. A framework consisting out of four elements has been conducted in order to provide insights on the biofuel market in a well-structured manner. It concerns the following elements: supply, demand, regulations and market.

Production of biofuels takes place worldwide. Biofuels are renewable energy sources, meaning that fresh supplies can be re-grown. Biofuels are a possible substitute product for fossil fuels. Compared with the latter product there are some advantages to subscribe to biofuels. Advantages and benefits of biofuels, however, depend on the categorization of the specific biofuel, type of feedstock used and technology applied to produce it. Biofuels are to be categorized by two types and these are labelled by either first and second generations or traditional and advanced generations.
Bio-ethanol, followed by biodiesel are the most produced types of biofuel. The United States (US) and Brazil are currently the leading ethanol producers and the expectations are that this will -at least until 2018- remain so. The European Union (EU) is the world's leading producer of biodiesel, which is starting to get more competition from developing countries such as Malaysia and Indonesia.

It is rather complex, if not impossible, to map out the exact production costs of biofuels. This is especially due to the fact that available literature does not provide exact details on all related costs. In order to sketch a picture of total production costs it is mostly the case that estimations and assumptions are used. Talking about traditional biofuels the general picture is that production costs of bio-ethanol are most competitive when produced from sugarcane in Brazil, followed by bio-ethanol from the US and the EU. Much less can be said on the exact costs and competitiveness of biodiesel.
The expectation is that total costs of advanced biofuels will be lower than traditional ones. However, information on the costs and/or developments of advanced biofuels is currently lacking. This is due to the fact that new technologies are employed to produce different new types of biofuels that are derived from more and different types of feedstock than traditional ones. This includes biofuels from lignocellulosic feedstock.

The demand for transport fuel has been increasing and expectations are that this trend will stay unchanged for the decades yet to come. In fact, with an worldwide increasing number of vehicles and a rising demand of emerging economies, demand will probably rise even harder. Transport fuel demand is traditionally satisfied by fossil fuel demand. However, resources of these fuels are running out, prices of fossil fuels are expected to rise and the combustion of fossil fuels has detrimental effects on the climate. Biofuels appear to be a solution to substitute fossil fuels because: 1) resources for it will not run out (as fresh supplies can be re-grown), 2) they are becoming cost-wise competitive with fossil fuels, 3) they appear to be more environmental friendly and 4) they are rather accessible to distribute and use as applicable infrastructure and technologies exists and are readily available.

Governmental policies are the driving force behind biofuel demand. This is realized by policies that stimulate and promote biofuel usage. Biofuel demand is, however, low in almost every country. The exact numbers are unknown, because any details on this are unavailable.
Yet, indications of demand do exist and the general picture of this is that both bio-ethanol and biodiesel demand are expected to grow worldwide. The US, Brazil and EU are expected to be good for a total consumption of 129 billion litres in 2018 up from an expected 68 billion litres consumption in 2009. Moreover, an expected biodiesel consumption for these three regions together is around 29 billion litres in 2018 up from a consumption of 14 billion litres in 2009.

Currently, there is some customer resistance to purchase biofuels. Governmental policies, stimulating and promoting biofuels, should be combined with technical and economical development In order to realize customer acceptance.
As opposed to first generation biofuels, advanced biofuels could possibly overcome customer resistance. Arguments for this, are that advanced biofuels appear to have: 1) greater environmental benefits, 2) are not in conflict with the food production (or at least less so), 3) are almost identical to fossil fuels, and 4) that their prices will be mostly lower than those belonging to the traditional ones.

The biofuel market is coordinated by governments that set specific targets and regulations. The EU has set percentage-wise targets on the consumption of biofuels. The US have targets related to the production amounts of renewable fuels. The targets of the Brazilian region related to biofuels are only clear for biodiesel (thus bio-ethanol targets are unclear).
The EU has set a target of 5.75% for 2010 and a 10% target for biofuel consumption to be reached in the year 2020. Expected is that both targets will not be reached. For the 5.75% target it is expected that the EU will only achieve a 4.2% of biofuel share. The 10% target is at present seen as too ambitious by the European Environmental Agency.
The US have set production targets for renewable fuels. It is not completely clear yet whether the production target of 163.659 billion litres of renewable fuels by 2022 is to be achieved.
Brazil has set a biodiesel consumption target of 5% by the year 2013. Expected is that Brazil will reach this target already by 2010 instead of the earlier projected year of 2013. Although Brazil focuses solely on this specif biodiesel target it can be stated that this country leader in consumption of all biofuels. This is made possible through the "flex fuel" engines, making ethanol consumption in the year 2008 higher than the consumption of petrol.

The market of biofuels is at the beginning of commercial development. The US, the EU and Brazil are the three major players in production and consumption. At present it is at one hand a free market as all parties are free to get and bring their product. At the other hand it is a complex and dynamic one due to the volatility of raw material prices.
The market knows many active stakeholders and it is developing on a global scale. There are multiple ways for companies to meet potential business partners and/or other stakeholders. In the years to come, biofuels are expected to increase enormously in supply.

Worldwide, countries try to secure their national energy supply. There are also many countries trying to reduce the emission of greenhouse gasses. Countries introduce different trade tariffs to protect the nation from foreign competitive biofuels and/or feedstock, which could otherwise reduce national employment and investments in biofuels.
Import tariffs limit the trade in biofuels. Besides import tariffs, countries also protect themselves by setting up discriminating standards, which also limits international trade and it also biases a country's national production.Tariffs limit (or possibly even stagnate) the progression of the biofuel market. The current situation is that total production is higher than the total use of biofuels on a global scale. In order to achieve an increase in worldwide trade it would be beneficial to abolish tariffs and discriminating standards. A probable proposition is the Biopact, that would end discriminatory standards and dismantle tariffs and subsidies.

Conflicts with other market such food-versus-fuel, biofuel-versus-fossil fuel and land use, are current challenging issues to overcome. The expectations are that a large amount of problems that relate to the first generation biofuels could possibly be solved by the launch of advanced biofuels onto the market.
Next generation biofuels could relief the stress on food prices and they could become an interesting substitute for fossil fuels. Calculations on the future assert that in 2030 second generation biofuels will make up a share between 62%-95% of the total existing biofuels. This implies that the future of the market will rely for a large part on the development and introduction of future generations of biofuels.

Preface

This master thesis is the last assignment product of our master study Entrepreneurship, Strategy and Organisation Economics at the Erasmus University of Rotterdam.
We declare that the text and work presented in this master thesis is original and that no sources other than those mentioned in the text and its references have been used in creating the Master thesis. The copyright of the Master thesis rests with the authors, who are also responsible for its contents.

During the summer we have worked intensively on this report at the Universities Library. We would like to thank some persons for their assistance and help during our research. First of all, we would like to thank our supervisor Dr. Ronald Huisman for his guidance. Secondly, we would like to thank each other for the support and put in effort in the master thesis. Doing this research together really made it a fun experience. Thirdly, our gratitude goes also out to Arnold Hieltjes and Sujan Lahiri for their comments on this paper.
Special thanks goes out to our parents, families and friends who have supported and encouraged us; without their contribution and support we would not have been able to follow and finish this study.

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Abbreviations

ABNT	Associação Brasileira de Normas Técnicas
ASTM	American Society for Testing and Materials
BP	British Petroleum
CAP	Common Agricultural Policy
CBI	Caribbean Basin Initiative
CEN	European Committee for Standardization
CH4	Methane
CO2	Carbon dioxide
CNG	Compressed natural gas
MC&T	Brazilian Ministry of Science and Technology
DDGS	Distillers dried grain with soluble
DME	Dimethyl etheran LPG-like fuel suitable for diesel engines
EEA	European Environmental Agency
EIA	Energy Information Administration
EREC	European Renewable Energy Council
EU	European Union
FAO	Food and Agriculture Organization
FFVs	Flex Fuel Vehicle's
FOSTA	Federation of Oils, Seeds and Fats Association
FQD	Fuel Quality Directive
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
GM	genetic modification
ICTSD	International Centre for Trade and Sustainability Development
IEA	International Energy Agency
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial
IPC	International Policy Council
LPG	liquid petroleum gas
MC&T	Brazilian Ministry of Science and Technology
MEP	Member of European Parliament
MVO	Productschap Margarine, Vetten en Oliën
NEB	Net energy balance
NIST	National Institute of Standards and Technology
NWBA	Northwest Biofuels Association
N2O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PNPB	Brazilian National Program on Biodiesel Production and Usage
Proálcool	Brazilian National Alcohol Program
RED	Renewable Energy Directive
RFS	Renewable Fuel Standard
RSB	Roundtable on Sustainable Biofuels
RSPO	Roundtable on Sustainable Palm Oil
RTD	Research and Technology Development
RTRS	Roundtable on Responsible Soy Associations
US	United States
USDA	United States Department of Agriculture
US-BX	US Biofuels Exchange
VNBI	Vereniging Nederlandse Biodiesel Industrie
WTO	World Trade Organisation

1. Introduction

There is worldwide an increasing interest for substitutes of conventional transport fuel. Much attention is given to one of the alternative energy sources; biofuels. As a transport fuel it is a ‘hot’ item in the daily news. Also, scientific studies on it, either on economical or any other related level, are widely present.
The development of the biofuel market, if one can speak about an existing one, is in its infancy. There are many uncertainties on the future of the different biofuel product types. It is hard to judge upon the value of available information provided by the different newsflashes and studies as it is often intertwined with different opinions and assumptions. There are many speculations both in the form of advantages and disadvantages.

The potential of biofuels appear to be enormous from an economical, political and environmental perspective. Speaking in terms of advantages, much heard is that they, as an alternative fuel, could solve several issues, amongst others:

- the increasing energy prices worldwide;
- the increasing need of energy imports;
- the negative environmental consequences of fossil fuel combustion;
- the security of national energy supply for many countries.

On a global scale governments attempt to encourage the production and consumption of biofuels. Many countries launched programmes that have an impact on many stakeholders; governments, consumers, businesses and producers. Usually, the programmes are supported by policies to ensure a minimal proportion of biofuels on the market.

Besides the advantageous potentials, there are continuously newsflashes and studies indicating possible negative impacts. Most disadvantages heard are the following claims that biofuels have;

- less environmental benefits than assumed;
- a lower net energy gain than fossil fuels;
- a weak competitive position;
- a negative impact on food prices.

Although much is being said and written on the biofuels market, up to now a comprehensive unbiased overview on it is not yet available. However, it is generally believed that governments have a profound influence on all biofuels. This raises questions such as what are the real facts on biofuels? And what is truly the current situation of the biofuel market?
With this thesis we try to deliver a general picture on the market of biofuels for transport that powers engines of vehicles; cars and motorcycles. The main focus is on the regions Brazil, United States (US) and the European Union (EU); the three leading global biofuel producers.

1.1 Objective and research questions

The report is written for a general audience that is interested in the development of the energy sector and especially in biofuels for transport purposes. The goal of this explorative research is to increase the knowledge of the current situation’s knowledge of the biofuel market for transport purposes to power vehicles (cars and motorcycle) and to provide insights on where the market is headed to.

The main question of this research is:

Does the biofuel market, at its current subsidised state, have a future in the form of a self-regulated market?

In order to provide an answer to this question, four supporting sub-questions are set out:

What is the current situation of the transport biofuel market?

Is it profitable to supply transport biofuels?

What is the demand for liquid transport biofuels and where does it come from?

How is the transport biofuel market regulated?

The aim is not only to provide answers on the sub questions related to the current situation. The future will also taken into account. The data collected to answer the sub questions will form the basis to answer the main question. Although there are factors that could possibly influence future outcomes it is not the aim to provide exact answers. This is in line with the above mentioned objective: the emphasis is not provide exact answers, but rather to increase knowledge and to provide insights on the transport biofuel market.

1.2 Framework

In order to structure the research around the main- and sub questions the following framework has been used:

Supply	Demand	Regulations	Market
Product	Transport fuels	Promotion and stimulation	Biofuel Market
Supply chain	Biofuel demand	EU	Exchange
Production	Purchasing factors	USA	Trade flows
Production costs		Brazil	Production versus use
			Environment
			Conflicts
			Developments

The framework is based on the basic classical economic model of supply and demand. Following each category will be explained. First, supply can be described as the provision and amounts of goods for sale. The item "the product" will provide a description on the characteristics of the manufactured product biofuel. The supply chain describes the channel starting from the producer and is 'stretching from raw materials to components to final products that are carried to final buyers' (Armstrong & Kotler, 2007). The production gives details on total biofuels produced and production costs presents the 'total monies expended in manufacturing a product for market consumption' (Clemente, 1992).
The category demand represents the '[c]onsumers' collective financial ability and desire to purchase goods' (Clemente, 1992), i.e. the biofuels for transport purposes. Under this category the discussion will be on the total quantification of transport fuel demand and in particular demand for transport biofuel. Next to this the item purchasing factors will discuss what factors play a role for consumers to purchase and use (certain types of) biofuels.
The category regulations gives on overview on the implemented regulations by governments. The first item will discuss in general why regulations are implemented. The other items will discuss regulations specifically set by the "EU", "US" and "Brazil". The centre of attention will be the EU.
The market, or '[t]he set of all actual and potential buyers of a product or service'(Armstrong & Kotler, 2007), is the fourth category of the model. The biofuel market will provide a general overview on the market. Trade flows are about the flows of international biofuel trade. The item production versus use reviews whether supply meets demand. Following is the environment of the biofuel market. Conflicts, are discussed that are caused by the biofuel market. And finally, developments on the biofuel market are described.

Although the aim is to describe the general picture on biofuels, the main focus of every single category is on the three regions: Brazil, US and EU. Other regions are here and there touched upon, but no thoroughly discussed in detail. The reasoning for this is threefold, namely:

1) Data availability. Less literature is available for other regions compared to the three chosen regions. A probable explanation for this is the later development of biofuels in those regions. Another issue is the language barrier, not all literature is provided in English. The language barrier applies to some extent also to Brazil. However, as Brazil is a rather developed region with respect to biofuels, English and translated literature is available in fair amounts.
2) Data significance. The three regions represent the market at a global scale as they 'accounted for 95% of biofuels production (IEA, 2006b)' (Doornbosch and Steenblik, 2007). Moreover, most of today's world biofuel consumption takes place within these regions.
3) Time limitation. Considering the total of three months that was originally set out for this study, there was a limitation of time. A similar analysis on other countries is possible, when more time is available.

1.3 Research design

The type of research conducted can be characterized as an qualitative, or explorative one. By de Leeuw (1996) it is stated that such a research explores and forms ideas, in other words it gives answers on an open question. An explorative research is ‘to satisfy the researcher’s curiosity and desire for better understanding’ (Babbie, 2006), i.e. it is discovery-oriented (Hair, 2003). As the goal of this research is to describe a current situation, a specific theory is not tested for.

1.4 Data collection

The thesis concerns a desk research; academic literature and internet resources are used for results. The objective is to summarize available information as-it-is. The reliability of the operations of the research should be in such a way that the collection and usage of information could be replicated with a similar outcome (Yin, 2003). This is assured by the analysis and use of different types of sources; academic papers and news from the media and governmental publications. This is done in order to minimize errors and biases in this study (Yin, 2003).

It might be that information is distorted or that something is left out. This could, for example, be the case when it concerns data from any governmental publications. As governments intervene within the biofuel market it could be such that the presented is coloured, only factual and/or not fully reliable. In order to ensure the reliability sources have been uses with all kinds of different perspectives; internet sources, scientifical and popular articles, government publications, etc.

1.5 Structure of the thesis

This thesis exists out of 7 chapters. The second until the fifth chapter will provide information on the different categories laid out in the given framework. Chapter two discusses supply, chapter three demand, chapter four regulations and chapter five the market. The structure of each chapter exists out of a short introduction, followed by the different items and a conclusion to finalize it.

The sixth chapter of this thesis provides an answer on the four sub questions and main question set out. This will be done with the support of the theory in the preceding chapters. The final chapter, chapter seven describes the limitations of our research and shows the way for future research.

2. Supply

2.1 Introduction

This chapter discusses the supply of biofuels for transport purposes, meaning the amount that is available for usage. Four items will be discussed, namely: the product (paragraph 2.2), the supply chain (paragraph 2.3), production (paragraph 2.4) and production costs (paragraph 2.5). First, the characteristics of biofuels will be explained (paragraph 2.2). This will be followed by the supply chain (paragraph 2.3), which will be described from cradle-to-grave. The third item, production (paragraph 2.4), will provide information on the current global production of biofuels. The last and fourth item, the production costs (paragraph 2.5), involves total expenditures on the product biofuel per biofuel category and per specific region. The chapter is finalized with a conclusion (paragraph 2.6)

2.2 The product

Biofuels are renewable energy sources, meaning that fresh supplies can be re-grown. The source of biofuels is biomass, and this 'refers to living and recently dead biological material' <www.greenbuilding.co.za>. Biomass 'can be used for energy in several ways: burned directly to generate heat and power, dried and densified into solid fuels such as wood and corn pellets, or converted into liquid or gaseous fuels such as ethanol for use in stationary or mobile source combustion' (Marshall, 2007). Biofuels appear to be more environment friendly in comparison to fossil fuels considering the emission of greenhouse gasses when consumed. Examples of those gasses are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Those gasses pose risks as they tend 'to warm the earth's surface' (Randelli, 2007).

Thus, biofuels exist in three different forms: solid, liquid and in a gaseous form. Biofuels in a solid form, like firewood, briquettes and pellets, are presently not used for transport, but rather for purposes like residential heating and cooking. 'Since the industrial revolution, wood has been gradually replaced as fuel […] Today, the world transportation system is almost totally dependent on fossil oil […] Apart from fossil based LPG (liquid petroleum gas) and CNG (compressed natural gas), liquid biofuels are currently one of the few possible substitutes for fossil oil based transport fuel' (Randelli, 2007).[1]
Liquid biofuels include ethanol, biodiesel and biobutanol. Biodiesel and biobutanol can be used directly in petroleum engines. 'Ethanol can be used as fuel for automobiles either alone (E100) in a special engine or as an additive [as a blend] to gasoline for petroleum engines' (Christofides, 2006).
Biofuels in a gaseous form includes carbon monoxide, methane and hydrogen. Cars need to be adapted to be able to run on biogas 'in so-called 'bi-fuel' cars, which run on both biogas and petrol" (Börjesson and Mattiasson, 2007). Another possibility is to convert the mixture of carbon monoxide and hydrogen, so-called synthetic gas or syngas, to methanol (a liquid) that can be used as a transport fuel.

The energy content of biofuels differs from conventional fuels. Total energy output per litre of biofuel is determined by the feedstock used, region where the feedstock is grown and production techniques applied. Randelli (2007) provides, for example, energy contents of biodiesel and bio-ethanol. According to Randelli, 'Biodiesel […] has an energy ratio compared to diesel of about 1.1 to 1, which means that its energy contents are 87% of those of diesel. Bio-ethanol […] has an energy ratio compared to gasoline of 1.42 (67% of gasoline)'.[2]
The amount that is similar to the amount of energy content of one litres gasoline is referred to as gasoline equivalent.

Biofuels can be categorized into four different generations. 'Generally, the first generation considered fuels [are] produced from traditional agricultural (edible) crops by established technologies: biodiesel from oil crops and ethanol from sugar and starch crops' (Hamelinck and Faaij, 2006). The first generation is also referred to as traditional biofuels.
The second and subsequent generation, also referred to as advanced biofuels, use non-food based feedstock, residues, dedicated energy crops and other lignocellulosic feedstock, and involves application of so-called 'advanced technologies' that makes a different conversion from biomass to bio-energy possible.

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[1] Substitutes in such a way that the gasoline can be either totally replaced or a portion of it can be complemented by biofuel in the form of blends.
[2] It is not explained to what feedstock and region this relates to.

‘Whereas the second generation intervenes at the bioconversion step, the third generation of biofuels is based on advancements made at the source - the production of biomass. This generation takes advantage of new, specially engineered energy crops’ <http://news.mongabay.com>, aiming to have higher biofuel yields and higher return on investments than the second generation. Crops are designed to be able to grow easier in multiple environments. Such type of crops ‘promise to make available a very large part of the world's land earlier deemed largely problematic for agriculture’ <http://news.mongabay.com>.
‘The fourth generation biofuels are based on engineering or breeding of energy crops that specifically absorb unusually high levels of CO2’ <http://environmentalchemistry.com>. ‘The resulting fuels and gasses are not only renewable, they are also effectively carbon-negative’ <http://news.mongabay.com>. The following table, table 2-1, shows the categorization of biofuels per generation type further specified by biofuel type. Examples of used biomass feedstock per type of crop and examples of specific input are also been given. Furthermore the table shows the related conversion process. Also taken up in table 2-1 is the net energy balance (NEB). That is ‘the amount of energy available after the transformation process (output) and the total energy used in the process (input)’ (Randelli, 2007). When biofuels are produced they demand considerable input of energy (transport, fertilizers, etc).
Although the above discusses the categorization of generations, such a categorization is not always strictly applied by all studies and authors. This can be somewhat confusing when literature is searched for or when one attempts to compare the different studies. For example, the study of International Energy Agency (IEA), 2008, talks only about the first and second generation. Hereby generations are only distinguished by the fact whether the used feedstock is edible (1st generation) or not (2nd generation), differences of technologies applied are not considered.

Table 2-1: Overview of the product biofuel, per generation type.

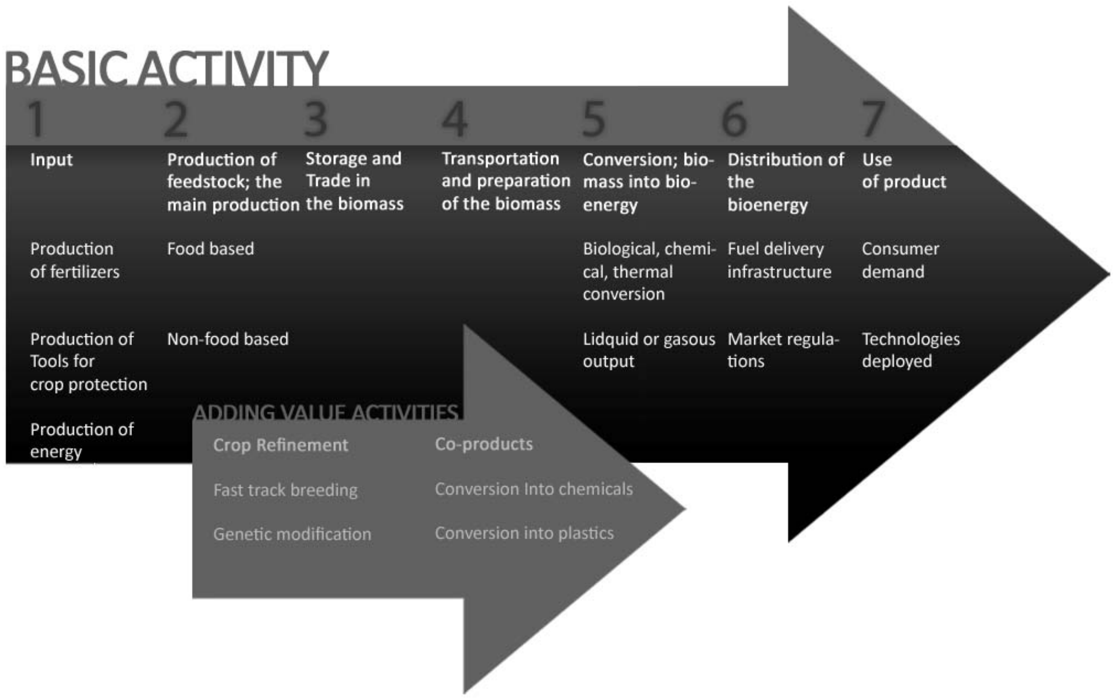
Biofuels								
Category		Generation	Biofuel type	More specific, or alternative name	Biomass feedstock	Examples of input	Conversion Process	Energy Balance
Traditional biofuels / Conventional Biofuels	Food-based	1st generation	Bioethanol	Conventional Bioethanol	Starch	Cassava (grain)	fermentation, transesterification	Weak (corn) to excellent (sugarcane)
						Maize (crop)		
					Sugar	Sugar beet (plant)		
						Sugarcane (grass)		
			Pure vegetable oil	Pure Plant Oil (PPO)	Oil Crops	Oil Palm/Palmoil Rapeseed Soybean		
			Biodiesel	Biodiesel from energy crops (RME, FAME)				
			Biodiesel	Biodiesel from waste (FAME)	Waste/cooking/fry oil	Animal fats		
			Biogas	Upgraded biogas	(wet) biomass	Fodder beet		
advanced biofuels	Non-food based, dedicated energy crops (Refined conversion process of feedstock input)	2nd generation	Bioethanol	Cellulosic bioethanol	lignocellulosic material	Grass species, trees, agricultural and industrial residues like: wood material; residues of carbonous material; switchgrass (grass); Jatropha (plant)	fermentation, gasification, fast-pyrolisis	Depends on feedstock, conversion process integration
			Synthetic biofuels	Fischer-Tropsch diesel Synthetic biodiesel Biomass to liquids				
			Synthetic biofuels	Heavier (mixed) alcohols Biomass to liquids				
			Biogas	Synthetic Natural Gas (SNG)				
	Non-food based, purpose designed energy crop (new, specially engineered energy crops)	3rd generation	Bioethanol	Cellulosic bioethanol	lignocellulosic material	Algae (plant)		Depends on feedstock, conversion process integration
			Synthetic biofuels	Fischer-Tropsch diesel Synthetic biodiesel Biomass to liquids		Leaves and stalks of (sweet) sorghum		
			Synthetic biofuels	Heavier (mixed) alcohols Biomass to liquids		Cassava (grain)		
			Biogas	Synthetic Natural Gas (SNG)		Eucalyptus		
	Non-food based, purpose designed energy crops with improved carbon storage (Genetically	4th generation	Bioethanol	Cellulosic bioethanol	lignocellulosic material	Trees, like: Dahurian Larch, Eucalyptus		Depends on feedstock, conversion process integration
			Synthetic biofuels	Fischer-Tropsch diesel Synthetic biodiesel Biomass to liquids				
			Synthetic biofuels	Heavier (mixed) alcohols Biomass to liquids				
			Biogas	Synthetic Natural Gas (SNG)				

(Source: Own elaboration, primarily based on http://news.mongabay.com)

2.3 The supply chain

Total supply of biofuels can be realized in the form of two different chains. The goal of both chains is to deliver bio-energy for transport purposes to the end consumer that is processed from biomass. The type of chain depends, however, on the input used. An overview of both chains will be given below. For both the core activities will be described.
The first chain is related to own produced biomass, whereas the other relates to the usage of collected existing biomass. The supply chain where biomass is produced before it can be converted into bio-energy is most common. It entails seven activities as can be seen in figure 2-1.

Figure 2-1: Biofuel supply chain related to biomass production.



(Source: Own elaboration, primarily based on Meeusen et al. 2009)

The choice of input is the first activity. This includes among others the use of fertilizers and crop protection tools.
Crop refinement is an optional adding-value activity. By developing dedicated crops and trees to breed plants for a purpose, it 'could lead to improvement of preferable traits like higher energy yield or the need for less input' (Meeusen et al. 2009). Several existing technologies are available to be used in order to improve these traits, including: 'the use of traditional plant breeding, genomic approaches to screen natural variation for incorporation into breeding programmes [fast-track breeding] and the use of genetic modification (GM) to produce transgenic plants' (Meeusen et al. 2009).

The second activity is the actual growth of the biological matter, i.e. production of the feedstock, which is either food-based (edible crops) or non food-based. The production results in output in the form of a main-product, which is eventually converted to a biofuel. Co-products (i.e. by-products) could also possibly be derived from the biomass; those can be converted in products, such as chemicals and plastics. Producing co-products could serve as an adding-value activity as the value of its sales lowers the total costs of total biofuel production costs.

The third activity involves the storage and the trade of the biomass. Often after production the biomass is subjected to a trader in the form of a wholesaler. The type of raw material determines the length of storage and the related specific treatment (this relates, for example, to whether the material is dry or wet). 'For dry material such as straw the risk of fire when stored in large piles is high. Green materials such as bagasse […] are also risky being prone to spontaneous combustion when stored in piles due to bacterial action causing heat

build-up‘ (IEA, 2008). Moreover, ‘[s]toring plant material can lead to loss of material by biological degradation or pest infestations […] ‘Feedstock such as wheat grain can be stored easily and provide a year round supply, whereas sugar beet is much harder to maintain quality as it degrades rapidly [...] [Moreover], storage opens up possibilities for slower pre-treatment processes or deliberately introduced process agents […] reducing the need for mechanical or thermal/chemical pre-treatment’ (The Royal Society, 2008).
‘Most forms of biomass […] tend to have a low energy density per unit of volume […] or mass […] compared with fossil fuels with the same energy equivalent’ (IEA, 2008). This makes storage more costly per unit of energy carried, which accounts also to the fourth activity; transportation and the preparation of the material (IEA, 2008).

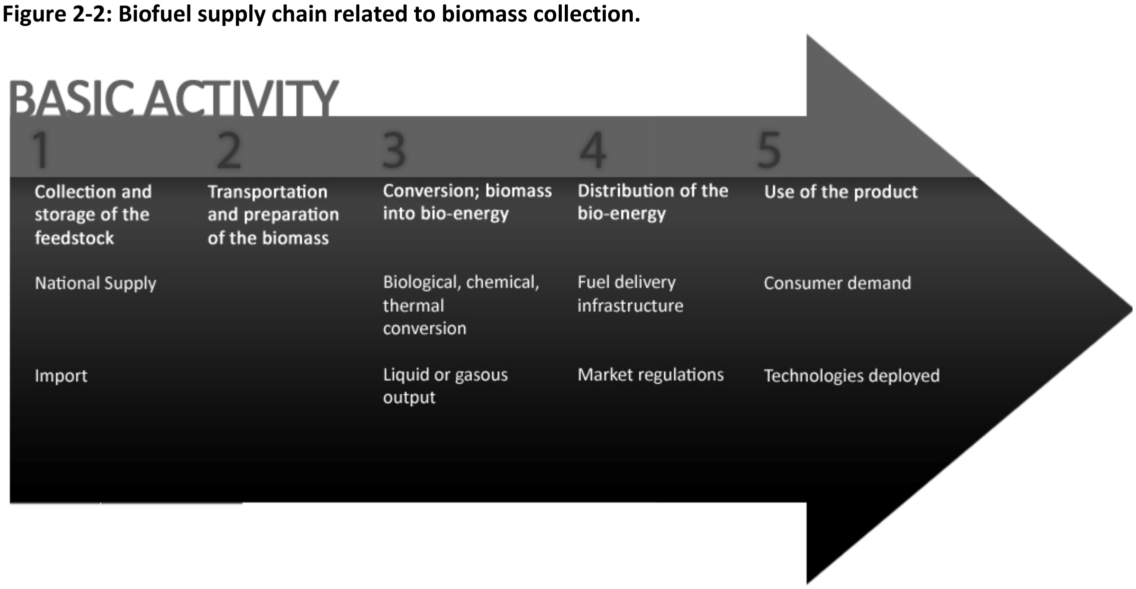
The fourth activity determines the efficiency and quality output of the conversion process. The preparation implies the process to make the material denser. This in order to make transport and conversion (the next activity) more efficient as it lowers total conversion costs (The Royal Society, 2008).

The conversion entails several steps. ‘Depending on the feedstock and the fuel that is to be produced, conversion can be done through several different routes using a range of biological, chemical and thermal conversion processes’ (The Royal Society 2008). The output is either in a liquid or gaseous form. ‘Developments in conversion technologies and bio-refineries will lead to more of the plant being used to produce a wider range of products [bio-fuels and co-products] and with greater flexibility in what is produced. Much of this development is technology dependent and will lead to improvements in environmental and economic performance of the processes and the supply chain’ (The Royal Society 2008).

After conversion the biofuel is ready to be distributed and to be used by the end consumer. These two activities are being influenced by the available fuel delivery infrastructure, (engine) technologies deployed, consumer demand and by market regulations set out.
‘Biodiesel fuel is much easier to transport than ethanol, because it can use the same transport and storage infrastructure as conventional diesel. Similarly, equipment that is used to store, transport and deliver diesel can also be used for biodiesel with no modification, whereas modifications and some degree of fuel separation is needed for ethanol’ (IEA, 2004)

The second supply chain variant relates to biofuels wherefore no individual production of biomass is involved. In this case input concerns residues and waste that is collected by either national supply or imports. Thus, the difference with the previous supply chain is the input of feedstock, it is either produced (supply chain 1) or collected (supply chain 2). The activities following transportation are theoretically similar and will thus not be explained again. As shown in figure 2-2 there are in total 5 activities.

Figure 2-2: Biofuel supply chain related to biomass collection.



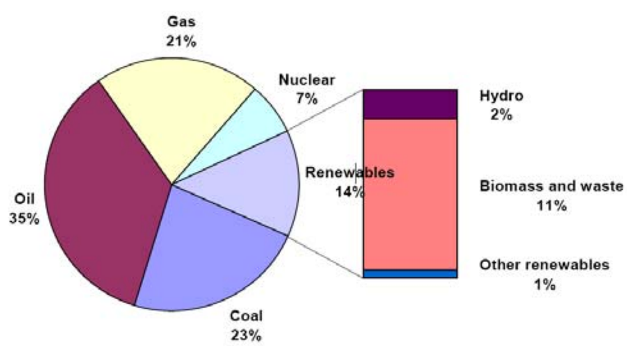
(Source: Own elaboration, primarily based on Meeusen et al. 2009)

2.4 Production

Production of biofuels takes place at a global scale, whereby commodities from different regions and producers are involved. Due to many continuous technological developments of both feedstock and production systems, the scale is likely to expand the coming years.
Production takes primarily place with the aim 'to fuel vehicles, but [it] can also [be produced in order to] fuel engines or fuel cells for electricity generation' (Demirbas, 2007). Bio-ethanol (as a gasoline replacement) and biodiesel (as a diesel replacement) are presently the two most produced biofuels because they can be used 'in most vehicles right now and can be distributed through the existing infrastructure' (Randelli, 2007). Production of gaseous biofuels (like methanol) have, even with tax incentives, not been able to be economically viable yet. This is because current natural gas feedstocks are so inexpensive (Demirbas, 2007). According to Börjesson and Mattiason (2007) biogas' competitiveness is limited based on energy crops, but biogas based on organic waste and liquid manure could currently, even without tax incentives, already be competitive. 'In future renewable methanol [a form of biogas] could eventually become commercial feasible and attractive as technologies are being developed' (Demirbas, 2007).

'Within a global context, fossil fuel consumption still dominates the world energy market […]. However, the uncertainty in future supply, currently unsustainable patterns of energy consumption, and the costs of expanding proven reserves of fossil fuels have lead many energy analysts and managers around the world to seek alternatives from other more renewable resources, such as bioenergy' (Rosegrant et al. 2007). 'Between 1980 and 2005, worldwide production of biofuels increased by an order of magnitude –from 4.4 to 50.1 billion litres, with further dramatic increases since' (Pin Koh and Ghazoul, 2008). Figure 2-3 shows that renewable energies make up for 14% of the world energy supply[3], this includes fuel wood, charcoal and other biofuels (around 10%), hydroelectric (2.7%) and other renewables, like wind, geothermal and solar (Nass et al. 2007).

Figure 2-3: Share of different energy forms in global total primary energy supply, 2002.



(Source: Adapted from Rosegrant et al. 2007)

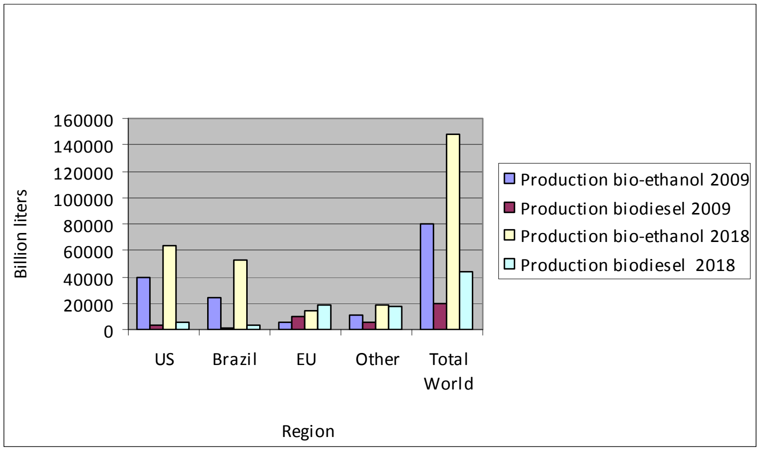
The majority of biofuels, based on biomass and waste, are derived from food-based feedstock, belonging to the 1st generation. The future potential consumption of fuels belonging to the advanced generations, based on more complex non-edible materials, is large <http://news.mongabay.com>. It is now possible that first commercial production plants for second-generation biofuels might appear online during the decade to come. The expectation is that these products will represent a considerable share of biofuel supply in rather a short time.

Currently, bio-ethanol 'is by far the most widely used biofuel for transportation worldwide – mainly due to large production volumes in the US and Brazil' (IEA 2004). In fact, '[g]lobally, bio-ethanol production is mostly concentrated in Brazil and the United States, which together accounted for nearly 90% of bio-ethanol production in 2005 (Licht)' (Rosegrant et al. 2007). Crops most used as raw materials for the production of ethanol are sugarcane (especially Brazil), corn (especially US), wheat and sugar beets. Materials also used are other grains (e.g. cassava and barley) and by-products of manufacturing industries (e.g. molasses). The production process involves the conversion of sugars into ethanol.[4] These sugars are not always easily derived <http://www.andrew.cmu.edu>, depending on the type of material and technology used a specific preparation is needed (de Vries et al. 2004).
Biodiesel production is based upon vegetable oils and waste grease (such as used frying oil and animal fats). 'The European Union is currently the global leader in biodiesel production and use, with Germany and France

[3] This is measured in global total primary energy supply at 10.345 mtoe (million tons of oil equivalent), 2002.
[4] The conversion process involves fermentation, distillation and rectification.

accounting for 88% of world production, followed by the United States, which produces 8% of global production (Hazell and Pachauri, 2006)' (Nass et al. 2007). Most used feedstock in Europe is oil based upon rapeseed[5] (about 90%), but other feedstock, like sunflowers can be used as well. Waste grease from animal fats or the food industry can also be used, although this happens yet pnly on a small scale (de Vries et al. 2004). Projected production in total billion litres of bio-ethanol and biodiesel for this year (2009) and for the near future, 2018, are provided by OECD-FAO (2009). Figure 2-4 shows this visually.

Figure 2-4: Production of bio-ethanol and biodiesel in 2009 and 2018.



(Source: Adapted from numbers provided by OECD-FAO, 2009)

2.5 Production costs

This part will go into detail on total production costs of biofuels. This is of importance as it can eventually give insights on whether the production costs (i.e. supply costs) meets up the total price, end consumers are willing to pay for it. (The amount consumers are willing to pay are discussed in the chapter demand).
Studies do generally not provide a cost breakdown on total costs of biofuels. This applies to every region and each type of biofuel. Randelli (2007) argues that there is not yet enough knowledge of biofuel production on a commercial scale to have a clear picture on the costs of a mature refinery process. The expectation is that current costs could drop, costs 'will likely continue to decline gradually in the future through technical improvements and optimizations, and as the scale of new conversion plants increases' (OECD, 2008).

Even though cost comparisons and analyses are hardly available, the general picture (among others Ryan et al. 2005, MVO 2007, Randelli 2007, The Royal Society 2008, IEA 2008, Meeusen et al. 2009) is that the biggest part of total biofuel cost price is determined by the feedstock, i.e. the crops used for input. Crop prices are rather volatile. As a matter of fact, world prices for a number of feedstock including maize and wheat have increased by 86% and 110% between 2004 and 2007 (OECD, 2008).
Most common direct related appointed factors of the crop price rises are the influences of:

- the region of production (climate and yield per crop),
- size and scale of the conversion facility (benefits of scope and scale),
- subsidy programs (like tax incentives),
- and the conventional fuel market (costs of input, heat, transportation and processing).

Next to this, it is also believed by some that the volatility is to some extent related to one or more of the following factors:

- food prices (e.g. Brown 2006),
- devaluation of the US dollar (e.g. Gundzik, 2006),
- growth of commodity imports of emerging economies like China and India (e.g. Lane, 2008),
- and trade tariffs (Whistler, 2008).

[5] The specific choice of rapeseed is mainly due to the norms of quality laid upon by laws.

Thus far in any study, however, real proof is lacking on the direct relationship between any of the latter factors and biofuel feedstock cost prices. Other influences on total production costs are geographical differences and 'prices of [other] raw materials, the method of production, the extent of refining undertaken, and the supplementary utilization of by-products and waste' (Randelli, 2007).

Below, total production cost calculations will be reviewed sorted by generation type. As there are rather big differences between traditional and advanced biofuels, by characteristics (specific feedstock types and technologies applied) and related costs, different sections are devoted to both categories.
Currently most conducted cost analyses of the traditional biofuels are related to ethanol and biodiesel. These analyses are often limited to Europe, North America and Brazil. In order to provide a clear overview on it the following structure has been set out. We start with an overview that is given on costs related to the 1st generation. This is followed by a division between ethanol and biodiesel. The discussion on ethanol costs includes a general impression and a look at the regions EU, US and Brazil, where all regions are being individually reviewed. To conclude this part, costs of ethanol are being compared with each other. From here on an assessment on biodiesel production costs follows. This assessment includes a general impression and an overview on costs related to the EU, US and Brazil. This part will also be closed by a short biodiesel cost comparison. The section on advanced biofuels is less comprehensive than that of traditional biofuels. This is due to the fact that relevant data on costs are not as widely available. This part will focus on general costs related to advanced biofuels. It does not include a specific analysis on the different regions.

Roughly spoken biofuels consists out of the following cost categories; raw material, storage, processing (i.e. conversion), capital investments, transportation and distribution. Every study differs however and does not necessarily use the same categorization. Thus, studies differ from each other by the used methodology to analyze the costs on biofuels. As mentioned previously, in most instances exact details (and methodology) on how the costs are derived are omitted. This makes the comparison between studies rather complex. To emphasize this, the following examples:

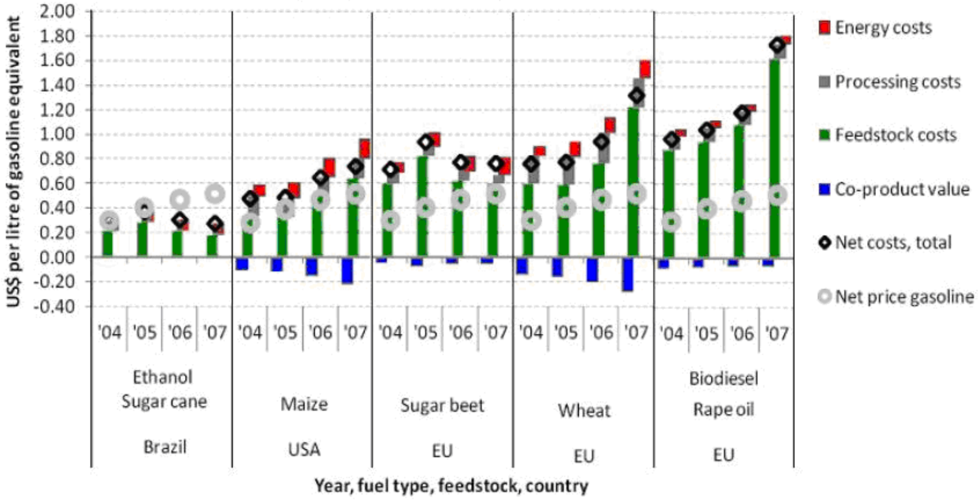
- Commonly, whenever a gasoline equivalent is presented, there is no, or hardly an, indication provided on how this calculation is built up. That is, in terms of the characteristics of the used feedstock and its related total energy content. Even when the exact energy content is given, it does not always meet the same calculations from other studies.
- Studies do not always indicate what exchange rate is applied. This is in terms of the exact date or averages being used. Different currencies are subjected to fluctuations, therefore it is actually rather important.

To overcome the second point all studies are converted into Unites States Dollar. This choice is based upon the observation that biofuels -and its substitute product gasoline- are mostly represented by this currency (as opposed to Euro's and the Brazilian Real). Moreover, another fact is that biofuels and its substitute product gasoline, are mostly represented in units of total litres (as, e.g. opposed to gallons). That is why units of biofuels are represented by litres.

2.5.1 Traditional biofuels - 1st Generation

The IEA (2008) provide with their work an overview on the 1st generation biofuels, which gives insights on the costs differences between regions as well as the developments from 2004 to 2007 (see figure 2-5, next page).

Figure 2-5: Production costs of 1st – generation biofuels 2004-2007.



(Source: IEA, 2008)

Key factors of total costs are feedstock and energy, contributing both to an increase in production costs. Figure 2-5[6] shows the cost structure on ethanol in Brazil[7] (from sugar cane), US (maize), EU (sugar beet and wheat) and biodiesel in the EU (rapeseed oil). Biofuels are provided by the costs in US dollars per litres of gasoline- equivalent.
Feedstock and energy costs have not caused a cost increase for Brazilian sugarcane ethanol over the presented years, as the country 'has been able to expand feedstock production in line with the growth in demand (for both ethanol and sugar), helping to prevent price escalations' (IEA 2008). Brazil is the cheapest ethanol producer in the world, followed by the US. The EU produces overall at a higher cost price. This includes the costs of producing biodiesel. Biodiesel appears to be more expensive than ethanol, especially due to higher feedstock costs and low value co-products.

In conclusion, the model shows that costs of 1st generation biofuels differ per region and by type of biofuel. Therefore from here on the discussion on 1st generation biofuels will be followed by a categorization of ethanol and biodiesel, specified per region.

2.5.1.1 Ethanol

Ethanol production costs can significantly differ. The literature appoints several causes. The general picture is that feedstock make up the most of all costs; it accumulates to around 40% and up. The production region and the processing costs appear to have a considerably impact on total costs as well, this is argued by several studies, including studies of Marshall (2007) and the IEA (2004). Both compare production costs in the US, Brazil and the EU.
Marshall groups production costs into feedstock and processing and he claims that both have a significant impact on total costs. The study of IEA (2004) appoints conversion plant sizes as one of the major reasons for the difference in price between Europe, the US and Brazil. Compared to the US and Brazil there are in Europe less and relatively smaller ethanol producing plants. Another point is that European production has not been optimized with respect to crops and other inputs. 'As a result, the typical cost for ethanol produced in Europe is significantly higher than in the US. Brazil is the lowest-cost producer, thanks to lower input costs, relatively large and efficient plants and the inherent advantages of using sugar cane as feedstock' (IEA, 2004).

Further along the three regions –EU, US and Brazil- will be individually discussed in order to give more insights on the exact details on factors and expenses that cause the differences in production and processing costs.

[6] See Appendix A for the details on the figure.
[7] The co-product value of exported electricity generated from bagasse in some plants in Brazil is not shown' (IEA, 2008).

2.5.1.1.1 EU

The most complete analysis on EU ethanol costs is most likely the analysis of Ryan et al. (2005). It includes data of several studies. This includes the study of Jungmeier et al., who reviewed 73 studies to get an estimate of biofuel costs.
Cost calculations are based on production, transportation, conversion and distribution. The cost structure is build up by categorization of crops; sugar- and starch crops as presented by table 2-2 and table 2-3. Three cost estimates are given; low, high and best estimate, whereby the last category stands for the most likely. Starch crops turn out to be more competitive than sugar crops.[8]
Production costs involving the use of future technologies (that is after 2010) are also predicted. Table 2-3 shows that reductions can be achieved. It is to be expected that starch crops will remain the most competitive crop considering low and high estimates. The best estimate presents, however, that sugar crops are to be the most competitive in the future.

Table 2-2: Costs of bio-ethanol produced using current technology (until 2010).

Estimated Costs at filling station ($2004/litres)			
Feedstock	**Low**	**Best estimate**	**High**
Sugar Crops	$1.09	$1.57	$2.31
Starch Crops	$1.01	$1.46	$1.96

(Source: Adapted from Ryan et al. 2006)

The authors use €2004. The authors indicate that 'actual costs' are used, but do not specify what actual is. In order to express them in US Dollars, the numbers are converted to the annual average exchange rate of 2004 from EUR to USD. Calculations are based on historical rates provided by the Oanda website <www.oanda.com>.

Table 2-3: Costs of bio-ethanol produced using future technology (after 2010).

Estimated Costs at filling station ($2004/litres)			
Feedstock	**Low**	**Best estimate**	**High**
Sugar Crops	$0.83	$1.19	$0.18
Starch Crops	$0.81	$1.20	$0.16

(Source: Adapted from Ryan et al. 2006)

Several authors review the costs of EU biofuels. It is, however, not always clear how many Member States of the EU are taken into account. Although the work of Ryan et al. regards 15 Member States, they state that the accession of 10 new Member States in 2004 would not significantly change any of the results. They refer to a work by Kavalov et al. (2003) claiming that the accession of the new Member States have a potential contribution of 1% of the enlarged EU fuels market. Total production costs appear to be rather similar. Although some cost components (like labor) might be less expensive, it is balanced out by lower yields. This implies that these costs calculations could be applicable at present with the current 25 Member States.

2.5.1.1.2 US

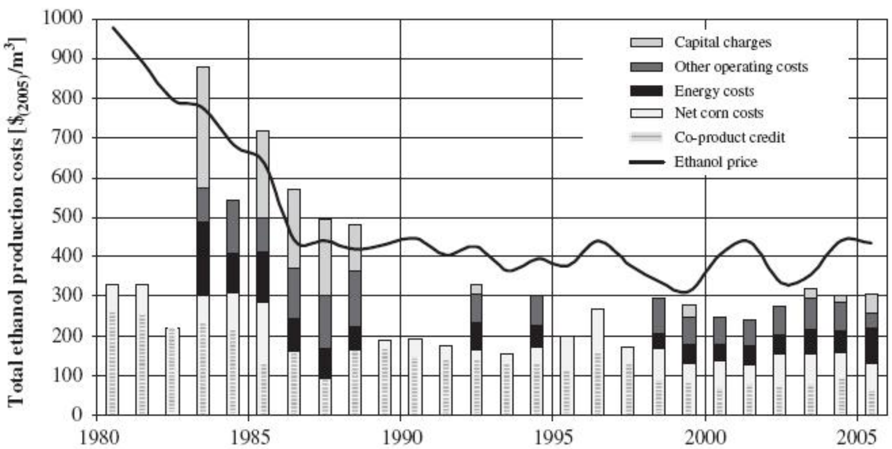
In the US total ethanol production is made of corn and this accounts for a total of 97% (Hettinga et al. 2008). This type of ethanol is the most competitive in the US. It also has the most complete cost analyses that are available on this. For these reasons the focus of this section will be on corn-based ethanol.

Hettinga et al. (2008) attempt to provide an overview on the cost-developments. They do this by reviewing the years from 1975 to 2005. Total costs are categorized by production and processing costs. This is related to US corn ethanol industry, average cost data based on average plant size (in 2005 dollar exchange rate). Although various studies exist on production costs, Hettinga et al. (2008) provide a comprehensive chronological

[8] The feedstock calculation could be confusing comparing it to the analysis of IEA (2004), figure 2-5. Here sugar crops (sugar beet) are cheaper than starch crops (wheat). This is not necessarily contradictory with Ryan et al's study as types of feedstock are compared instead of specific individual types of crops.

overview of costs and give insight on the developments of these costs: 'production costs declined by 57% from around 712$2005/m3 [or 0.712 dollar-cents/litres] in the early 1980s to approximately 300$2005/m3 [or 0.30 dollar-cents/litres] in 2005' (Hettinga et al. 2008). Production costs are grouped by capital charges, energy costs, net corn costs, co-product credit and other operating costs. The following figure presents developments of production costs and prices of the early 1980s to 2005. Although there have been major process cost reductions from 1983, due to developments in scale, technology and production capacity, total costs averaged over the years 1992 – 2004 with about 0.30 dollar-cents per litres (IEA, 2004). These costs are comparable with most recent calculations of 0.27 dollar-cents/litres by Marshall (2007).

Figure 2-6: Development of total ethanol production costs and ethanol prices between 1980 and 2005. Note that not for all years full costs data are available.



(Source: Taken from Hettinga et al. 2008)

Energy costs have been an increasing cost component. Moreover the credit (i.e. value) of co-products, and especially distillers dried grain with soluble (DDGS) have become more important recent years. This is an ongoing trend, which is also presented in figure 2-6.

Besides fluctuations of energy prices and DDGS prices, corn prices can significantly influence the production costs of ethanol. 'Net corn costs have always made up a large share in total production costs, up to 50%' (Hettinga et al. 2008). Shapouri and Gallagher (2005) confirm the share of corn costs of around 50%. Their work is based on 21 surveys in 1998 and 2002 of dry-mill plants in the US. It includes variable costs (feedstock and plant operation) and capital expenses. They state that net corn costs changed little in 2002 comparing it with 1998. Net feedstock costs, calculated here as feedstock costs minus the value of by-products, were in 1998 0.1411 dollar-cents/litres compared to 0.1440 dollar-cents/litres in 2002. Considering 0.30 dollar-cents/litres of Hettinga et al., they confirm the large share of corn costs of around 50%.

2.5.1.1.2 Brazil

Brazilian sugarcane ethanol production serves as an excellent case study for production in different places of the world (Nass et al. 2007). 'Ethanol production in Brazil has a long, interesting, and turbulent history. It is a story compounded by both national and international factors and is complicated by dependence on a raw material, sugarcane, that has products in two commodity groups, fuel and sugar' (Nass et al. 2007). As most ethanol is produced by the usage of sugarcane, most analyses are aimed at this type of ethanol. This being said, one could assume that information on exact cost calculations are widely available.

Yet, according to De Almeida et al. (2007) estimating costs of ethanol production in Brazil is a rather complex task. In their work they explain the cause of this: production and processing costs depend highly on the production area. This determines the amount of sugarcane production, productivity and harvesting and transportation technologies. Moreover, the authors argue that cost calculations of most studies tend to be distorted as issues are omitted. A few issues are pointed out. Especially costs of sugarcane, crucial to the ethanol cost estimation, tend to be underestimated by most studies.

An item often excluded are the opportunity costs of the feedstock sugar cane. From sugar cane producers can make ethanol as well as sugar as a final product, in this way a switch can be made between both products.

Logically, the type of production choice is influenced by the total expected value.[9] This item is crucial due to the fact that a total of 77% of the Brazilian ethanol mills are able to produce both ethanol and sugar.
Also often in most studies 'the aspects related to the logistics to bring ethanol to the market have not been considered' (De Almeida et al. 2007). Next to this, the size and organization of the plant influences costs as well. A final point is that not all studies include capital opportunity costs and capital depreciation costs.

The Brazilian Ministry of Science and Technology (MC&T) estimated the average costs of one litres ethanol to be $0.23 cents in 1990. See table 2-4 for the cost analysis. 'This study was used as reference in the International Energy Agency's study on Biofuels (IEA, 2004). After that, most references on the cost of ethanol in Brazil point to the same value' (De Almeida et al. 2007). Despite the fact that these costs are lower than current costs in other countries, it is remarkable that they are still being used as, in the 90's and this century there have been quite some industrial developments and related cost reductions due to a learning process. Also, costs are subjected to fluctuations in the exchange rate –from real to dollar-, feedstock and oil prices, changes in subsidies and other items. De Almeida et al. (2007) estimate the average cost of a standard Brazilian ethanol plant at $0.37/litres. Table 2-5 shows their cost analysis.

Table 2-4: Ethanol production costs in Brazil (around the year 1990).

Costs	**Average cost 1990 US$/litre**
Operating Costs	0.167
Labour	0.006
Maintenance	0.004
Chemicals	0.002
Energy	0.002
Other	0.004
Interest Payments on working capital	0.022
Feedstock (sugarcane)	0.127
Fixed Costs	0.062
Capital at 12% depreciation rate	0.051
Other	0.011
Total costs/litres	0.23
Total per gasoline-equivalent litre	0.34

(Source: Adapted from IEA, 2004)

Table 2-5: Ethanol Production costs in Brazil (around the year 2007).

Costs	**Average cost 2007 US$/litre**
Sugarcane productivity	71.5 t/ha
Sugarcane consumption	2,000,000 ton/year
Harvesting days	167
Ethanol productivity	85 litres per ton
Ethanol production	170,000 litres per year
Surplus power produced	40 kWh/ton of sugarcane
Investment cost in the mill	US$ 97 millions
Investment cost for sugarcane production	US$ 36 millions
O&M Costs	US$ 0.07
Sugarcane Costs	US$ 0.17
Capital costs	US$ 0.13
Total costs/litres	**US$ 0.37**

(Source: Adapted from De Almeida, 2007)

The authors van den Wall Bake et al. (2008) provide an overview on the Brazilian production costs of sugarcane bio-ethanol over the last three decades. Their study shows that there has been a continuously decline of two types of costs; feedstock and production costs and industrial processing costs.
An increase in total yields was the most important that contributed to the cost reduction of feedstock and production costs. Feedstock of sugarcane and total ethanol production costs declined both in a similar way and this applies percentage-wise to all existing components; costs of land, soil preparation, crop maintenance, harvesting and cane transportation to the ethanol plant. Still, 'the contribution of feedstock around 60% of the total costs has remained relatively stable over the last three decades. This was also widely confirmed by experts in the industry' (van den Wall Bake et al. 2008).
Reductions related to industrial processing costs were mostly related to economies of scale (i.e. larger plants). Costs related to industrial process costs are grouped by the following: investments, operational and management costs (including labour and materials), administration and other costs.[10]

[9] The authors add the following: 'The ethanol and sugar flexibility is not 100%. The maximum sugar production is 75%, since it is important to produce ethanol with the molasses produced in the sugar process in order to increase the mill's efficiency' (De Almeida et al, 2007).
[10] The cost breakdown of industrial costs are represented by figure B-1, which can be found in appendix B.

The authors estimate total costs for 1 litres ethanol for 2005 at $0.342 and this is based upon the assumption of average prices between 2000 and 2004, using a standard deviation as a bandwidth for any occurring fluctuations. Industrial costs would comprise $0.161, reflecting 47.08%, and feedstock $0.181, reflecting 52.92%. These costs are per pure litres ethanol and not per gasoline equivalent.
When the outcome of $0.342 is compared with some other cost calculations it turns out to be slightly higher. Macedo & Nogeuria (2005) calculated $0.21/litres, the World Bank (2006) claims the costs to be ranging between 0.23 – 0.29/litres, consulting firm IDEA (2006) comes up with $0.18, De Almeida et al. (2007) calculated $0.37/litres and the OECD (Steenblik, 2008) presents $0.20 per litres ($0.30 of gasoline equivalent). Ryan et al. (2005) calculated costs on Brazilian sugarcane in gasoline equivalent in a similar way to the calculation of European biofuels and these estimates range from $0.15-$0.44, whereby the most likely estimate is calculated at $0.37.[11]
Table 2-6 provides an overview of the various mentioned cost estimates. Costs range from $0.10-0.37/litres. Although deviations between the estimates could result from the use of different cost measurements of currency fluctuations throughout the years, the difference between the lowest and highest cost calculation is rather large.

Table 2-6: Study comparison in cost estimates.

Study	Year	$/litres	$/litres gasoline equivalent*	Additional Information
Most studies		$0.10		
MC&T	1990	$0.23	$0.34	
Ryan et al. (2006)	2004	$0.37		Based on production, transportation, conversion and distribution
Macedo & Nogueira	2005	$0.21		Based on center-south region of Brazil, which is the most efficient
Wall Bake, van den et al. (2008)	2005		$0.34	Based upon average cost prices 2000 - 2004
World Bank	2006	$0.23 - 0.29		
IEA	2006	$0.18		
De Almeida et al. (2007)	2007	$0.37		Includes cost of capital, excludes cost of land
Wall Bake, van den et al. (2008)	2020	$0.22-0.26		Future estimations

(Source: Own elaboration)
*** The amount that is similar to the amount of energy content of one litres gasoline is referred to as gasoline equivalent**

2.5.1.1.3 Cost comparison

At the beginning of this chapter a figure of the IEA/OECD (figure 2-5) is presented with cost comparisons between biofuels from Brazil, US and the EU. A shortcoming of the results is that not all costs are explained. There are other studies however that have conducted a comparative cost analysis. 'The most cited study was done by the consulting group F. O. Lichts in 2004' (De Almeida et al. 2007). Brazilian sugarcane ethanol is being compared with ethanol produced in the US and the EU, using other feedstock (corn, beat and wheat). Thus, every region is reviewed by its most competitive type of biofuel. These calculated costs are compared with each other. By this costs can be compared between regions. See table 2-7 (next page) for the results.

Sugarcane costs were estimated between $0.10-0.12 per litres and beet and corn range between $0.20 and $0.35. In line with other studies these calculations also show that Brazilian sugar cane ethanol biofuel is the most competitive, followed by the US and lastly Germany (i.e. EU). Although a few items are ignored, -opportunity costs, scale of production and the influence of the exchange rates-, it is clear that Brazil has clear comparative cost advantages in costs of equipment, labour, raw material and operational costs. This also applies when US ethanol benefits from government interventions.

[11] Ryan et al. use €2004 average rates between July-December, these are converted between brackets into $2004, average rates between July-December from EUR to USD average rate. Calculations are based on historical rates provided by www.oanda.com.

Table 2-7: Cost comparison of ethanol between regions.

Cost Category	USA	Germany (EU)		Brazil
	Corn	Wheat	Beet	Sugar Cane
	US Dollars/litres			
Buildings	0.00485	0.01020	0.01020	0.00261
Equipments	0.04229	0.06592	0.06592	0.01430
Labor	0.03520	0.01741	0.01741	0.00647
Insurance, rates and others	0.00759	0.01269	0.01269	0.00597
Raw material	0.26034	0.34517	0.43659	0.12190
Operational costs	0.14068	0.00000	0.00000	0.00000
Others	0.00000	0.00000	0.00000	0.00000
Total production costs	0.49108	0.68363	0.74097	0.18011
Sales by-products	-0.08346	-0.08458	-0.08956	-
Federal and state subsidies	0.09864	-	-	-
Net production costs	$0.31	$0.60	$0.65	$0.18

(Source: Adapted from De Almeida, 2007)

2.5.1.2 Biodiesel

As opposed to the production of ethanol, biodiesel's details on costs is not as clear and this is mainly due to a tougher competition. Pousa et al. (2007) states that unfortunately producers 'do not report biodiesel production costs, so it is difficult to distinguish production costs from company profits'. Also several other authors indicate that companies do not allow insights in their financial issues.

A learning process that drives costs significantly down, similar to one that can be seen in the ethanol industry, has not taken place yet. 'The cost of biodiesels varies depending on the base stock, geographic area, variability in crop production from season to season, the price of the crude petroleum and other factors' (Demirbas, 2007). 'Biodiesel production costs are even more dependent on feedstock prices than are ethanol costs' (IEA, 2004). According to Meeusen et al. (2009) feedstock costs concern even 75% of the total production-costs. Particularly by developing cheaper feedstock, major reductions in the production costs could be achieved. Next to this there are two other factors that can reduce costs considerably. The first is finding alternative ways to increase the value of the key co-product crude glycerol (or glycerin). The glycerol, provided is sufficiently pure, can be sold within different markets like foods, cosmetics and the pharmaceutical industry. The sales are an essential element as it has a crucial impact on the profitability of the biodiesel industry. The glycerin competes, however, with glycerin derived from oleo chemical industries (de Vries et al. 2004). Moreover, glycerol markets are limited. 'Under a scenario for large-scale production of biodiesel, the excess supply of glycerine (or "glycerol") could cause its price to fall to near zero' (IEA, 2004).
The second factor is economies of scale related to plants. However, compared to ethanol, this reduction in costs applies to a smaller extent (IEA, 2004).

A few studies give clear insights on the cost differences that are presented by the various reports that are available. Mostly production costs of Europe and US are compared with each other, or the two regions are in some way combined to estimate total costs. Brazil and developing countries are often individually analyzed. For this reason further along costs will be discussed related to US & EU and Brazil.

2.5.1.2.1 US & EU

Costs on biodiesel related to the US and the EU are so far in any study calculated based on assumptions and estimations. The following provides an overview on this. Two studies in particular, that of Bender (1999) and Haas et al. (2005) provide good insights on this.

Bender (1999) reviewed 12 studies on the economic feasibility of biodiesel that covered 1983 to 1996. Costs were estimated to range in the 90's between $0.54-$0.62/l for vegetable oil biofuel, between $0.34-$0.42/l for waste grease biofuel and $0.30-$0.69 for oilseed biofuel. However, a sufficient disaggregation of costs has not been provided by most of these studies. Important factors that could influence costs are also not always present; the production area is, for example, not always specified; some studies are based upon biodiesel produced in one or more states of the US and others upon a combination of the US and the EU. Also, due to assumptions on prices of in- and output, the relative costs of biodiesel are not always determined with certainty.
Haas et al. (2005) emphasizes that reports on cost estimations up to 2005, including Bender's review, are ambiguous. According to them this is because all these reports estimated total biodiesel production costs based on assumptions regarding production volume, feedstock and chemical technology.
Haas et al. (2005) developed a specific model to approximate operating and capital costs. This is done with the goal to estimate costs with more accuracy than preceding studies. The design of it is based upon production practices including reactant equipment and supply costs by using modern simulation software. The model is flexible as it can be changed according to the type of feedstock and its related processes. The feedstock soybean, produced by a moderately-sized industrial production facility, is calculated for. Including all expenses one litre soybean biofuel is estimated to be $0.53.

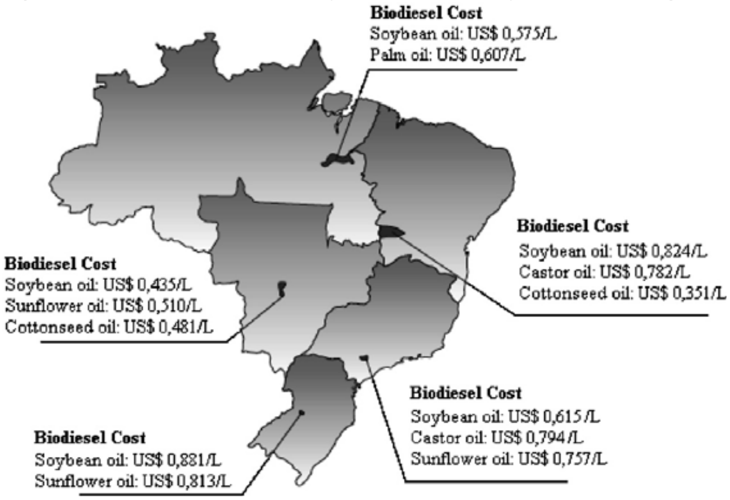
Next to these two works, there are some other studies related to cost calculations conducted in and following 2005; amongst others Ryan et al. (2005), Pimentel (2005) a study of Randelli (2008), OECD-FAO (2008) and a cost analysis review study of Sharma et al. (2008). From all these cost studies cost for biodiesel range between $0.26 and $2.54. An overview of the mentioned studies can be found in appendix c.

2.5.1.2.2 Brazil

'The prospect for Brazilian biodiesel cost evolution is not clear so far. The Brazilian government and other agents involved in biodiesel in Brazil have the expectation that, similarly to ethanol, biodiesel learning process will drive significant cost reduction in the near future. However, innovation economics shows that this learning process depends on a technological selection process that is still to be done in Brazilian biodiesel. At this point, too many technological alternatives in terms of feedstock and oil processing technologies are in competition' (De Almeida et al. 2007).
Similar to other regions information on detailed production costs on Brazilian biodiesel is hardly available. Currently the most comprehensive study seems to be the study by Barros et al. (2006), originally a Portuguese work, referred to by Pousa et al. (2007) and De Almeida et al. (2007).

The work of Pousa et al. (2007) refers to the following of Barros et al.: 'the production costs for biodiesel obtained from different raw materials (soybean oil, palm oil, castor oil, cottonseed oil and sunflower oil) by each Brazilian region were estimated, considering: (i) raw material production costs, (ii) oil production cost, and (iii) biodiesel production cost'. Although De Almeida et al. state that total production costs include all variable costs and machinery depreciation, three different production scales, feedstock's production costs and opportunity costs are taken into account as buying the feedstock is in some instances cheaper than production. Exact details on the cost breakdown are missing. The sum of expenses per litres begin at $0.35 from cottonseed in the Northeast and rise up to $0.88/litres from soybean oil in the South region, see figure 2-7 (next page).

Figure 2-7: Estimated biodiesel production costs per Brazilian regions, in US$/Litres.



(Source: Pousa et al. 2007)

2.5.1.2.3 Cost comparison

A comparative cost breakdown analysis on biodiesel per region (or between them) seems to be unavailable. When details on ethanol costs are presented by studies that discuss both ethanol and biodiesel, details on biodiesel costs are omitted (e.g. the study by OECD-FAO, 2008).

Currently biodiesel costs appear to be higher than ethanol costs. As a matter of fact, it has not yet seen many development in costs reductions as in the ethanol sector. A review on several studies shows that costs of biodiesel range for the EU&US between $0.26 and $2.54. For Brazil the cost range is between $0.35 and $0.88. Much cannot be said on these cost, however, as details are not provided, it concerns rather estimates on total expenses.

2.5.2 Advanced biofuels

The second and subsequent generation biofuels use lignocellulosic feedstock, which differs from traditional agricultural feedstock, it demands new, or advanced, conversion technologies. Data on costs are not as widely available as the traditional biofuels, therefore in this part there will be a focus on costs in general and not specifically on the different regions.

The use of different feedstock relates to a number of cost advantages, namely: lower (than current) costs related to rapeseed-based biodiesel and cereal- or beets-based ethanol, higher energy yield, higher reduction of environmental benefits, demand for less valuable land and there is lower need to use fertilizers. Also, compared to the traditional biofuel, there is a bigger variety of feedstock to choose from (Hamelinck and Faaij, 2006). However, 'most advanced processes appear [to be] expensive, and the potential for future cost reductions is uncertain […] If costs can be reduced to acceptable levels, they could become very attractive options for future transport fuels' (OECD-FAO, 2008).

Estimations of current (that is 1999) production costs of advanced processing techniques range between $0.27 and $4.91. Table 2-8 (next page) shows the different types of ethanol and related costs. All calculations include all costs up to the retailer. Most estimations are higher than current 1st generation biofuels.

Several studies argue that the advanced generations become cheaper than the first generation in the future. 'The future projected costs of lignocellulosic biofuel are wide-ranging, partly depending on the feedstock costs chosen for the assessment (IEA, 2008).[12] Ryan et al. (2005) claims, for example, that this occurs with future technologies (that is after 2010) where lignocellulosic crops and residues will become cheaper than ethanol and biodiesel from the EU. According to the EU Biofuels progress report, advanced generation are to be

[12] Second generation biofuels include here the 3rd and 4th generation as well, as the IEA does not go further than the second generation.

predicted to become commercialized between 2010 and 2015: they 'are likely to be more expensive than first-generation. Their costs are expected to fall by 2020' (EU, Biofuels Progress Report). The expectation is that the most competitive will be biofuels from residues, followed by lignocelluloses crops and this is increasingly so compared to starch, oil and sugar crops. Related to the first generation biofuels Brazilian sugarcane ethanol will, however, remain cost competitive compared with advanced generation.

Table 2-8: Estimates of production for advanced processing techniques dating from 1999.

Fuel	**Feedstock/location**	**Process**	**$/litres gasoline equivalent***
Biodiesel	Rapeseed	oil to FAME (transesterification)	$0.80
Diesel	biomass - eucalyptus (Baltic)	HTU	$0.56
Diesel	biomass - eucalyptus (Baltic)	gasification/ F-T	$0.68
Diesel	biomass - eucalyptus (Baltic)	pyrolysis	$1.36
DME	biomass - eucalyptus (Baltic)	gasification/ DME conversion	$0.47
Ethanol	biomass -poplar (Baltic)	enzymatic hydrolysis (CBP)	$0.27
Ethanol	biomass -poplar (Baltic)	enzymatic hydrolysis (CBP)	$0.27
Gasoline	biomass - eucalyptus (Baltic)	gasification/ F-T	$0.76
Hydrogen	biomass - eucalyptus (Baltic)	Gasification	$4.91
CNG	biomass - eucalyptus (Netherlands)	Gasification	$0.46

(Source: Adapted from IEA, 2004)

* **The amount that is similar to the amount of energy content of one litres gasoline is referred to as gasoline equivalent**

2.6 Conclusion

Transport biofuels are a possible substitute product for fossil fuels. In comparison with fossil fuels there are two major advantages to subscribe to biofuels; they can be re-grown and they appear to be more environment friendly. The specific advantages and other traits depend on the categorization of the biofuel, whether it belongs to the traditional or advanced generation, type of feedstock used and technology applied.

Production of biofuels takes place worldwide and future expectations are that the scale of it will grow. Currently bio-ethanol is by far the most produced type of biofuel. The US and Brazil are currently the leading producers. Biodiesel is the second most produced type of biofuel. The European Union is in this case world's leading producer.
Of importance are the production costs in order to be able to say something about the amount of total supply costs. To map out production costs, however, is rather a complex task. This is due to several reasons and especially the following:

- In most instances exact details and methods applied to derive any of those details on costs are omitted.
- Whenever costs are provided in gasoline equivalents there is no, or hardly, a cost breakdown provided on it.
- It is not always indicated what exchange rate is used.

Costs of the first generation are reviewed by bio-ethanol and biodiesel. For costs calculations on ethanol, Brazilian biofuel turns out the be the most competitive, followed by the US and the EU. On production costs related to biodiesel much less can be said than on ethanol. This is due to the fact that studies do not provide details, but use estimations on cost. Costs on biodiesel from EU and US range from $0.26-$2.54 and biodiesel from Brazil range between $0.35 and $0.88. Much information on the costs and/or developments of advanced biofuels are not available either. This is due to the fact that new technologies are employed to produce other biofuels derived from more and different types of feedstock, including lignocellulosic ones. The expectation is that total costs of advanced biofuels will be lower than traditional ones in the years after 2020.

3. Demand

3.1 Introduction

This chapter provides insights on the total biofuel demand. First, information will be provided on the general demand for transport fuels (paragraph 3.2). This will be followed by a general discussion on biofuel demand (paragraph 3.3), specific demand on bio-ethanol (paragraph 3.3.1) and biodiesel (paragraph 3.3.2). Paragraph 3.4 discusses purchasing factors, it provides insights on where demand comes from and what kind of action should be undertaken in order to increase purchase volume. The chapter is finalized with a conclusion (paragraph 3.5).

3.2 Transport fuels

'The transport sector is [a] major consumer of petroleum fuels such as diesel, gasoline, liquefied petroleum gas (LPG) and compressed natural gas (CNG)' (Demirbas, 2006). Next to conventional fuels, renewable fuels can also be used for consumption as a transport fuel. 'Demand for transport fuels […] has risen faster than total energy demand during the past few decades. There has been little sign of this trend declining' (IEA, 2008).

Forecasts are that transport on a global scale will increase demand for conventional fuels with up to a maximum annual growth of 1.3% up to 2030. This would result in a daily demand of around 18.4 billion litres (up from around 13.4 billion litres per day in 2005) (The Royal Society, 2008). The risen demand can be explained by the increase of vehicles based on petroleum fuels that have increased worldwide (Demirbas, 2006). Especially in developing countries transport fuel consumption is expected to increase. China and India, for example, are already counting as world emerging economies and their role is set to become even more crucial in global transport fuel consumption (Asif & Muneer, 2007).
Conventional fuels, however, 'are predicted to become increasingly scarce' (The Royal Society, 2008) as 'petroleum reserves are limited' (Demirbas, 2006). For this reason these fuels are set to become increasingly costly in the decades to come.[13] 'The expected scarcity of petroleum supplies and the '[n]egative environmental consequences of fossil fuels […] have spurred the search for renewable transportation biofuels' (Hill, Nelson, Tilman, Polasky & Tiffany, 2006).
Renewable fuels, made from biomass, 'have enormous potential and can meet many times the present world energy demand' (IEA, 2008). 'Biomass can be used for energy in several ways, [one of these is the conversion] into liquid or gaseous fuels such as ethanol for use in […] mobile source combustion' (Marshall, 2007). As opposed to renewable transport fuels, like electricity or solar energy, liquid biofuels are 'readily available transport [fossil] fuel substitutes that work with our current engine technologies [and therefore] has captured the attention of industry, policymakers, and the public' (Marshall, 2007).
In fact 'global demand for liquid biofuels more than tripled between 2000 and 2007. [And] [f]uture targets and investment plans suggest strong growth will continue in near future' (IEA, 2008). This projected growth of demand could possibly also be partly met by biogas that could become in future commercially feasible to supply (Demirbas, 2006).

Biofuels are rather accessible, for this Börjesson and Mattiasson (2007) point out four factors that are related to the producers' and consumers' side (i.e. from a commercial and residential perspective):

i. 'high profitability for farmers cultivating […] crops for energy purposes, driven by various incentives, as compared with production of these crops for food or feed;
ii. the existence of commercial technologies for fermentation of cereals and for oil extraction from oil crops;
iii. an existing infrastructure that can be used for the distribution of the biofuels (e.g. ethanol can be blended with petrol and biodiesel into diesel);
iv. the suitability of biofuels for use in existing cars – bio-ethanol is used in ordinary petrol-fuelled cars and biodiesel in diesel-fuelled cars.'

The first two factors mentioned are especially related to the demand of the producers side whereas the latter two are related to both the producers' and consumers' side.

[13] More detailed: 'production levels [of fossil fuels] will peak, making the extraction of remaining oil supplies far more difficult and expensive [and] even if we find ways to wring every available drop of oil from the earth, the resource itself will actually run out' (Prendergast, 2004).

3.3 Biofuel demand

Biofuel demand is largely policy-driven (Gerber et al. 2008). Also future 'growth is largely affected by policy decisions' (IEA, 2008). These policies are in the form of public support (e.g. subsidies) and consumption targets (OECD-FAO, 2009). Exact numbers on current biofuel demand are not available (de Nie and Blom, 2008). This is due to the way the demand of biofuel is defined in the literature. Given the supportive policy actions (such as consumption targets), most studies define total demand as "equal to supply", "equal to production" or as "total use". Due to the fact that the minimum production-targets set by governmental policies are often the only factor that is accounted for, most studies state that both production and demand are closely related. The general picture that biofuel demand (more or less) equals production-targets set by governments accounts also to future predictions. Generally demand potentials are based upon production potentials, which is based on projections of transport fuel demand (IEA, 2004). Two other players that should play a significant role in creating demand, namely the commercial players and end consumers are frequently omitted.

In the IEA report it is confirmed that the consumption of biofuels relies heavily on policies from governments. 'Compared to petroleum, the use of biofuels for transport is still quite low in nearly every country. By far the largest production and use of ethanol is in the United States and Brazil […]. But even in the United States, ethanol represents less than 2% of transport fuel (while in Brazil it accounts for about 30% of gasoline demand). However, many IEA countries, including the US, Canada, several European countries (and the European Union), Australia and Japan […] could result in much higher [consumption of] biofuels over the next decade [especially due to the use and adoption of biofuel policies]. Many non-IEA countries are also adopting policies to promote the use of biofuels' (IEA, 2004).

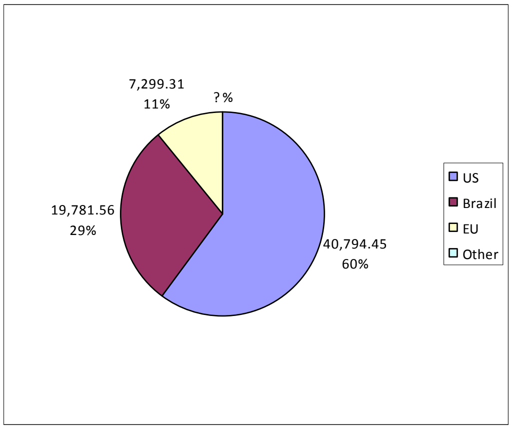
Most studies discussing and projecting demand are oriented on a medium and long-term horizon, between e.g. 2050-2100 (IEA, 2004). Yet, in order to give a general idea on current demand and expectations on a short term basis data of the report by OECD-FAO (2009) will be used further long, that is for the year 2009 and 2018. Although the exact amounts are not given, biofuel demand within this work is largely seen as demand for transport purposes. Some uses by other sectors (e.g. replacing heating oil) are taken up as well within the totals.
Demand is reviewed here by total (expected) use, which is expected to increase due to public measures, mandated use and total global transportation use. Although the mentioned study by OECD-FAO is an attempt to reach total numbers on demand, it should be noted that demand does not necessarily equal use. Actual demand could be higher, for example, when total production, or supply, does not meet the demanded amount. Further along the demand provided by this study will be discussed under a subparagraph devoted to ethanol (3.3.1) and biodiesel (3.3.2).

3.3.1 Bio-ethanol

The OECD-FAO, projects total use of ethanol to grow rapidly worldwide. The total current ethanol use of the regions US, Brazil and the EU of (2009) are shown in figure 3-1. These three regions US, Brazil and EU consume together almost 68 billion litres. The US uses 40.8 billion litres, or 60% of all ethanol, Brazil 19.8 billion litres (29%) and the EU 7.3 billion litres, or a share of 11%. These shares are related to the total of the three regions and not to total world use of ethanol. As the study did not provide data on its share, numbers of total use of other countries are not presented. The pie chart indicates the share of other countries with a question mark. The three regions use around 14 billion litres of all biodiesel; the EU makes up 79%, the US 12% and the Brazil 9%.

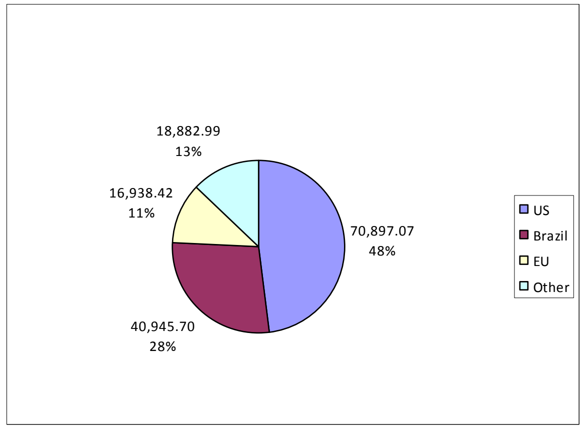
By 2018 global biofuels use is calculated to reach almost 148 billion litres, of which the US, Brazil and the EU, should reach a consumption of almost 129 billion litres, or approximately 87%. Consumption is expected to be dominated by the three regions, the US (48%), Brazil (28%) and the EU (11%). The figures 3-1 and 3-2 on the next page show the shares each region are expected to obtain.

Figure 3-1: Projected use of bio-ethanol in 2009 (in billion litres).



(Source: Adapted from numbers provided by OECD-FAO, 2009)

Figure 3-2: Projected use of bio-ethanol in 2018 (in billion litres).



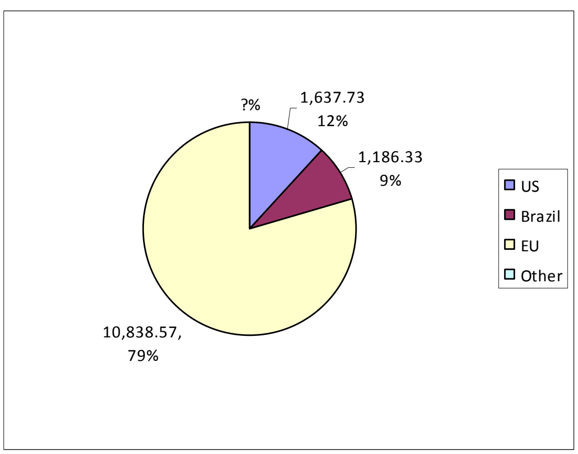
(Source: Adapted from numbers provided by OECD-FAO, 2009)

3.3.2 Biodiesel

Currently the biggest user of biodiesel is the EU with a total of almost 11 billion litres. The US and Brazil have, compared to the EU, a rather low consumption, respectively two billion and one billion litres. The following figure, figure 3-3, shows totals of use of the three regions projected in 2009. Share and totals of other countries are not presented, as the study did not provide data on this. Therefore the pie chart indicates the share of other countries by a question mark. The three regions use around 14 billion litres of all biodiesel; the EU makes up 79%, the US 12% and the Brazil 9%.

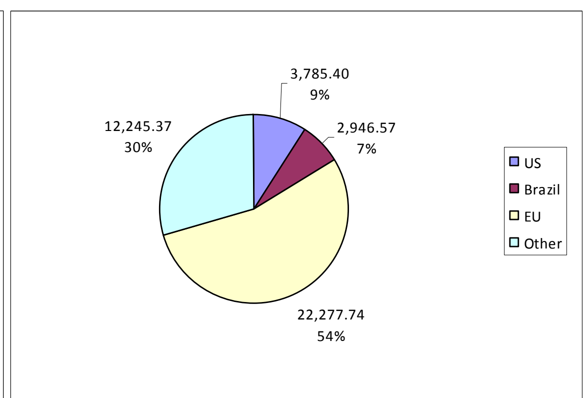
Future calculations for the year 2018 do provide insights on other countries. In this way a worldwide comparison can be presented. 'With 54% of global biodiesel use in 2018 the EU remains the largest biodiesel market in the world' (OECD-FAO, 2009). The three regions will be good for 91%, or 29 billion litres, of global use. Other countries (30%) contain, amongst others India, make up a 17% of total use.

Figure 3-3: Projected use of biodiesel in 2009 (in billion litres).



(Source: Adapted from numbers provided by OECD-FAO, 2009)

Figure 3-4: Projected use of biodiesel in 2018 (in billion litres).



(Source: Adapted from numbers provided by OECD-FAO, 2009)

3.4 Purchasing factors

This paragraph discusses the factors that play a role in creating and meeting the rising demand for biofuels. It will touch upon the policies set by governments, other required developments and motives that influence buying behaviour[14] from an end user perspective.

It can be understood, from the previous paragraphs, that the government acts as the main driving force of total biofuel demand. In order to realize a certain amount of biofuel usage it is, 'unlikely that biofuels use will grow rapidly in the future without continuous policy pressure. [This is due to the] currently high production cost of biofuels compared to petroleum fuels' (IEA, 2004). 'With few exceptions […] production costs of biofuels are significantly higher than those of fossil fuels. Therefore, promotion measures are indispensable for ascertaining substantial domestic biofuel demand' (Peters and Thielmann, 2007).[15]

'Biofuels have a limited, but potentially useful, ability to replace fossil fuels, largely due to technical and economic constraints. Meeting the rising demand for transport will require combining biofuels with other developments' (The Royal Society, 2008). Stimulating and promoting the usage of biofuels requires the support of developments related to distribution and end use of biofuels and especially to specifications and adaptations of vehicles, engines and infrastructures.

Governments attempt to promote and stimulate biofuel production with various instruments (chapter 4 elaborates more on this), leading to a possible increase of the amount of (different types of) biofuel offers and/or producers. Due to these developments more (potential) consumers could become aware of the existence of biofuel as a product. When 'the consumer becomes aware of the […] product, he lacks information about it' (Armstrong & Kotler, 2007). Providing information on the product could stimulate interest and lead to customer acceptance. 'Public perception issues will […] have an important role and will need to be dealt with openly. These include the potential positive initial reaction to use to biofuels, through to issues related to ambiguous engine warranties and engine damage due to biofuel usage and potentially increasing scepticism of consumers about whether biofuels can offer real environmental benefits' (The Royal Society, 2008).
Customer acceptance could lead to the decision to try and to a possible adoption of the product as a regular user (Armstrong & Kotler, 2007). Thus, customer acceptance is a crucial issue in order to encourage buying behaviour. Although, finding out 'the *whys* of consumer buying behaviour is not so easy' (Armstrong & Kotler, 2007), The Royal Society (2008) attempts to provide insights on this. According to this work one or more of the factors might be related to the motivations to purchase biofuels from an end user perspective. The factors are related to technical and nontechnical issues and these are the following:

- Usability
  Relates to the ease biofuels can be used within the existing infrastructure.
- Reliability
  Relates to the quality of the delivered fuel.
- Environment
  Relates to the environmental benefits and total use of land.
- Cost
  Relates to the cost per litres compared to one litre of fossil fuel.

'First generation bio-fuels are not fully compatible with existing engines and engine systems' (Lemon, 2007). The ease of application are discussable to some types (including pure types and high blends of bio-ethanol and biodiesel) and this is related to issues such as 'difficulties with cold starting […] viscosity [and] impacts on air quality where use of biofuels can lead to increased production of [greenhouse gases]' (The Royal Society, 2008). At this moment there is some customer resistance towards first generation biofuels (The Royal Society, 2008).
There is a cap on the improvement and development of first generation biofuels. Although 'flexi-fuel vehicles can help the transition to increased biofuel usage […] [Currently] neither bio-ethanol nor biodiesel are exact analogues for petrol or diesel respectively' (The Royal Society, 2008)

[14] 'The buying behaviour of final consumers- individuals who buy [biofuels] for personal consumption' (Armstrong & Kotler) in order to power vehicles.
[15] See chapter 5 for a comparison between prices on fossil fuels versus biofuels.

Research and development and new chemical and biological routes of novel biofuels could lead to a product with characteristics closer to fossil fuels (The Royal Society, 2008). In fact, the expectations are that advanced generations, compared to most types of first generation biofuels, are and will be superior in matching with one or more of the above mentioned purchasing factors. As of this, it is predicted that they have more potentials to increase possible purchases of biofuel (read: increase possible demand). The following provides further details on this.
First of all the 'use of biofuels has several implications for the end use and distribution chain, including on fuel quality, fuel vapour pressure, viscosity, engines and their fuel supply lines etc. Specific biofuels and the different blends offer advantages and disadvantages in each of these aspects. [The usability could be improved by advanced, or synthetic biofuels as they] 'are almost identical to conventional transport fuels, they can be delivered and used in the existing distribution and end use infrastructure without the need for any modifications to engines and fuel supply lines' (The Royal Society, 2008).
Secondly, '[w]here the synthetic biofuels are finished in existing oil refineries, consumers will be familiar with the quality and performance of the product as they will have to meet the quality and standards of oil derived fuels and so reduce the risk of consumer resistance' (The Royal Society, 2008). Quality and standards of oil derived fuels are here referred to as standards set by governments, such as the EU Fuel Quality Directive.
Thirdly, the production of biofuels that belong to the advanced generations (i.e. synthetic biofuels), 'such as hydrocarbons or cellulosic ethanol, if produced from low-input biomass grown on agriculturally marginal land […] from waste biomass, [or produced on water such as algae] could provide much greater […] environmental benefits than food-based biofuels' (Hill et al. 2006).
And finally, '[a]n analysis of customer acceptance and attitude towards biofuels showed that important customer requirements are prices not higher than those of fossil fuels, no engine modification costs or loss of power, high availability and easy handling' (Festel, 2007). Advanced biofuels are expected to meet these needs in a better way and most of the prices are expected to drop below these of the first generation (amongst others Ryan (2007), The Royal Society (2008) Koh and Ghazoul (2008))

3.5 Conclusion

The demand for transport fuel has been increasing over the last decennia and the expectations are that this trend will stay unchanged for the decades yet to come. In fact demand will probably rise even harder with an increasing number of vehicles and an increasing demand of emerging economies.

Transport fuel demand is traditionally satisfied by fossil fuel demand. However:

- resources of these fuels are running out;
- prices of fossil fuels are expected to rise, and;
- the combustion of fossil fuels has detrimental effects on the climate.

Biofuels appear to be a solution to substitute fossil fuels that traditionally satisfies transport fuel demand, as biofuels:

- are a renewable energy source, thus resources will not run out;
- become cost-wise competitive with fossil fuels and will therefore be more interesting to produce and consume as a substitute product;
- appear to be more environmental friendly;
- are rather accessible to distribute and use (for producers and consumers) as applicable infrastructure and technologies exists and are readily available.

Governmental policies are the driving force behind biofuel demand. Policies in order to stimulate and promote biofuel usage are put into practice. Currently, however, biofuel demand is low in almost every country. The exact numbers are unknown, because numbers of demand are unavailable.
Yet, indications of demand exist. They inform that both bio-ethanol and biodiesel are expected to grow worldwide. The three regions together (US, Brazil and EU) are expected to be good for a total consumption of 68 billion litres in 2009 and 129 billion litres in 2018. Moreover, an expected biodiesel consumption for the three regions together (US, Brazil and the EU) is around 14 billion litres in 2009 and 29 billion litres in 2018.

Currently, there is some customer resistance to purchase biofuels. In order to realize customer acceptance, governmental policies -to stimulate and promote biofuels- should be combined with technical and economical development.

As opposed to first generation biofuels, advanced biofuels could possibly overcome customer resistance. Arguments for this, are that advanced biofuels:

- appear to have greater environmental benefits;
- are not in conflict with the food production (or at least less so);
- are almost identical to conventional fossil fuels;
- prices will be mostly lower than those belonging to the first generation.

4. Regulations

4.1 Introduction

This chapter attempts to give a closer look at how biofuels are implemented and supported by policies in the EU, US and Brazil. The main focus is on the various targets and developments in the different governments. The instruments (subsidies, taxes, etc) used to achieve the targets are basically the same, but are applied differently. They will be discussed only to explain certain facts that relate to set targets and goals and therefore they will be not be dealt with in detail. The most important EU legislation will be discussed in paragraph 4.3, this is followed by legislation on the United States (paragraph 4.4) and Brazil (paragraph 4.5). The chapter will be conclused with a conclusions (paragraph 4.6).

4.2 Promotion and stimulation

Many governments have set out ambitious and challenging targets related to renewable energies (i.e. renewables). A big part is dedicated to bio-energy (Meeusen et al. 2009), whereby biofuels play an important role. National objectives, directives and policies are (being) implemented to promote and stimulate biofuel production (Marshall, 2007).[16] The targets set out are primarily based on a perspective of social responsibility and have an impact on many parties, including non-governmental organizations, knowledge institutions, companies and consumers (Meeusen et al. 2009). The perspective of social responsibility embraces several concerns. Literature appoints that it is largely lead by three important issues; climate protection, stability of energy supply and support of economic development of rural communities.

The first issue is related to 'a strategy to mitigate greenhouse gas emissions' (Randelli, 2007). To effectively change the climate environment, one have to take a closer look at the energy policies. The transport sector is an important element in this, since it uses more than 30% of our total energy and it shows a rising emission of greenhouse gases' (de Vries et al. 2004). As transport has a significant role, '[b]iofuels are a good alternative to reduce the greenhouse gases; 1) they reduce the usage of fossil fuels, 2) have a positive energy balance, 3) and reduce the emission of greenhouse gases. The amount in which it reduces the greenhouse gases, depends on the used commodity' (de Vries et al. 2004). Biofuels can be seen as a part of measures to comply with the Kyoto protocol. The objective of the Kyoto protocol is to reduce the emission of greenhouse gases to improve the climate environment.[17]
The stability of energy supply is the second issue. Biofuels can help to reduce the large dependency on fossil fuels (and thereby the dependency of supply by politically less stable countries).
The third issue is related to an economic perspective. The development of biofuels can be an economic incentive for the agricultural sector, on a national and international level, as it creates opportunities to create and produce new products that add value and possibly improve the competitive position.

4.3 European Union

The EU promotes biofuels through the use of several policies. First the Biofuels Directive will be discussed, which is described in paragraph 4.2.1. Following, the Fuel Quality Directive (paragraph 4.2.2), certification (paragraph 4.2.3), Renewable Energy Directive (paragraph 4.2.4) and the Common Agricultural Policy (paragraph 4.2.5) are being described.

4.3.1. EU Biofuels Directive

4.3.1.1 EU Directive 2003/30/EC

The EU Directive 2003/30/EC[18] is the most important pillar related to EU legislation on biofuels because of its big influence due to the later mentioned targets. The Directive is about the promotion of using renewable fuels

[16] This is needed as there is a cost differential with fossil fuels (Randelli, 2007). The most common policy is a tax measure either on producers side, or consumers' side (remission of excised duty) (Meeusen et al, 2009).
[17] In the beginning of 2009 there were 183 countries, under which the EU Member States, that signed the Kyoto-protocol as of 1997. http://ec.europa.eu/environment/climat/campaign/what/fightingcc_nl.htm.
[18] EU Directives are legislative acts of the European Union that requires member states to achieve particular goals without dictating the means of achieving these goals.

(including biofuels) for transport. The Directive urges Member States to promote the use of these renewables by taking measures that help to overcome market barriers. More on these market barriers can be found in the chapter on the market (chapter 5).
In article 3, of the EU Directive 2003/30/EC, targets can be found regarding the amounts of biofuels. Member States need to ensure a certain market share is subjected to the consumption of biofuels and other renewable fuels, therefore they should set national indicative targets. 'A reference value for these targets shall be 2%, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005. A reference value for these targets shall be 5.75%, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2010', *EU Directive 2003/30/EC*. 'Member States were required to set indicative targets for 2005, taking this reference value into account. These national indicative targets, once adopted, are not mandatory. While they constitute a moral commitment on behalf of Member States, there is no legal obligation for them to achieve the levels of biofuel use they have chosen to target' (Biofuels Progress Report, 2007).

'A proposal to agree on a binding target of 10% biofuels in 2020, as well as a binding target of a 20% share of renewable energy in the overall energy consumption, was supported by the Ministers of the Member States during the Spring Summit of 2007' (Market Analysis Oils and Fats for Fuel, 2007). In the presidency conclusions of the summit it is mentioned, that the 10% target includes a sustainability criteria to prevent large scales investments in cheaper but more damaging biofuels. Moreover biofuels that do not at least reduce 35% of CO2-emission in comparison with fossil fuels and biofuels grown in protected areas, highly bio diverse grassland, forests and wetlands are not considered to contribute to the target of 10%. The target is presumed to be reasonable when the second generation technologies are becoming commercially available <www.euractiv.com>.

Each Member State is obliged to annually address a report to the Commission, providing insights on the progress of reaching Member States' individual targets. As of 2004 this report has to be finished before the 1st of July every year. This obligation is mentioned in article 4.1 of the EU Directive 2003/30/EC. According to the European Union's Web site[19] <http://europa.eu> the report must address the following:

- the measures taken to promote the use of biofuels and other renewable fuels;
- the national resources allotted to the production of biomass for energy purposes other than transport;
- the total quantities of fuels for transport sold in the course of the year.

The report coming from the individual Member States formed the basis for another report that was presented by the Commission to the European Parliament and to the Council prior to 31 December 2006; the Biofuels Progress Report. This report is another obligation that is mentioned in article 4.2 of the EU Directive 2003/30/EC. The most important elements related to this report are presented in the following paragraph.

4.3.1.2. Biofuels Progress Report

The Biofuels Progress Report is published every two years and evaluates the progress of the EU on biofuels in general. The most recent report dates back to 2007 and covers the period of 2003-2005. It informs about a few important aspects: in most Member States diesel includes biodiesel in low blends, major oil companies have announced biofuel investment programmes worth hundreds of millions of euro's and vehicle manufacturers have begun marketing cars capable of running on high bio-ethanol blends.

The report looks back at the indicative targets of the year 2005. Table D-1 shows the difference between the actual market share and the indicative targets. The market share has reached an estimated share of 1%, which is lower than the 2% target value. Moreover, progress was uneven. Only Germany (3.8%) and Sweden (2.2%) were able to achieve the target. The two countries had a so-called kick start. The report elaborates on the reasons for this by mentioning several policies. 'Both promote both high-blend or pure biofuels (giving the policy visibility) and low blends compatible with existing distribution arrangements and engines (maximizing the policy's reach). Both have given biofuels tax exemptions, without limiting the quantity eligible to benefit. Both have combined domestic production with imports (from Brazil in the case of Sweden, from other Member States in the case of Germany). Both are investing in biofuel research and technology development (RTD) and have treated first-generation biofuels as a bridge to second-generation' (Biofuels Progress Report 2007).

[19] http://europa.eu/scadplus/leg/en/lvb/l21061.htm.

The used biofuels tax exemptions by Germany and Sweden are described in multiple Directives. One of them is the EU Directive 2003/96/EC. It restructures the framework for the taxation of energy products and electricity; there can be a total or a partial tax exemption for biofuels. Another Directive which describes the tax exemptions is Directive 92/81/EEC, or "excise-duty in relation to biofuels". The Directive gives the Member States the opportunity to make use of tax exemptions through an amendment. The amendment provides the Member States the opportunity to use excise deductions for biofuels with a maximum period of six years. This way Member States could create a production platform for biofuels, largely made possible through the differentiation of excises. These excise deductions are necessary, because the production costs for biofuels are far higher than those of petrol and diesel.

In table E-1 the indicative targets are to be found for the period 2006-2010. A total of 19 Member States have set targets for 2010. 'If they all achieve the shares they have targeted, biofuels share in these Member States will reach 5.45% - a shortfall of 0.3% compared to the objective. The experience of 2005 suggests that in practice the shortfall will be larger. In 2005, among 21 Member States for which data are available, only two achieved the targets they had set. The average Member State achieved only 52% of its target. Even if the shortfall is only half as much as this in 2010, the Union would only achieve a biofuels share of 4.2% in 2010. The Commission considers that this is a reasonable estimate of the likely outcome on existing policies and measures. The Commission's conclusion is therefore that the biofuels directive's target for 2010 is not likely to be achieved' (Biofuels Progress Report, 2007).

As stated above, the Commission concludes that the indicative targets of 2010 are not likely to be achieved. As opposed to the indicative targets a more realistic way to increase market share of biofuels is the possibility of amending the 2003/30/EC Directive by setting mandatory targets. Article 4.2 of the EU Directive 2003/30/EC creates this opportunity. The following is mentioned on this: 'By 31 December 2006 at the latest, and every two years thereafter, the Commission shall draw up an evaluation report for the European Parliament and for the Council on the progress made in the use of biofuels and other renewable fuels in the Member States […] If this report concludes that the indicative targets are not likely to be achieved for reasons that are unjustified and/or do not relate to new scientific evidence, these proposals shall address national targets, including possible mandatory targets, in the appropriate form'. According to the Biofuels Progress Report, in particular a mandatory target has to be set of 10% by 2020 for the whole EU and also as regarding to the measures to encourage high-quality biofuels**.**

Although mandatory targets are a possibility the European Environmental Agency (EEA) is critical about it: 'The overambitious 10% biofuel target is an experiment, whose unintended effects are difficult to predict and difficult to control. Therefore the Scientific Committee recommends suspending the 10% goal; carrying out a new, comprehensive scientific study on the environmental risks and benefits of biofuels; and setting a new and more moderate long-term target, if sustainability cannot be guaranteed' (EEA, 2008).
Suspending the indicative 10% target and changing the target in a mandatory one are two possibilities, another is to do everything possible to reach the indicative targets. It is important to closely monitor the Member States especially for this last option. If Member States try to achieve the results at any costs, they will probably try to bend the rules so that the targets are achieved as fast as possible. One example is that the Member States produce higher polluted biofuels, which are cheaper and easier to create. Then the EU has to take charge. The Member States should be monitored and correct if necessary. Correcting Member States can be done by amending EU Directives.

Several Member States have introduced in the years 2005 and 2006 a new form of support: biofuel obligations.[20] This legal instrument creates an obligation for fuel suppliers to include a given percentage of biofuels in the total amount of fuel they place on the market. 'Some Member States are using these obligations as a complement to tax exemptions, others as an alternative. There is good reason to believe that in the long run, biofuel obligations will bring down the cost of promoting biofuels –in part because they ensure large scale deployment - and will prove the most effective approach. The Commission encourages their use' (Biofuels Progress Report 2007).

[20] France and Austria's obligations came into force in 2005, Slovenia's in 2006. The Czech Republic, Germany and the Netherlands have introduced obligations in 2007, the UK in 2008.

The main issue the EU is facing at the moment is reaching the EU biofuel targets at the cost of rising food prices. In July 2008 EU ministers distanced themselves from the indicative targets due to a World Bank report, which revealed that biofuels pushed up the food prices worldwide by 75%. The European Parliament's Environment Committee voted to scale down the target to just 4% by 2015. 'EU environment and energy ministers also appeared to be seeking to manoeuvre themselves out of their biofuels commitment', as stated on the website of EurActive <http://www.euractiv.com>. This behaviour is explained by the disbelieve of not reaching the target on time and also because of the implications on the food prices.

In September 2008 there was an initiative to reduce the influence of biofuels on the food prices. 'Parliament's Industry and Energy Committee, which has the lead on the dossier, went in a similar direction, approving a report drafted by Luxembourg Green MEP, Member of European Parliament, Claude Turmes. While confirming the 10% target by 2020 and setting an interim 5% target for 2015, Turmes' report nevertheless specifies that at least 20% of the 2015 target and 40% of the 2020 goal must be met from "non-food and feed-competing" second-generation biofuels or from cars running on green electricity and hydrogen' <http://www.euractiv.com>. The previous initiative and the behaviour of the EU shows a certain effort to change and optimize the targets. Optimizing in such a way that there is going to be a reduced influence on the food prices.

4.3.2 EU Fuel Quality Directive

The Fuel Quality Directive (FQD) is based on Directive 98/70/EC, which sets the environmental specifications on fuels for vehicles equipped with positive ignition engines (like petrol) and with compression ignition engines (diesel). Several improvements have been made with the creation of the FQD. The Directive's goal is to guarantee engine performance and to minimize environmental impact. As opposed to the Biofuels Directive 2003/30/EC, where the focus is on reducing the greenhouse gases by targets of a minimal share of biofuel, the FQD offers carmakers other opportunities to achieve these goals like increasing the efficiency of fuels.

The FQD obliges the Member States to publish an annual report on fuel quality. These reports form the basis for another annual report on the Member States fuel quality which is written by the European Commission. The latest report from the European Commission dates from the first of December of 2008: Quality of petrol and diesel fuel used for road transport in the European Union: Fifth annual report (Reporting year 2006). The specifications defined for petrol and diesel fuels by Directive 98/70/EC were in the year 2006 generally met. It is emphasised that the total share of sulphur fuels improved significantly within the period from 2001 to 2006. Also most Member States are now selling sulphur-free fuels. The Commission foresees problems in the absence of labelling fuels complying with the <10ppm sulphur criterion. It is explained that this aspect is an obstacle to the spread of vehicles using this type of fuel, which would have a beneficial effect on the environment in terms of lower pollutant and greenhouse gas emissions.

The goal of the FQD, guaranteeing engine performance and minimizing environmental impact, is backed up by two EU biofuel standards; EN590 and EN14214. 'EU fuel standards like the EN590 (diesel) and the EN14214 (biodiesel) aim to set specifications for fuels in order to ensure motor performance. At this moment the EN590 limits the use of biodiesel to 5% on the condition that the fuel meets the specification of the EN14214' (Market Analysis Oils and Fats for Fuel 2007). 'The European biodiesel standard EN14214 is widely perceived as favouring production of biodiesel from rapeseed (the dominant feedstock grown in Europe) and thus making it more difficult for biodiesel produced from other plant varieties elsewhere to comply with the standard' (Mathews 2007). This creates a national bias for all the Member States, besides this it also protects their production, since the production is being favoured by the biodiesel standard EN14214.
The biodiesel standard EN14214 will effectively act as a non-tariff trade barrier, creating global disturbance and preferences for particular biofuels. For this reason, the European Commission took the initiative to create global collaboration to come to a global biofuel standard. The collaboration consists of the US National Institute of Standards and Technology (NIST) and the Brazilian Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO) and the Directorate General of Energy and Transport of the European Commission. These organisations meet each other in multiple conferences. 'The above organisations in close cooperation with their respective standardisation bodies (CEN, ABNT and ASTM International) facilitated the Tripartite Work on Biofuels standards that resulted in the publication of the White Paper on Internationally Compatible Biofuels Standards: These conferences aim to facilitate the continuation of the Tripartite work on technical specifications, test methods and reference materials. Further more the conference will provide the

opportunity to all stakeholder to discuss on sustainability criteria issues in an informal way' <http://www.biofuelstp.eu/events.html>.

4.3.3 Certification

'Defining and developing clear criteria for the sustainable production of biomass [and biofuels], and eventually developing a certification process for producers, is a goal sought by a wide range of governments and organizations' (IEA, 2008). Certification could help to regulate the biofuel market and it could create a sustainable growth and development of the global market. This is however a complex issue, as Matthews (2008) states: 'The major obstacle to the further growth and development of a global biofuels market is not so much the tariff barriers and subsidies that distort markets (bad enough as these are) but the issue of demonstrating sustainability and 'certified' contribution to greenhouse gas emission reductions'.
In Europe several initiatives were undertaken related to the development of sustainability criteria and certification. Similar projects were started. In the United Kingdom it led e.g. to the development of a progress report duty. The Netherlands wanted to follow the UK in this case. In 2006 a project group, 'Duurzame productie van biomassa', was established in the Netherlands to come up with sustainability criteria for the production of biomass for transport, chemicals and energy. Dr. Jacqueline Cramer was the head of the project and is now the Dutch minister of environment in the Netherlands (2009). The Cramer Commission had the opinion that there was a need for a monitoring system on macro level. Germany finalized the criteria and made it ready for legislation. All these national undertaken developments came to an end when the European Commission decided to include sustainability criteria in the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD).

The decision to include sustainability criteria resulted into a need for an institution where all stakeholders could meet and collaborate. This way sustainability criteria and certification could be created more central. The meetings were held by platforms, so-called roundtables. Roundtable initiatives define and implement sustainability criteria in the fields of environment, social and economics. There are several roundtables that relate to biofuels, namely:

- the Roundtable on Sustainable Palm Oil (RSPO), it promotes the growth and use of sustainable palm oil <www.rspo.org>,
- the Roundtable on Responsible Soy Association (RTRS), it develops and promotes a standard of sustainability for the production, processing, trading and use of soy <www.responsiblesoy.org>,
- the Roundtable on Sustainable Biofuels (RSB), the goal of the RSB is to ensure the sustainability of biofuels production and processing <http://cgse.epfl.ch/page65660.html>.

One of the organisations that participates in different working groups by providing input from its expertise with the different roundtable is Product Board for Margarine, Fats and Oils (MVO). Product Board MVO focuses on the national sustainability framework. In their report they stress the importance of linking up with existing international initiatives for the development of criteria, such as the roundtables. This is crucial if one wants to succeed using sustainability criteria. Broad consensus on a international level is also very crucial. If there is only a consensus on European level, certain criteria can become non-tariffs. Global standards would avoid these biases.

Reaching broad consensus is one thing, another is the compatibility with international trade agreements. 'The International Policy Council (IPC) published in October 2006 the report WTO Disciplines and Biofuels: Opportunities and Constraints in the Creation of a Global Marketplace' (Market Analysis Oils and Fats for Fuel 2007). It is the first report to explore the opportunities in what way sustainability criteria can be introduced without having the risk to be considered as a trade barrier' (Market Analysis Oils and Fats for Fuel 2007). The compatibility criteria was tested by the Dutch government on the Cramer criteria, created by the Cramer Commission. It consisted of 9 sustainability principles and criteria. It was tested whether or not the criteria could be put into law and to which extent this would cause problems in the light of WTO and EU law. 'The analyses concludes that while the introduction of greenhouse gas performance criteria into legislation would be possible, most other sustainability criteria are likely to meet legal objections or are considered to be in breach with existing EU or WTO legislation' (Market Analysis Oils and Fats for Fuel 2007).

Sustainability criteria and certification could solve three issues. First: it would ensure that the produced biofuels, under certification, are highly qualitative products. It is important that certification is used globally,

since only then this would have the biggest and positive effect on the international trade market. When the supporting area is globally it avoids conflicting situations concerning certification. Everybody then knows what is produced under which circumstances. A Biopact between the North and the South could help to improve the international trade of biofuels. One of the conditions for a Biopact between the North and South would be fulfilled with these criteria and certification. The Biopact is further described in the market (chapter 5).
Second, market certification could solve some organizing problems concerning sustainability according to Mathews (2008): ‘Sustainability criteria could settle the issue of who is responsible for certifying and could settle the issue of allocation costs’.
Third, a certification system also has an impact on irresponsible behaviour in the industry. It simply prevents this from happening, because certification will be a signal to the different parties. A recent development in certification is the system of social certification, which Mathews (2008) describes as: ‘social certification introduced by Brazil to ensure that biodiesel produced is contributing to the social development of rural areas […] in Brazil’s impoverished NorthEast through growing oilseeds’.

4.3.4. EU Renewable Energy Directive

Biofuel objectives are part of a broader Renewable Energy Policy. The EU Renewable Energy Directive (RED) is part of this Renewable Energy Policy. It stimulates energy needs from renewables such as biomass, wind, solar and water. The RED began with the EU Directive 2001/77. The Directive describes an overall target for energy to consist out of 12% renewables in 2010. Although each Member State has different policies and specific programs to stimulate production and to promote the use of renewables in order to achieve the target, the system of “feed-in” is commonly used. The feed-in system subsidizes a certain amount of money when producers produce a certain amount of renewables. Similar to the Biofuels Directive, the RED requests a delivery of progress reports on a yearly basis; Member States are obliged to send progress reports to the Directorate-General of Energy and Transport.

Following the targets set by the Directive a White Paper, “Energy for the future: Renewable Sources of Energy”, was published in November 1997 by the European Commission. ‘This document sets out a strategy how the market share of renewable energies in gross domestic energy consumption can be doubled by 2010 to 12%. It also includes an Action Plan with a timetable how this objective can be achieved’ <http://www.task39.org>.

In March 2007 new Member States’ targets were formulated within the ‘Renewable Energy Roadmap’. The previously created targets for 2010 were expanded with a binding target for 2020. This binding target entails that in 2020 EU’s overall energy consumption should on average exist out of 20% renewables, where every individual Member State should achieve at least a 10% consumption of biofuels for transport.[21] Besides this, each Member States needs to achieve a 20% greenhouse gas emissions reduction by 2020. These amendments can be found in Directive 2009/28/EC.

Following the new targets of march 2007, a new renewable energy Directive was proposed in January 2008 to replace the existing measures of 2001 by new ones.[22] This has been adopted by 17 December 2008 under the name Directive 2009/28/EC. The change resulted in every Member State having its own individual target to achieve, which is based on the state’s the per capita GDP. All these different targets can be found in table F-1. By June 2010 each state is obliged to prepare a National Action Plan (NAP) to meet the 2020 targets. It is free to decide on the ‘mix’ of renewables: ‘Under certain conditions it will be allowed to import 'physical' renewable energy from third-country sources […] ‘Virtual' imports, based on renewable energy investments in third countries, cannot be counted towards national targets’ <http://www.euractiv.com>.
To ensure a steady progress towards the targets of 2020, the commission proposed a series of interim targets:

- 25% average between 2011 and 2012, 35% average between 2013 and 2014,
- 45% average between 2015 and 2016 and a 65% average between 2017 and 2018.

‘Senior EU officials have admitted that the 20% target would be challenging to meet, considering that Europe as a whole was only meeting 6.4% of its overall energy needs with renewables in 2007. The European Renewable Energy Council (EREC) voiced concerns regarding implementation, saying that "setting an ambitious target does not automatically deliver the results". "We need to go ahead at full speed in implementing the

[21] Subjected to a sustainable production and to a commercial production of second-generation biofuels.
[22] The 12% target for 2010.

legislative framework, which will guarantee that renewable energy in all its sectors and potentials will be exploited," said EREC President Arthouros Zervos' <http://www.euractiv.com>.

4.3.5. Common Agricultural Policy

The Common Agricultural Policy (CAP) aids and encourages, since 1992, the production of energy crops in the EU. Examples of these are oilseeds used for biodiesel and sugar beets for bio-ethanol production. In 2003 the EU geared the CAP 'towards consumers and taxpayers, while giving EU farmers the freedom to produce what the market wants' <http://ec.europa.eu>. This meant a reform of the CAP, whereby the following was introduced: the Single Payment Scheme, a scheme that helps to facilitate the supply of energy crops. When energy crops are grown on set-aside land the farmer will receive payments under the Single Payment Scheme, plus a yearly payment up to €45,- per hectare for new energy crops. This €45,- premium is only eligible if the energy crops are used for biofuel production or as biomass in the production of electric and thermal energy. 'These new "single farm payments" will be linked to the respect of environmental, food safety and animal welfare standards. Severing the link between subsidies and production will make EU farmers more competitive and market orientated, while providing the necessary income stability. More money will be available to farmers for environmental, quality or animal welfare programmes by reducing direct payments for bigger farms' <http://ec.europa.eu>.

The CAP's aim is to contribute to a balanced supply of energy crops in the EU. The CAP controls for too much supply by setting limits to the area that is eligible for the premium. The area cannot exceed 1.5 million hectares across the EU. The total area supported in the year 2005 was e.g. 570.000 hectares.

4.4. United States

The US started to promote biofuels due to the rising oil prices, the economy and energy security. The Renewable Fuel Standard (RFS) is a provision of the US Energy Policy Act of 2005 with the goal to promote the use and production of renewable alternatives under which biofuels. Multiple sections of this act refer to biofuels, a list and summary on this can be found on the website of the Federal Network for Sustainability <http://www.federalsustainability.org>.

The most important section in the Energy Policy Act is section 1501; Renewable Content of Gasoline. It mentions that it '[r]equires the creation of regulations within 1 year of enactment to ensure that gasoline sold or introduced into commerce in the US, on an annual average, contains the applicable volume of renewable fuel. "Renewable fuel" includes biodiesel, though focus of legislation is on ethanol in gasoline. EPA is tasked with writing implementing regulations that are to include biodiesel' <http://www.federalsustainability.org>. This section provides targets for the amount of renewable fuels to be produced, which can be found in table 4-1 below. The final goal is to achieve an amount of 34.0956 billion of litres renewable fuels by 2012. The target of 2012 has already been reached in the year 2008, when the total production was 40.9148 billion.[23] The US consumed in the year 2008, 626.451 billion of litres making the production of renewable fuels around 6.5% of the total consumption in the US. Details are available from the Energy Information Administration's Web site <http://www.eia.doe.gov>.

Table 4-1: Production targets renewable fuels US.

Year	Renewable Fuels (billion of litres)
2006	18.1843
2007	21.3666
2008	24.5488
2009	27.7311
2010	30.9134
2011	33.6410
2012	34.0956

(Source: adapted from http://www.ethanolrfa.org/)

[23] Source: F.O. Licht <http://www.ethanolrfa.org>.

In 2007 the Bush administration approved a renewed Energy Bill. Under the bill, the RFS increased to 163.659 billion of litres by 2022 to be produced. These 163.659 billion of litres are to be achieved by the use of corn-based ethanol and advanced biofuels; the majority of which are cellulosic biofuels belonging to the latter category. Some states have higher targets supporting the target with different fiscal incentives. Each State differs with tax exemptions. Some States also have targets for biodiesel consumption. This accounts especially to those States that have environmental concerns and/or are home to soybean growers (Market Analysis Oils and Fats for Fuel 2007, p. 13).

The Energy Information Administration (EIA) gave the following opinion about the feasibility of reaching the target set by the Bush Administration: 'The US will not be able to meet the target of 163.659 billion litres of biofuels by 2022 set by the Bush Administration […] The EIA calculates that the US will only reach levels of around 136.382 billion litres of corn-based ethanol and advanced biofuels by 2022' <http://www.eia.doe.gov>.

4.5. Brazil

Brazil has a long history with biofuels. In 1975 Brazil started with their first biofuels program, the National Alcohol Program (Proálcool). This program was a response to the oil crisis of 1973. 'Proálcool essentially focused on the production of ethanol from the distillation of sugar extracted from sugar cane. The program effectively created a nationwide ethanol production chain based on a system of government subsidies and tax rebates to sugar cane producers and distillers' (Colares, 2008). 'The ethanol content in those blends started as 5% and has been increased during the three decades of Proálcool and actually varies from 20% to 25%' (Pousa et al. 2007).

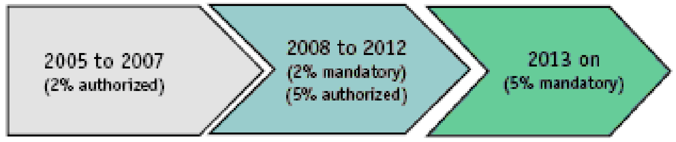
In the year 1985, 96 percent of automobiles sold in Brazil were ethanol-powered. This declined through the significant drop of the oil prices[24] in the years 1986-1990. In hand with the decline of ethanol-powered automobiles was the decline of ethanol consumption. 'During the 1990s, the fall in ethanol consumption was partially offset by a legislated increase in the ethanol content (22%) added to gasoline, as gasoline-powered automobiles made a comeback' (Colares, 2008). This changed the legislation in a positive way for the Brazilian ethanol production. It created the opportunity to introduce a new technology, the "flex fuel" engine (Colares, 2008). This engine allowed the consumer to switch between consumption of either gasoline, ethanol or a combination of the two. The choice was influenced by the prices at that moment. 'In 2006, 83 percent of automobiles sold in Brazil could run on either fuel. Working in tandem with efforts to increase oil production, Brazil's ethanol program gradually moved the country toward oil self-sufficiency—a goal Brazil finally achieved in early 2006' (Colares, 2008). Brazil's current targets for ethanol production are not clear at the moment. Only vaguely it is mentioned in a report: "Ethanol 2020: Global Market Survey, Next-Generation Trends, and Forecasts, which is made by Emerging Markets Online. In this report is the following mentioned: 'Europe, Brazil, China and India each aim to replace 5% to 20% of on-road gasoline consumption with ethanol'. Multiple players, a range for the target and the lack of the year when it has to be achieved, does not help to create a clear picture of Brazil's ethanol targets. On the other hand there is a clear signal of a large company. Brazil's Petrobas announced an export target. Petrobas set an export target for themselves of 5.45530 billion of litres for 2012 <http://www.biofuelsdigest.com>. The ethanol consumption in Brazil was in the year 2008, 17.6842 billion of litres while petrol consumption was in that year 16.6841 billion of litres according to the National Agency for Petroleum, Natural Gas and Biofuels.

The targets for biodiesel are made clear through the latest development, the National Program on Biodiesel Production and Usage (PNPB). 'Law No. 11,097 of January 13, 2005 prescribes that in an initial stage (from 2008 until 2012) two percent of Brazilian consumption of petrol-based diesel be replaced with oilseed- and animal fat-derived biodiesel. The law also provides that this percentage will increase to five percent starting in 2013' (Colares, 2008). In figure 4-1 (next page) one can see that it is mandatory to consume 2% within the period 2008-2012 and 5% by 2013.

In 2007 the news was brought out that there would come an increase of 11 biodiesel factories. This increase would have a serious effect on the targets. 'According to Arnoldo de Campos, the coordinator of the National Program for Biodiesel Production and Use, the increased capacity means the deadline can be brought forward by three years, to 2010' <http://news.mongabay.com>.

[24] Making the competitive position of ethanol weaker

Figure 4-1: Schedule for targets biodiesel in Brazil.



(Source: Adapted from Sauer, 2008)

4.6 Conclusion

The three largest players in the biofuel industry have set their own targets and goals related to the consumption and production of biofuels. The EU have set percentage-wise targets on the usage of biofuels and the US on renewable fuels. The targets of the Brazilian region related to biofuels are only clear for biodiesel.
The EU has set a target of 5.75% for 2010 and a 10% target for biofuel consumption to be reached in the year 2020. Expected is that both targets will not be reached. For the 5.75% target it is expected that the EU will only achieve a 4.2% of biofuel share. The 10% target is for currently seen as too ambitious by the European Environmental Agency.
The US has set production targets for renewable fuels. In the year 2008 the US achieved a 6.5% of biofuels consumption, produced by the US. It is not completely clear yet whether the target of 163.659 billion of by 2022 is to be achieved. The Energy Information Association does not believe so.
Expected is that Brazil will reach the target of 5% of biodiesel consumption by 2010 instead of the earlier projected year of 2013. This result can not be compared to the US and the EU, because they base their targets on biofuels/renewable fuels while the target of Brazil only focuses on biodiesel. However, what can be stated is that Brazil is the leader in biofuel consumption. This is made possible through the “flex fuel” engines, making ethanol consumption in the year 2008 higher than the consumption of petrol.

5. Biofuels market

5.1. Introduction

This chapter provides insight on the biofuels market. First, a market overview will be given in paragraph 5.2, that involves a paragraph on stakeholders (paragraph 5.2.1), exchange (paragraph 5.2.2) and the coordination of the market (paragraph 5.2.3). On the market there is being imported and exported, in other words biofuels are being traded. For this reason, trade flows on the market (paragraph 5.3) are discussed. This involves the following paragraphs: trade in ethanol (paragraph 5.3.1), trade in biodiesel (paragraph 5.3.2) and trade barriers (paragraph 5.3.3). Not only the trade flows will be discussed, but also a comparison between production and consumption will be given in paragraph 5.4, where first ethanol (paragraph 5.4.1) will be discussed, followed by biodiesel (paragraph 5.4.2). Paragraph 5.5 discusses the environment of the biofuels market, which involves geographic factors (paragraph 5.5.1), ecological factors (paragraph 5.5.2), economical factors (paragraph 5.5.3) and technical factors (paragraph 5.5.4). In paragraph 5.6 two conflicts, mentioned a lot in the literature, are described namely the food-versus-fuel (paragraph 5.6.1) and the biofuel-versus-fossil fuel (paragraph 5.6.2). Paragraph 5.7 informs the reader about the latest development on the market, public policies (paragraph 5.7.1) and technological developments (paragraph 5.7.2). The chapter will be finalized with a conclusion (paragraph 5.8).

5.2. Market overview

Meeusen et. al (2009) describes the biofuels market as: 'a free market, where all can bring and get their products. Commodities are in proper amounts available. At one hand the market is rather transparent, because a large share of bulk products is traded on exchange markets and the prices are visible for everybody. On the other hand the market is complex and dynamic. This due to the so-called increased volatilitythe last years. This is related to the feature of agro markets: on short term inelastic. Which means that demand and supply on short term badly react on price changes', having a negative influence on trade. [25,26]
Ceaser et al. (2007) describes ways to handle the volatility. According to Caeser et. al (2007): companies that decide to enter […] will have to mitigate risk by hedging their bets and building relationships that could help reduce uncertainty and volatility. Integration along the value chain can diminish risk and volatility. Meeusen et. al (2009) confirms this by stating that: 'A trend is signing off to vertical integration'.
Thus, in order to minimize the impacts, if any, of the uncertain price fluctuations of commodities companies tend to vertically integrate, hedge bets and build relationships. Not only companies, but also governments are trying to be a helping hand in this. 'Governments have introduced a variety of policy tools that reduce risk and uncertainty in response to investor and producer concerns about the double-edged uncertainty of volatile feedstock and energy input prices and biofuel output prices. The most common tool is a requirement to blend biofuel with its fossil fuel counterpart to provide a guaranteed market for biofuels. The nature of this requirement varies around the world in the extent to which it is mandatory' (Coyle, 2007).[27]

5.2.1. Stakeholders

The biofuels market is being controlled by three major players –the US, Brazil and the EU- that account for 95% of the biofuels production worldwide (Doornbosch et al. 2007). Providing an overview that includes all stakeholders active on the market appears to be difficult, if not impossible, due to the big existing amount. However, in order to provide insights in what stakeholders are around, two studies will be touched upon. The first is the report "Market Analysis Oils and Fats for Fuel (2007)" and the second concerns a work by Caeser et al. (2007).

The report "Market Analysis Oils and Fats for Fuel (2007)" shows an overview of the different stakeholders. These stakeholders are briefly discussed below, where needed additional information is given:

- Producing and consuming countries

[25] In retail, unpackaged, fresh products displayed in bins in large quantities and sold by the piece or the pound, such as grains, sweets or snacks <http://dictionary.babylon.com/Bulk_Product>.
[26] The measure of the tendency of prices to fluctuate widely <http://dictionary.babylon.com/volatility#business>.
[27] More on volatility can be read in the chapter supply.

US, Brazil and the EU are the three global biofuel producing and consuming leaders. A logical result is that these three regions are the most discussed within the literature. Today, developing countries are making their appearance. Countries such as Malaysia and Indonesia are rapidly developing their production in biodiesel (ICTSD, 2008).

- End-users
  End-users are especially those individuals who use biofuels for personal consumption in order to power vehicles, that is: cars and motorcycles. Although, in the literature it is not always clear how end-users are defined.
- Associations and federations in the Biofuels industry[28]
  Many regions/countries have initiated associations for biofuels. Two examples will be given on this, one related to the Netherlands and the other to the US.
  First, the Dutch Association for the Biofuels Industry. The "Vereniging Nederlandse Biodiesel Industrie's" (VNBI) goal is to promote biodiesel use and inform government, politics and consumers (Market Analysis Oils and Fats for Fuel 2007, p 53).
  Secondly, the Northwest Biofuels Association (NWBA) for the northwest region of the US. 'The NWBA is a non-profit trade association structured to represent the business interests of its members while supporting the development of the biofuels industry as a whole' <www.nwbiofuels.org>.
  One example of a federation is the Federation of Oils, Seeds and Fats Association (FOSTA). The FOSTA represent the interest of the oil and fat traders. The federation has developed e.g. standard trade contract rules.
- Fuel suppliers
  Fuel suppliers are active on a worldwide level. Examples are: Shell, British Petroleum (BP) and Petrobas. Petrobas plays a large role in the Brazilian export of biofuels, as mentioned in chapter 4 (regulations).
- Government institutions/projects
  Many government institutions and projects publish valuable information on the biofuels market. Many of the institutions have an advisory role. One example is Refuel, which is financed by the European Commission. 'Refuel is designed to encourage a greater market penetration of biofuels' <www.refuel.eu>.
- Car manufacturing sector
  The sector of the car manufacturers has been hit hard by the current economic crisis (which started last year). Due to the crisis the sector is changing and currently producing more efficient fuel cars, such as biofuel cars. One of them is Bentley, who started manufacturing a biofuel car in the year 2009 <www.edmunds.com>.
- Farmers
  Farmers play an important role in the biofuel market. This is because they are the producers of feedstock for biofuels. Decisions on food for consumption or food for feedstock depends heavily on the amounts of subsidies and taxes provided.
- Scientist and Engineers
  The people who are constantly researching for new methods and improving the technologies used.

The focus of Caeser et. al's (2007) work is on stakeholders per segment. The end-user is not included in this overview. In total three different segments have been introduced that exist within the biofuel industry:

- Asset owners (including agribusinesses, petroleum companies, chemical companies, plant operators, and small farmers);
- Product and service providers (including seed companies, engineering and equipment companies, and biotechnology firms developing enzymes and fermentation organisms);
- Market participants (including gasoline blenders, farmers, agricultural equipment companies, suppliers of inputs such as fertilizers, and logistics providers).

[28] A federation is an alliance of associations.

5.2.2. Exchange

Companies active within the biofuel supply chain need to meet other companies in order to be able to conduct business. There are multiple opportunities for companies to meet potential business partners and/or other stakeholders, namely:

- Conferences
  Companies can attend conferences. It provides a possibility to learn (more) about the developments in the industry and to meet up with other stakeholders as well. One of these conferences is the "Biofuels International" that was held in Amsterdam in 2009. It was the second time that the conference was held.
- Roundtables
  Roundtables are another way to get in touch with stakeholders. Roundtables are described in detail in chapter regulations.
- The internet
  The internet is another instrument to conduct business. Several websites offer services to trade in biofuels. These websites are to be divided between websites providing overviews in the form of lists, providing overviews of producing companies and websites that facilitate the trade of biofuels through an exchange system. BioXchange and the US Biofuels Exchange are two examples of websites that use an exchange system to facilitate trade.
  The BioXchange project is initiated to develop a European wide biomass trading floor. According to the BioXchange website: 'The aim of the BioXchange project is to make the market more transparent, so that: all available biomass resources are utilized, transport distances are shortened and biomass power plants are optimized'.
  The US Biofuels Exchange focuses on the US. The initiative is currently in beta testing. The aim is to set up an exchange market for the US. 'The US-BX is open to Biofuel Producers (Biodiesel and Ethanol), Brokers, Distributors, Importers, Exporters and Marketers (resellers). […] Exchange members are able to list both "Biofuels for Sale" and "Biofuels Wanted". Buyers are informed by Sellers regarding key product statistics and characteristics, as well as product locations, availability dates, terms and more. Likewise, sellers are informed by buyers as to their exact needs. The US-BX can accommodate transactions in Gallons, Truckloads and Rail Cars. [...] Members can compare current biofuel pricing as well as keep track of lots bought and sold and offers made and received. US-BX members stay current with up-to-date US-BX and biofuel industry news, information and announcements' <http://www.us-bx.com>.
- Joining associations
  Joining associations can help to meet (potential) business partners and/or stakeholders. More on this alternative can be found on the previous page within the paragraph on stakeholders (5.2.1).

5.2.3. Coordination

Developments and investments within the biofuel market lean heavily on subsidies and mandatory obligations. Several authors give attention to this, such as Ryan et al. (2005), Meeusen et al. (2009), The Royal Society (2008) and de Nie en Blom (2008).
The study of de Nie en Blom (2008) e.g. states that company investments related to any form of biofuel production are strongly dependent on governmental policies in the form of mandatory obligations and subsidies. Without this the biofuels industry would probably not have made, and will most probably not make in future, any considerable progress.
Meeusen et al. (2009) acknowledges the role of the government by stating: 'The trade in biofuels is driven by the government. It has to deal with an increasing number of demanded requirements with respect to quality assurance, food safety and specific quality's expressed in specifications. To improve the response to the demand of the end-user, a trend is going towards an alignment of quality control systems'. The demanded requirements expressed in specifications are set by the government. Developments in the market are analyzed and where needed directed in such a way that sustainable development is guaranteed. For all the mentioned reason it can be concluded that the market is being coordinated by the government.

5.3. Trade flows

Trade flows refers to the international flow of goods and services for money. The current trade in biofuels and biomass feedstock is modest compared to total consumption. In 2005 trade covered about 10% of the world's biofuel consumption (Doornbosch et al. 2007). 'Many trade flows take place between neighbouring regions or countries, but trade is increasingly being conducted over long distances. Examples are export of ethanol from Brazil to Japan, the EU and the US, palm kernel shells from Malaysia to the Netherlands […] These trade flows may offer multiple benefits for both exporting and importing countries. For example, exporting countries may gain an interesting source of additional income and an increase in employment' (Faaij et al. 2006). Importing countries use trade e.g. to (temporary) solve gaps in their energy supply.

The international trade is driven by different forces. As mentioned above, additional income, employment and filling gaps in the energy supply are three of them, besides these there are the following factors according to Faaij et al. (2006):

- Raw material/biomass push
  These drivers are found in most countries with surplus of biomass resources. Sugarcane ethanol export from Brazil is an example of such a country with a successful push strategy.
- Market pull
  Import to the Netherlands is facilitated by the very suitable structure of the leading big utilities. This makes efficient transport and handling possible and leads to low fuel costs compared to those available to users in other countries where the conditions are less favourable.
- Effects of incentives
  The introduction of incentives based on political decisions has increased the strength of the driving forces and triggered an expansion of bio-energy trade.
- Entrepreneurs and innovators
  In countries such as Austria and Sweden, individual entrepreneurs and innovators have had a leading role in the development of bio-energy trade. This has led to a more diversified pattern.
- Unexpected opportunities
  Storms, forest fires, insect attacks, etc., may lead to short-term imbalances in the supply. Technical failures and other reasons for shutdown cause disturbances for the user and in distribution systems. Such short-term opportunities can lead to new trade patterns, some of which may remain even when the conditions return to normal.

5.3.1. Trade in Ethanol

'About 20 percent of the ethanol produced in the world today is traded internationally' (ICTSD, 2008).[29] The numbers in table 5-1 and table 5-2, include not only ethanol that is used for fuel purposes, but also ethanol that is used for the basis of alcoholic beverages, as a solvent and for other industrial applications (ICTSD, 2008). This makes the table give a bit what misleading information, because not only ethanol for transportation purposes is included.

In the year 2006 a volume of 7.8 billion litres bio-ethanol was traded worldwide compared to a 5.9 billion litres in 2005 (ICTSD, 2008). Brazil had a large share in this worldwide trade of bio-ethanol. In 2006, the Brazilian export of fuel ethanol reached 3.5 billion litres (44.8% of worldwide trade) and in the year 2005 a 2.6 billion litres (44.1% of worldwide trade) (F.O. Lichts, 2006) (ICTSD, 2008). In 2005, fuel ethanol exported by Brazil was approximately 44% of worldwide trade in comparison to ethanol which was approximately 48% of the worldwide trade, making the differences not that great.

As shown in table 5-1 (next page), the main exporting country of ethanol is Brazil, accounting for 48% of the world's total ethanol trade. The US and Japan are the two biggest ethanol importers.

Table 5-2 (next page) shows that India and the US have received in 2004 the most Brazilian ethanol. Although the US is the largest ethanol producer there is yet a high import of this product as well. Explanations could be the fact that there are higher biofuel mandatory targets set by government policies and/or that Brazilian ethanol is more cost competitive than US ethanol. Some Brazilian ethanol is not even subjected to tariff quotas: 'Some Brazilian exports are flown into the US indirectly via Central America and the Caribbean, where it is processed and can enter tariff-free under the Caribbean Basin Initiative (CBI), a regional preferential trading program' (ICTSD, 2008). The CBI is bounded to a quota, preventing an overflow of ethanol import in the US.

[29] The International Centre for Trade and Sustainable Development.

Table 5-1: Ethanol -exporting and –importing countries, 2005.

Import	%	Export	%
US	18	Brazil	48
Japan	11	US	6
India	8	France	6
Germany	8	South Africa	6
The Netherlands	8	China	5
UK	6	UK	5
Korea	5	The Netherlands	4
France	4	Germany	2
Others	32	Others	18
Total	100	Total	100

(Source: Walter et al. 2007)

Table 5-2: Brazilian ethanol exports, 2004.

Import country	Export (%)
India	19.7
US	17.7
South Korea	9.9
Japan	8.7
Sweden	8.2
Netherlands	6.5
Jamaica	5.5
Nigeria	4.4
Costa Rica	4.4
Others	15
Total	100

(Source: Adapted from Walter et al. 2007)

5.3.2. Trade in biodiesel

‘At present, there is no significant international trade in biodiesel. Germany is the world’s largest producer of the fuel (from rapeseed), but this is mainly for use domestically and within the EU’ (ICTSD, 2008). For this reason there is not much written on the trade in biodiesel. ‘Despite its smaller share of the global market, it appears that the international biodiesel market may also expand rapidly in response to growing global demand. Although Europe currently manufactures 95 percent of the world’s biodiesel, developing countries are building infrastructure to supply regional and international biofuels markets’ (ICTSD, 2008).

5.3.3. Trade barriers

There are three barriers that often come up in the literature: trade tariffs, lack of sustainability criteria and non-tariff barriers. The three barriers limit the international trade. Each country in the world has different rules and tariffs for the import of biofuels and/or commodities. Doornbosch et al. (2007) describes this as: ‘tariffs on imported biofuels […] tariffs are especially high on ethanol […] The leading OECD countries producing ethanol apply import tariffs that add at least 25% to the cost of imports […] Moreover, the countries most affected by import tariffs are generally developing countries with a comparative advantage in biofuel production’.
The second trade barriers is the lack of sustainability criteria on a global level. The lack of such a criteria creates uncertainty about the product and the way the product has been produced. As mentioned in the chapter regulations, certain initiatives have been taken to create such a (global) sustainability criteria.
Finally there are also non-tariff barriers, such as the biodiesel standard EN14214 that favours the EU in production of biodiesel made from rapeseed compared to the rest of the world (Mathews 2007, p. 3564). All these barriers can decrease the amount of trade between countries. but it can also result in less investment by companies in the market.

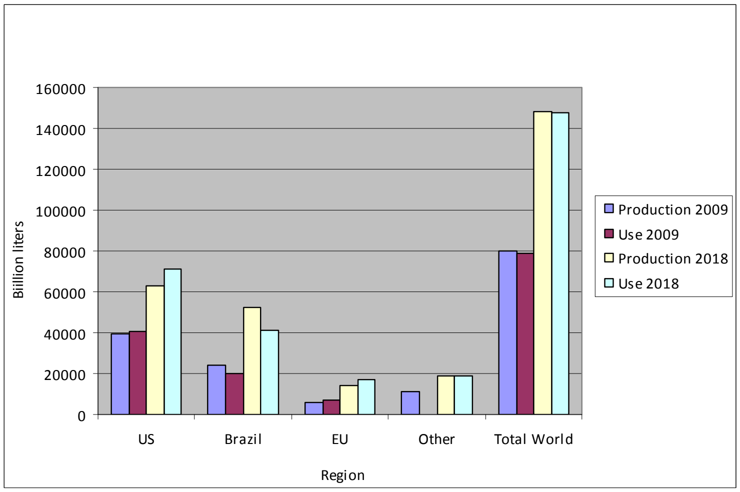
5.4. Production versus use

Production and use projections were already individually discussed in the chapter supply and chapter demand, but in this paragraph a comparison is being made. On a global scale there is for both biodiesel and bio-ethanol a higher total production than there is total use. This does not account for every individual region and it also differs by type of biofuel. Whenever production is higher than use, there are possibilities to export biofuel and whenever demanded use is higher than production, there are import possibilities.

5.4.1. Ethanol

In figure 5-1 (next page), bio-ethanol’s projected production and use of 2009 and 2018 is shown (data is taken from OECD-FAO, 2009). Currently, the US produced and consumes the most ethanol in the world. It does consume, however, more ethanol than domestically produced. The differences between production and use will increase in the future (2018). The predictions for Brazil on the other hand, are that both in 2009 and 2018, production is higher than consumption. Similar to the US, the EU consumes more than it produces; this applies to 2009 and 2018. In case of the other countries, numbers of total use in 2009 are missing so nothing can be said on the interaction between production and use. In 2018 the predictions are that production and use will be rather similar.

Figure 5-1: Bio-ethanol projected production and use in 2009 and 2018.

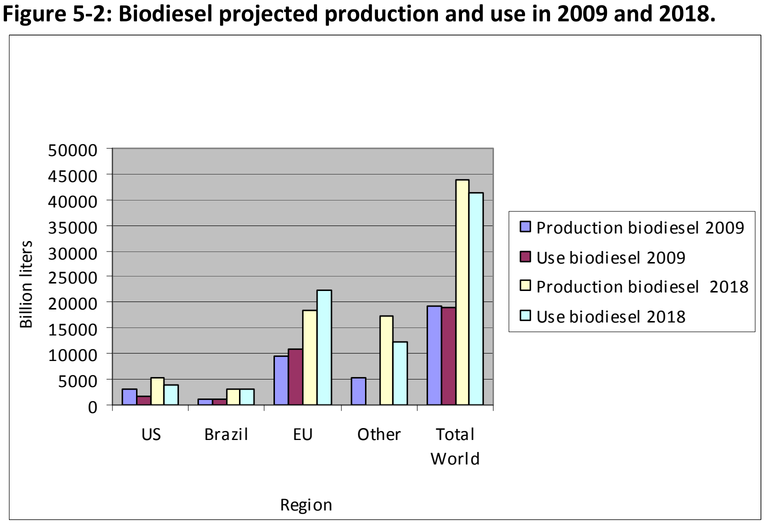


(Source: Adapted from numbers provided by OECD-FAO, 2009)

5.4.2. Biodiesel

In figure 5-2, projected biodiesel production and use of 2009 and 2018 is shown (data is taken from OECD-FAO, 2009). Currently, the EU produces and consumes the most biodiesel on a global scale. It does consume, however, more biodiesel than domestically produced. The differences between production and use is about to increase in the future (2018). The US produces somewhat more than it consumes. Percentage-wise this difference will stay alike. Brazilian production equals usage, both in 2009 and 2018. In case of the other regions, there is more production than use 2018. Numbers of total use in 2009 are missing so nothing can be said on the interaction between production and use in this year.

Figure 5-2: Biodiesel projected production and use in 2009 and 2018.



(Source: Adapted from numbers provided by OECD-FAO, 2009)

5.5. The environment

5.5.1. Geographic factors

Geographic factors are related to the location and e.g. the distances between locations <http://zakelijk.infonu.nl>. In the literature a lot is spoken about the differences between the 'North', representing the OECD countries, and the 'South', representing the developing countries. The South has a tropical climate making them benefit from enough rainfall, land availability and a higher yield per hectare, while the 'North' has really high needs concerning energy-supply (Mathews, 2008).
In the literature, a Biopact is being pushed forward to increase international trade and to stimulate the economy in developing countries. 'The BioPact, in short, is an understanding between North and South countries by which the South becomes the major producers of biofuels to supply their internal demand as well as the incremental demand of the North, as the latter gradually abandons grain and edible oil-based biofuels production' (Mathews, 2008). Not only in the literature the Biopact is being addressed as the problem solver, also the United Nations Food and Agriculture Organization (FAO) is of this opinion. '[…] the FAO's director-general Jacques Diouf points out that such a Biopact presents a win-win strategy that can benefit the world's poor, while solving part of the climate change problem' <www.news.mongabay.com>. A Biopact could have an influence on three things; benefit the world's poor, solve part of the climate change and create energy security in the developed world.
But to reap these benefits, the countries of the North need to open up their markets, which means agreeing to treat biofuels as fuels rather than foodstuffs; dismantling tariffs and subsidies; and ending discriminatory standards. (Mathews, 2007)

5.5.2. Ecological factors

Ecological factors focus on the environment <http://zakelijk.infonu.nl>. The ecological factors that are described are the efficient land use and water scarcity (Festel et al. 2008). Food-versus-fuel is another example that is related to ecological factors, but this is described in paragraph 5.6.1.

It is expected that the land used for the production of biofuels is going to be far more efficient than it is currently the case as probably yields per hectare will be increased. This entails a possible reduction of land usage. The IEA (2008) reports on this that: 'grain and sugar beet production will probably continue to expand in the future, this is mainly because yields are expected to improve […] crop yields continue to improve. The United States Department of Agriculture projects that corn yields per hectare will improve by another 10% over the next ten years, and that soy yields will improve by about 5%. Similar types of improvements are likely to occur for wheat and rapeseed in the EU […] crop production per hectare for all crops is assumed to improve at 1% per year over the next 20 years. Conversion yields are also assumed to improve, at about 1% per year for ethanol (litres per ton of feedstock), and at a slower rate (0.3%) for biodiesel, since the process of crushing oil-seeds and converting to methyl ester (biodiesel) is not likely to benefit as much from technological improvements or scale increases'.
Some debate is going on related to the amount of land needed for the production of biofuels, which is very difficult to determine. It depends a lot on the type of crops that are used for the production of biofuels. One crop does not give as much yield per hectare as another tupe. This has an enormous impact on the amount of land that is needed for the total production of biofuels, making it very difficult to determine the required amount of land. Not every type crop is suitable for each type of land.
The EEA has estimated the amount of available arable land for bio-energy production without harming the environment in the EU. The estimated amount should be sufficient to meet the 10% target of 2020 (EEA Report No 7/2006). Estimates however need to be adjusted when there is e.g. bad management. Bad management could have negative effects on agriculture, such as deforestation and water scarcity. 'The competition in water is going on between food production, nature, biodiversity and biofuel production. The local effects are difficult to determine, thanks to uncertainties about climate changes on local and regional scale. But that there will be negative effects is rather clear' (Feiten en Cijfers over bio-energie in Nederland, 2008).

5.5.3. Economical factors

Economical factors focus on items such as the economic climate, employment and inflation <http://zakelijk.infonu.nl>. The economical factors that are here of concern are governmental subsidies, taxes and tariff barriers.[30] The price of biofuels is influenced by the way governments regulate their country. ‘The balance of support to biofuels are provided in ways—through tariffs, excise-tax concessions and mandates, or some combination of these—that are directly related to levels of production, consumption or input use, and therefore potentially market and trade distorting’ (Kutas et. al., 2007). One example is given by Kutas et al. (2007) which shows that through the use of these measures it has negative effects on the market. ‘In principle […] mandates, tax concessions and area payments for energy crops do not specify particular feedstocks, and in the future could be met by ethanol and biodiesel made from a great diversity of biomass types. Because the costs of producing biofuels from feedstocks other than food or feed crops (and a limited volume of waste or by-products) are still prohibitively high, however, the current support policies are directly affecting production choices in favour of crops used for making first-generation biofuels—namely, wheat, maize and oilseed rape’ (Kutas et al. 2007). Favouring crops used for first-generation by different measures, puts more pressure on the food-versus-fuel issue.
Another effect of these governmental measures is that it becomes riskier to invest in the industry. Faaij et al. (2006) states that: ‘In order to promote bio-energy many developed and some developing countries have stimulated the development and use of biomass for electricity, heat and transportation by the introduction of different measures […] an often-heard criticism from the market side is that these measures may not be sufficient, since they are mostly temporary and tend to change frequently. This discourages long-term investment, as it is considered too risky’. Discouraged long-term investments could lead to less development on the market, which could lead to less or slower innovations.

5.5.4. Technical factors

In this paragraph the technical factors will be discussed in terms of: technical specifications, raw material supply, transportability and engine technologies. This categorization is take from the work by Festel et al. 2008. Following, the four factors will be discussed.

‘The technical specifications of biofuels and of fossil/biofuel blends should be clear, standardized and applicable on the entire market’ (Eyes on the track, Mind on the horizon, 2008). The chapter on regulations explains that there is currently no (global) certification and that there is a need for it. Without any (global) certification, consumers do not know what quality to expect from the product. A standardized and certified product expresses information on the quality and thus leaves no room for different expectations.

Technical factor related to raw material supply is whether or not the raw material is being handled in a standardized and/or certified way. In others words, it is about whether it is produced in a sustainable way and how it is transported.

The transportation of biofuels could limit the reduction of greenhouse gasses. Whether this is the case, or not, depends on the way biofuels are transported during the production process. Within the supply chain transportation of commodities and distribution of the end product is frequently needed from one party to another. When these movements involves the combustion of fossil fuels, total reduction of the emission of air pollutants is being limited (since fossil fuel combustion increases the emission of greenhouse gasses) (Factbook Biobrandstoffen, 2004).
Transportation problems are expected in the form of harbour and shipping capacities. In Eyes on the track, Mind on the horizon (2008) the following is mentioned on this: ‘Harbour and shipping capacities may become a limiting factor for the rapid set-up of new supply chains for biofuels and their feedstock. However as agricultural and energy commodities are already traded around the globe, we expect that the key limiting factor will be the production and local logistics of feedstock, not their long-distance transport’.

The last point on technical factors is the engine technology. The (possible) use of blends and/or pure versions of biofuel is dependent on the method and the pace car engines, or complete cars. As mentioned in Eyes on the track, Mind on the horizon (2008): ‘High blends (or pure versions) of biofuels, particularly of ethanol and

[30] Tariff barriers are described in paragraph 4.3.3.

biodiesel, may require vehicle adaptations. Fleet replacement becoming a potentially limiting factor for the penetration rate of blends'.

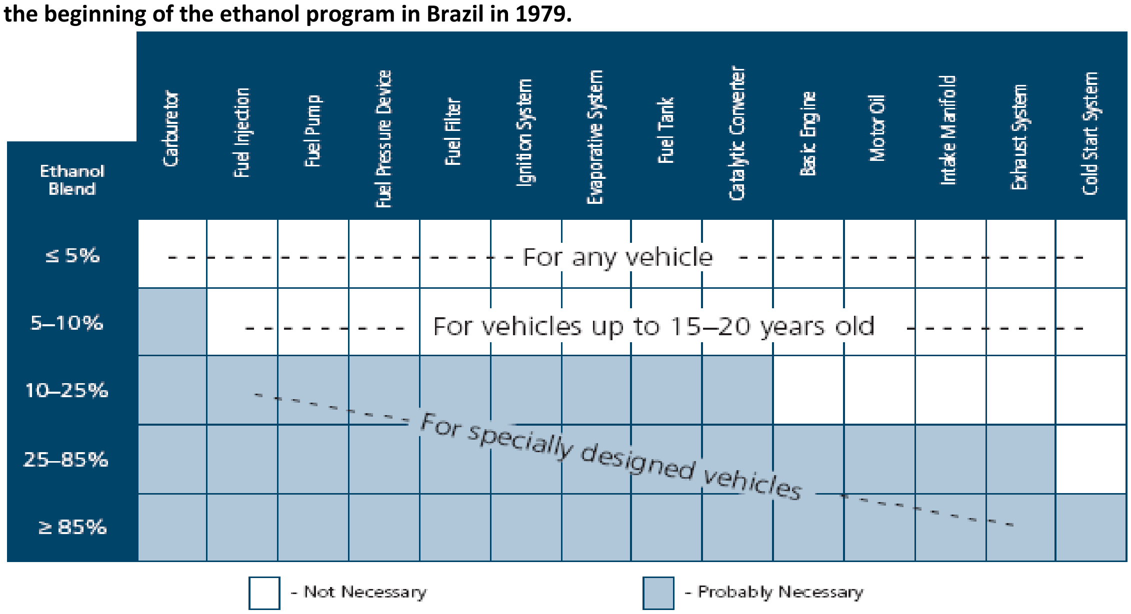
Joseph (2007) confirms that engine modification is a necessity and focuses particularly on the use of bio-ethanol : 'Developments in engines will be required if they are to burn larger blends of ethanol because it is corrosive and degrades a range of the materials found in specific components of the engine and fuel supply systems'. Information on diesel engines is given by The Royal Society (2008): 'if biodiesel meets the EU standard set by the Fuel Quality Directive, then no modifications to diesel engines are required' (The Royal Society, 2008). Otherwise there are (possible) modifications required.

A solution could be the use of "flex fuel" engines as in Brazil. The engine allows the consumer to switch between consumption of either gasoline, ethanol or a combination of the two. 'The petrol and bio-ethanol FFVsoffer several advantages and have been used extensively in Brazil and to a lesser extent in the USA and Sweden' (Joseph 2007).[31]

In other countries there is still the problem of the so-called 'chicken and egg cycle'. On the one hand there are the fuel suppliers that are reluctant to supply biofuels until the market is big enough. On the other hand there are the vehicle manufactures that are not willing to invest in order to innovate and supply new biofuel capable vehicles until the fuel can be supplied in sufficient quantities. Therefore, according to Royal Society (2008), governments should intervene to create appropriate market incentives to encourage development and supply of the FFVs, so there is more flexibility to increase biofuel usage.

Figure 5-3 displays the necessary modifications to engines to cope with increasing ethanol/petrol blends. For ethanol blends of ≤ 5% there is no need for engine modification on any vehicle. For 5–10% there is a need to adjust the carburetor. Other parts of the engine are not needed to be adjusted when the vehicles is up to 15-20 years old. When the blend is of ≥ 10%, there is a need for specially designed vehicles. It shows that there is in the future a need for new vehicles/engines. Moreover, it emphasizes that if there are not enough market incentives for vehicle manufactures and fuel suppliers the pressure will be on the governments to create these incentives to make biofuels work.

Figure 5-3: Necessary modifications to engines to cope with increasing ethanol/petrol blends. This figure is based on necessary modifications introduced by the Brazilian automobile industry (mainly Volkswagen) since the beginning of the ethanol program in Brazil in 1979.



(Source: Joseph, 2007)

[31] FFVs: Flex Fuel Vehicle's.

5.6. Conflicts

5.6.1. Food-versus-fuel

Brown (2006) illustrates the relevance of the issue food-versus-fuel by the following example: 'Since almost everything we eat can be converted into fuel for automobiles, including wheat, corn, rice, soybeans, and sugarcane, the line between the food and energy economies is disappearing.
As the price of oil climbs, it becomes increasingly profitable to convert farm commodities into automotive fuel, either ethanol or biodiesel. In effect, the price of oil becomes the support price for food commodities. Whenever the food value of a commodity drops below its fuel value, the market will convert it into fuel' (Brown, 2006). This indicates how the industry will react on changing prices.

Many factors have an effect on the food prices making it very difficult to determine the contribution of biofuels production. A lot of reasons can be appointed for this, under which the differences in time periods, prices (export, import, wholesale, retail), coverage of food products, currency used, price increases, inflation adjusted and interaction with other markets. Mitchell (2008) states that: 'Estimates of the contribution of biofuels production to food price increases are difficult, if not impossible to compare'.
Mitchell indicates that it is difficult to assess the effect of biofuels production on food prices. His observation on this is that: 'Many other potential drivers of the escalating food prices are mentioned in discussions, but there are few quantitative estimates of their impacts. For example, a recent USDA report (Trostle, 2008) attributed the increase in world market prices for major food commodities such as grains and vegetable oils, to many factors including biofuels as well as other factors including the declining dollar, rising energy prices, increasing agricultural costs of production, growing foreign exchange holdings by major food-importing countries, and recent policies by some exporting countries to mitigate their own food-price inflation.' Nevertheless ´[d]espite all the differences in approach, many studies recognize biofuels production as a major driver of food prices´ (Mitchell, 2008). The study of Rosegrant et. al (2007) is an example of one of these studies. Three scenario's are described to give a clear projection of the future. The first scenario is the baseline scenario. 'Biofuel demand follows historical patterns through 2006, increases by 1% per year between 2006 and 2010, and then for most countries remains constant at 2010 levels' (Rosegrant et. al, 2007). The second scenario is the biofuel expansion scenario. 'This scenario, based on actual national biofuel plans, assumes continued biofuel expansion through 2020, although the rate of expansion declines after 2010 for the early rapid growth countries such as the United States and Brazil. Under this scenario, significant increases of biofuel feedstock demand occur in many countries for commodities such as maize, wheat, cassava, sugar, and oil seeds' (Rosegrant et. al, 2007). The final scenario is the drastic biofuel expansion scenario. 'This scenario assumes very rapid growth of biofuel demand and is expected to result in drastic impacts on the global food market, food consumption, and malnutrition at the country level' (Rosegrant et al. 2007). In the study of Rosegrant et. al (2007) demand is shown to have an effect on food prices.
The first scenario, the baseline scenario, is most likely not going to happen. The targets set by governments and the increasing production capacities indicate that one of the other two scenario's is going to take place. 'Under the "biofuel expansion" scenario, 2020 world prices are 26% higher for maize, 18% higher for oilseeds, 12% higher for sugar, 11% for cassava, and 8% for wheat compared with the 2020 prices in the baseline scenario. The "drastic biofuel expansion" scenario shows dramatic increases in 2020 world prices for feedstock crops relative to the baseline, with the maize price 72% higher, oilseeds price 44% higher, cassava and sugar price 27% higher, and wheat 20% higher' (Rosegrant et al. 2007). The scenario's clearly show that there is a food-versus-fuel trade-off and that biofuels production will have a significant impact on the food sector.

5.6.2. Biofuel-versus-fossil fuel

In a study from Ryan et al. (2006) the relation between biofuels and fossil fuels is compared in costs. Table 5-3 shows this cost comparison between biofuels and petroleum fossil fuels. All the biofuels are more expensive than the fossil fuels, except for bio-ethanol from Brazilian sugarcane. It should be mentioned, however, that the data used in table X is based on estimates, does not include future developments, any subsidies and does not look at country-specific data. This makes it somewhat harder to use the data. It is, for example, expected that the costs of cellulosic ethanol will drop considerably (Department of Transport (UK), 2003; Fulton et al. 2004). The data does gives a general impression that biofuels, except for Brazilian bio-ethanol, are not viable at the moment.

Table 5-3: Cost Comparison of biofuels with petroleum fossil fuels.

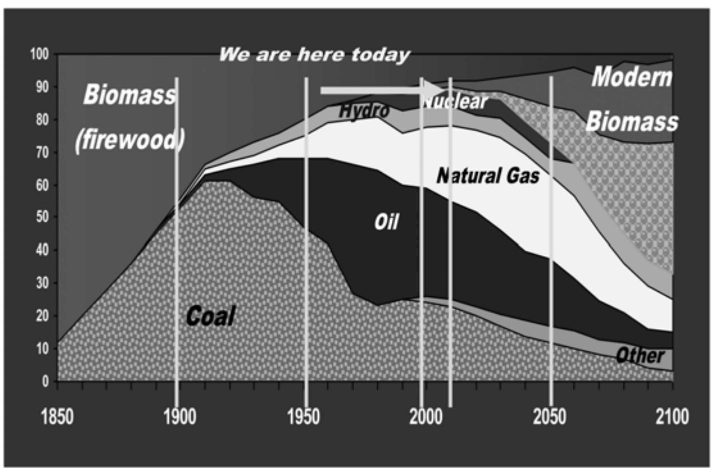
Biofuel	Cost at filling station (€) 2004 / 1000 l			
	Feedstock	Biofuel	Fossil fuel	Difference
Bio-ethanol				
	Sugar crops	1265	366*	899
	Starch crops	1173	366*	807
	Lignocellulosic crops	1448	366*	1082
	Lignocellulosic residues	1316	366*	950
	Brazilian sugarcane	294	366*	-72
Biodiesel				
	Oil seeds	945	386**	559
	Used oil/fat	454	386**	68

(Source: Ryan et al. 2005)

* Petrol price
** Diesel price

The conflict biofuel-versus-fossil fuel can also be further discussed by looking at the energy needs of humankind. Figure 5-4 shows the way the energy needs of humankind are fulfilled during the years. Figure 5-4 confirms the fact that biofuels are at the moment in the beginning of their development. Until 1910 coal was the only real dominant source of energy. Today oil is the leading source, while gas will take over the leading position. In future biomass, nuclear and other renewables are the remaining sources. The expectations are that biofuels will play in the future a very important role in the energy supply.

Figure 5-4: Dominant energy in the period 1850-2100.



(Source: Nakicenovic et al. 1998)

It is unclear whether the biofuels will consist solely out of first/second generation or a combination of these two. The report "Eyes on the track, Mind on the horizon" (2008) has made some predictions about the composition. The predictions are based on several perspectives, each focusing on different aspects, such as the reduction of greenhouse gasses, biodiversity and agriculture. The balance predicted in the year 2030 shows a 5%-38% for 1st generation biofuels and a 62%-95% range for the 2nd generation biofuels. The report explains these predictions by showing the advantages of 2nd generation biofuels on 1st generation. These advantages are the lower emission of greenhouse gasses and a better land efficiency.[32]

'The timing of the deployment of these second-generation technologies on a large scale is uncertain' (Childs and Bradley 2007). As of late 2007, there were nine demonstration plants in the world, with an estimated production capacity of about 12 million litres per year. Although none of these is a commercial-scale plant, a large number of other plants are under development, and the results of their performance will be an important indicator of the scope for more innovative and better-performing biofuels' (ICTSD, 2008). Although advanced generation biofuels are not yet commercially available the EU expects second generation biofuels to become

[32] Higher average biofuels yields per hectare.

commercially available between 2010 and 2015. Moreover it is predicted that this generation will make up a considerable share of total biofuel supply by then. This is stated by the EU Directive on Renewable Energy (OECD, 2008).

5.7. Market developments

The success of biofuels 'will depend on how far it is possible to change today's production of goods and services gradually from fossil to biological raw materials. The re-arrangement of whole economies to biological raw materials as a source for increased value requires completely new approaches in research and development. On the one hand, biological and chemical sciences will play a leading role in the generation of future industries in the twenty-first century. On the other hand, new synergies between biological, physical, chemical and technical sciences have to be elaborated and established. This will be combined with new traffic technologies, media and information technologies and economic and social sciences' (Kamm and Kamm, 2003).
The main market developments will be discussed below, these are: public policies and technological developments (OECD-FAO, 2009 and Meeusen, 2009).

5.7.1. Public policies

Public policies are about biofuel promotion and the stimulation of biofuel demand. More and more countries, including developing countries, are implementing policies 'as concerns about the security of energy supply and climate change are moving into the focus of policy makers. […] Biofuel promotion policies have led to substantially increased production in several countries […] promotion measures are required for stimulating demand' (Peters and Thielmann, 2008), because biofuels are usually not competitive with fossil fuels.
Yes, it is expected that biofuels demand will keep on rising. It is also expected that the demand for transportation fuel will grow. Even though the total use of transport fuel could lower due to more efficient vehicles and/or lower vehicle travel (IEA, 2004).

5.7.2. Technological developments

Technological developments are about the advances in research and development concerning biofuels and its use. This relates to the type of feedstock used, conversion technologies and end use (vehicle, engine and fuel specifications).

'[W]hen considering a long-term perspective, new biofuel production systems need to be developed because several of the 'first generation' biofuels, such as ethanol from wheat and corn and biodiesel from rape seed, have limitations regarding their resource efficiency' (Börjesson and Mattiasson, 2007). However, successful development of advanced biofuel is not yet guaranteed; 'how and when commercial scale-up can be realized is the key question' (IEA, 2008).
Expectations are that in the near future potential technological breakthroughs are under way <www.mongabay.com>. These breakthroughs 'could steadily reduce the economic cost and environmental impacts of biofuel production' (Coyle, 2007). 'Biotechnology may also determine the future role of biofuels […] Advances in plant genomics could lead to the production of higher yielding biofuel crops, reducing both land requirement and energy input, which may reduce land-use conflicts and GHG emissions […], although lower production costs may also enable greater penetration of the transportation fuel market, which may in turn increase biofuel demand and the amount of agricultural land required to grow biofuel crops […]. Biofuel crops may also be genetically engineered to be more resistant to pests, diseases, or abiotic stresses (e.g., drought), which would insure a stable supply of feedstock […]. Furthermore, dedicated biofuel crops may be genetically modified to grow faster, have lower lignin content, or even contain cellulases within the crop biomass itself in order to enhance the efficiency of cellulosic ethanol production' (Pin Koh and Ghazoul, 2008).
Not only current feedstock could be improved in the future, other new feedstock will be researched and maybe even used for the production of biofuels, such as 'biodiesel out e.g. jatropha, coconut, tangle and algae' (De Nie and Blom, 2008).

5.8. Conclusion

The biofuels market is a free market (as all parties are free to get an bring their products) and a complex and dynamic one (due to the volatility of raw material prices). The market itself is at the beginning of commercial development. At present governments coordinate the market by targets and regulations.
Three major players are the leaders in the market of production and consumption, namely: the US, the EU and Brazil. In the years to come biofuels are expected to increase enormously in supply. At the moment the biofuels market, with its many active stakeholders, is developing on a global scale. There are multiple opportunities for companies to meet potential business partners and/or other stakeholders.

Worldwide countries try to secure their national energy supply. There are also many countries trying to reduce the emission of greenhouse gasses. Countries introduce different trade tariffs to protect the nation from foreign competitive biofuels and/or feedstock, which could otherwise reduce national employment and investments in biofuels. Import tariffs limit the trade in biofuels. Besides import tariffs, countries also protect themselves by setting up discriminating standards, which also limits international trade and it also biases a country's national production.
The current situation is that total production is higher than the total use of biofuels on a global scale. In order to achieve an increase in worldwide trade it would be beneficial to abolish tariffs and discriminating standards. A probable proposition is the Biopact, that would end discriminatory standards and would dismantle tariffs and subsidies.

Tariffs limit (or possibly even stagnate) the progression of the biofuel market. Issues, such as food-versus-fuel, biofuel-versus-fossil fuel and land use, are current challenging topics to overcome. The expectations are that a large amount of problems relate to the first generation biofuels could possibly be solved by the launch of advanced biofuels onto the market. With the exception of Brazilian ethanol, total prices of biofuels are not competitive compared to fossil fuel prices.
The expectations are that a large amount of problems relate to the first generation biofuels. These possibly could be solved when second generation biofuels become commercially available on the market. First of all, this generation could relief the stress on food prices and it could become an interesting substitute for fossil fuels. Calculations on the future that are set out in the report "Eyes on the track, Mind on the horizon" (2008) points out that in 2030 second generation biofuels will make up a share between 62%-95% of the total existing biofuels. This implies that the future of the market will rely for a large part on the development and introduction of future generations of biofuels.

6. Conclusion

This research has been an explorative study that examined the global market of transport biofuels. The aim was to provide insights on transport biofuels' current market situation and the expectations for the near future. The main focus was on the EU, US and Brazil as these three regions are representative for the global market. Moreover, they are the three global leaders concerning production, consumption, and development of and regulations on the transport biofuel market.
This research has set out to answer the following (explorative) question: *"Does the transport biofuel market, at its current subsidized state, have a future in the form of a self-regulated market?"* The main question is supported by four sub questions. Below the sub questions will be discussed, followed by an answer on the main question.

Sub questions

- What is the current situation of the transport biofuel market?

The transport biofuel market can be characterized as a market in its beginning commercial phase. The market is continuously developing. It is a free market, but also a complex and dynamic one.
Governments steer the market by setting specific minimum biofuel consumption and production targets and by encouraging businesses to produce and develop biofuels. The main goals are to secure national energy supply and to reduce emission of greenhouse gasses.

The specific targets of the three biggest global players -the EU, US and Brazil- are the following:

- The EU has set specific consumption targets for biofuels calculated on the basis of energy content related to all petrol and diesel for transport purposes placed on the market. The targets concern a market consumption share of 5.75% in 2010 and 10% in 2020. It is not likely that these targets will be achieved.
- The US has set production targets for the production of specific amounts of renewable fuels, includes biofuels. The targets set a minimum renewable fuel production of 30.9134 billion of liters by the year 2010 and 163.659 billion in 2022. It is not clear whether these targets will be achieved.
- Brazil has only set a specific target for the consumption of biodiesel, namely a share of 5% that has to be achieved by 2013. Projected is that this will already be achieved in 2010.

The transport biofuel market has several issues which are a result of the present production of commercially available biofuels. First of all, there are numerous coordination problems. Secondly, there are conflicts with the market of food ("food-versus-fuel") and the market of fossil fuels ("biofuel-versus fossil fuel"). Thirdly, there are environmental conflicts resulting from the production of feedstock, these are issues related to water scarcity, land use and deforestation. The governments attempt to solve these issues by the support of different institutions. It is expected that advanced biofuels will overcome the conflicts, as the become commercially available. It can be concluded that at the moment the market has a lot of issues to deal with. At the same time it is expected that these issues will be solved when advanced biofuels will become commercially available, which is expected to be between 2010 and 2015.

- Is it profitable to supply transport biofuels?

Considering total production costs of biofuels as an end product, without benefitting from any economic benefits from the government, it is not profitable to supply any type of transport biofuel. The only exception on this is bio-ehtanol of Brazilian sugarcane.
As biofuels are possible substitutes for fossil fuels, prices should be lower than the fossil fuels in order to be competitive (and to derive more potential purchases). Currently this is not the case and this accounts to both bio-ethanol and biodiesel, where the latter has generally higher total production costs. Nevertheless, both biofuels are available and are entering increasingly onto the market. Reasons for this is that governments provide different subsidies and economic benefits to stimulate and make supply of it possible.
The above merely indicates that the end price of most biofuels are not profitable solely based upon costs compared to fossil fuels. This, does not indicate that there is no profit made at all by any actor within the supply chain, possibly even without any governmental economic benefits. This research, however, focused on the end-product.

- **What is the demand for liquid transport biofuels and where does it come from?**

Exact details on demand, defined as the consumers' collective financial ability and desire to purchase goods, are not provided for within the literature. The general picture is that a different definition is given to the term demand and that it is usually defined by either "equal to supply", "equal to production" or as "total use". Whatever definition used, total demand (in the form of bio-ethanol and biodiesel) appears to be largely driven by policies. Demand for biofuels is actually artificially created as biofuel are mainly pushed on the market by the governments with the use of different instruments. EU policies, for example set minimums of consumption totals.

At present there is some customer resistance. This is because most of the traditional biofuels do not match up with the required demand. This is related to one or more of the following factors: usability, reliability of fuel quality, related environmental benefits, and total costs. To encourage demand it is important to create customer acceptance. The expectations are that advanced biofuels have good potentials for this. Compared to most types of first generation biofuels, they will be superior in matching with one or more of the mentioned, demanded requirements of end consumers.

- **How is the transport biofuel market regulated?**

The biofuels market is coordinated by the government, which is done by the use of regulations related to production/consumption of the products. The governments apply one or more of the following existing instruments:

- Consumption/production targets
  The three regions, touched upon within this thesis, have each set individual targets. The EU has set consumption targets for biofuels, the US has set production targets for renewable fuels and Brazil has set a target for biodiesel consumption.
- Taxation and subsidies
  Tax exemption are e.g. used by to make the introduction of biofuels much easier and this applied by countries like Germany and Sweden within the EU. Another example is the Common Agricultural Policy, which includes subsidies being used in the EU to support farmers to produce feedstock for the biofuel industry.
- Trade policies
  - Tariffs
    Different rules and tariffs affect the international trade making developing countries lose their comparative advantage.
  - Non-tariffs
    In the form of, e.g. discriminatory tariffs like the biodiesel-standard EN14214 from the EU, favouring the EU with the production of biodiesel.
- Blends with fossil fuels
  In most Member States of the EU, diesel includes biodiesel in low blends.

Main question

- **Does the transport biofuel market, at its current subsidized state, have a future in the form of a self-regulated market?**

The above stated question demands an answer on a situation that will happen in future. Answers on such questions are generally an "either-or situation", as the outcome is uncertain. However, one can look at what variable(s) could possibly influence the future. This accounts also to the transport biofuel market. Key for the future of transport biofuel market is research and development. Consequently, its future depends highly on developments within the biofuel industry. The answer on the main question will be provided in the form of two possibilities, namely: 1) "the biofuel market, at its current subsidized state, will less likely have a future in the form of a self-regulated market" and 2) "the biofuel market, at its current subsidized there, will most likely have a future in the form of a self-regulated market". Whether a self-regulated transport biofuel market is probable, considering the current subsidized state, depends mainly on the development of demand and profitability of the product. Aspects related to this are relevant to both possible outcomes set out below.

Possible "less likely future" outcome:

The transport biofuel market, at its current subsidized state, will less likely have a future in the form of a self-regulated market when one, or all, of the following development takes place:

- The majority of the consumers will keep on rejecting to use biofuels as a transport fuel. Number of vehicles are increasing worldwide, but as long as most users do not desire to purchase and use biofuels, total demand will remain rather low. This issue is to some extent related to the following point.
- Current conflicts with the fuel versus food markets will not be solved. As first generation biofuels make use of feedstock of edible crops it is generally believed ("assumed to be", as real proof is lacking) that biofuel production is a major driver of food prices. This limits the development of the biofuel market. Biofuels of advanced generation, yet to be developed, are expected to solve this issue by applying technologies that makes the production of biofuels from non-edible crops possible.
- Production costs will not reduce and therefore there will be no change of the disadvantageous competitive position of biofuels compared to fossil fuels. Currently production costs of biofuels are higher than those of fossil fuels. Biofuels of advanced generations, yet to be developed, are expected to solve this issue.
- The expected product launch of any of the second and subsequent generation biofuels, as a commercial product on the market, will either never happen, or be postponed for too long a time period resulting in a strategically weak introduction compared to other (then) existing possible substitute products.
  Compared to first generation it is predicted that advanced biofuels will possess superior characteristics and will have a better competitive position with relation to substitute products like fossil fuels. A delay or a cancellation of advanced biofuels will make it very complex, if not impossible, to compete with substitute products such as fossil fuels (and other possibly newly developed renewable energy sources).

Possible "more likely future" outcome:

The transport biofuel market, at its current subsidized state, will more likely have a future in the form of a self-regulated market when one, or all, of the following developments takes place:

- Customer resistance is overcome. Biofuels should meet required demand in the form of one or more the following factors; usability, reliability of fuel quality, environmental benefits and the end price. Advanced biofuels, could by research and development and new chemical and biological routes, lead to a product that will meet these requirements.
- Current conflicts with the fuel versus food markets will be solved. Biofuels of advanced generation are expected to solve this as they are to be produced from using residual non-food parts of crops. Technologies are being developed and several technologies already exist to realize this but has yet to be applied on a commercial scale.
- Researched and (newly) developed production techniques are actually commercially implemented and applied. The application of most of the newly developed techniques depends on the commercial value and on the industry learning process' pace in order to reduce costs of deployed techniques. New production techniques could possibly lower total costs and improve the growth and conversion of feedstock.
- Advanced generations become commercially available. Compared to first generation it is predicted that advanced biofuels will possess superior characteristics and will have a better competitive position. Examples of superior characteristics are the ease of application, quality of the fuel and more environmental benefits.
- End prices of competitive substitute product, like fossil fuels, rise above total production costs of biofuels. This could possibly increase the total biofuel demand as a result of a better competitive position in the transport fuel market. In addition, this situation could eventually lead to a cancellation of governmental subsidies as they will not be required anymore.

The division of the answer is not strong enough to state that there is only a choice between a definite either a less likely future, or a more likely future (referring to an either-or situation). An answer in the form of a combination of different aspects of the less and more likely outcome is also possible. As mentioned before, reasoning behind this is that the provided answers are rather indicative as a definite outcome is truly unknown.

7. Limitations and further research

The outcome of the main question depends mainly on the issues of biofuel supply and supply related policies. This is because of the large influences on the profitability for companies to supply (new) biofuel types and total (reduction of) production costs. Therefore, information provided on supply could be considered as an essential part. Basically, it could be stated that when it is profitable to supply biofuels it could be quite likely that more (types) will be launched onto the market. However, not every possible aspect is discussed on the supply of biofuels. Especially the following aspects are to be considered limitations for this research.

Firstly, a thorough analysis on the influence of economic benefits on total production costs of biofuel is lacking. Within the thesis it is stated that production costs consist mainly out of costs related to raw material, storage, processing (i.e. conversion), capital investments, transportation and distribution. It is further mentioned that methodologies applied by the different studies providing details on these costs are not necessarily similar, which makes a comparison rather complex. This complexity is compounded by the involvement of economic benefits. Economic benefits exist in various forms, a few examples: tax cuts, tax incentives, direct subsidies for investments (in e.g. conversion facilities and feedstock plantation) and direct subsidies through price support (to reduce prices in order to make the product competitive with substitutes).

The benefits could influence the production costs in such a way that costs are reduced. A further research could analyse e.g. what effect it has on the studies reviewed by this thesis and other and/or the effects of subsidies within the entire supply chain.

Secondly, (possible) limitation is the issue whether the potential to produce traditional and/or advanced biofuels is high enough. Considering a total replacement of fossil fuel demand it could be questionable whether there is a sufficient amount of land available and/or waste to produce the demanded quantity. There are several studies discussing these issues. A further research could draw attention to this.

Thirdly, profitability of other actors within the supply chain, next to that of the end user, are not taken into consideration. The thesis paid specific attention on the profitability of the biofuels as an end product (or at least on the competiveness with substitutes by terms of total production costs). A further research could possibly answer how profitable it is to supply biofuels for all the actors active within the biofuel supply chain. This could be of interest especially concerning the fact that it is a at present a trend that companies decide to vertically integrate.

Fourthly, profitability is merely discussed in terms of capital. Further research could be conducted to find out what the impact is of the production and use of biofuels in terms of social costs.

Fifthly, not much attention is given to other developing countries in the biofuels industry. The three regions discussed in our thesis are the largest and most important ones at the moment, but the other countries are developing as well. Perhaps further research can bring interesting facts to light.

Sixthly, the regulations of the US and Brazil are briefly discussed, further research is required.

Seventhly, subsidies and taxes are briefly discussed within the thesis. Only a few examples are provided for within this thesis. Further research could be beneficial to find out the precise impact of these two instruments. not the impact on the biofuel supply chain is supposed

Finally, it has not been research to what extent there is market uncertainty for firms to conduct research and development of new technologies. It could be of interest to further research what influence governments have on this issues related to biofuels in order to speed up market R&D developments. Usually it is the case that a higher uncertain market leads to delayed investments. Value of waiting could become higher by learning from industrial process conducted by other firms.

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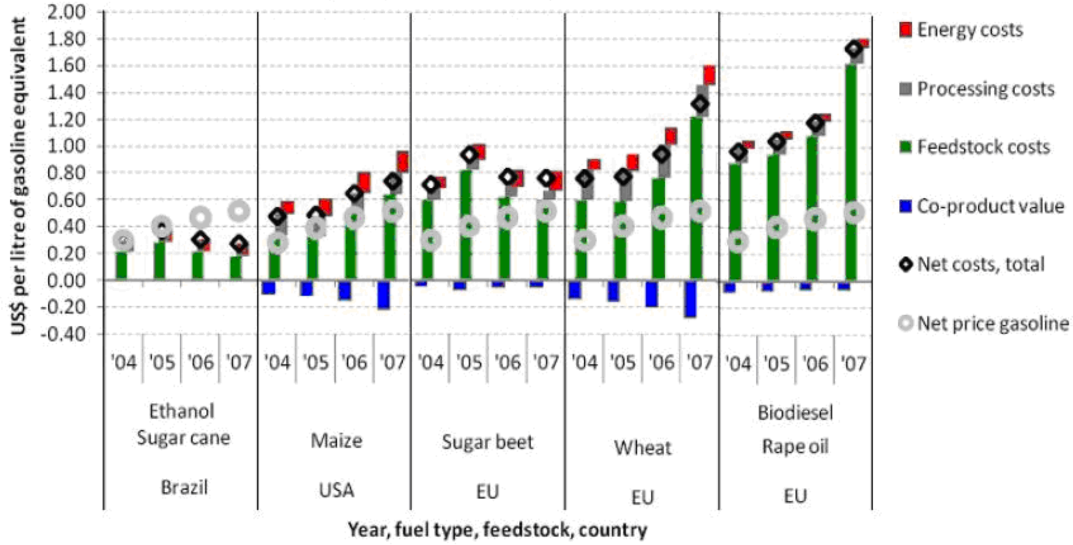
Appendix A Production costs 1st generation

Figure A-1: Production costs of 1st – generation biofuels 2004-2007.



(Source: IEA, 2008)

According to this study, it is theoretically stated that feedstock costs range between 55%-70%. These feedstock commodity prices are assumed to be subjected to subsidies, the level of conventional oil prices, increased demand for food commodities, declines in crop yield due to climate impacts, energy prices, possibly speculative trading, export restriction in several countries and the deprecation of the US dollar. However, the exact relation and impact of the factors is not explained.

The cost-range theoretically stated is in contrast with the numbers of the provided figure of the same institute, see the tables below. Six rows are given, namely: co-product value, feedstock costs, processing costs, energy costs, net costs, total and net price gasoline. One row is added in order to confirm on the given cost-range. A simple calculation shows, however, that costs range between 66%-93% for ethanol and 90%-93% for biodiesel. This is rather confusing and questions the reliability of the study.

Table A-1: Cost breakdown for Brazilian ethanol (based on sugar cane) and US ethanol (based on maize), period 2004-2007.

	Brazil Sugar cane Ethanol				**US Maize Ethanol**			
Cost breakdown	**'04**	**'05**	**'06**	**'07**	**'04**	**'05**	**'06**	**'07**
Co-product value					-0.108	-0.121	-0.156	-0.224
Feedstock costs	0.211	0.279	0.210	0.180	0.336	0.324	0.488	0.637
Processing costs	0.080	0.088	0.089	0.089	0.153	0.153	0.162	0.157
Energy costs					0.093	0.128	0.150	0.165
Net costs, total	**0.291**	**0.368**	**0.299**	**0.269**	**0.474**	**0.483**	**0.644**	**0.736**
Net price gasoline	**0.293**	**0.396**	**0.465**	**0.512**	**0.276**	**0.386**	**0.465**	**0.512**
% Feedstock costs	0.726	0.760	0.702	0.668	0.710	0.670	0.758	0.866
Net costs - net price gas	-0.002	- 0.028	- 0.166	- 0.243	0.197	0.097	0.179	0.224

(Source: Own elaboration and adapted from http://www.sourceoecd.org/9789264045903, accessed on 13/06/2009)

Table A-2: Cost breakdown for EU biodiesel (based on rape oil) and EU ethanol (based on sugar beet), period 2004-2007.

	EU Rape oil Biodiesel				**EU Sugar beet Ethanol**			
Cost breakdown	**'04**	**'05**	**'06**	**'07**	**'04**	**'05**	**'06**	**'07**
Co-product value	-0.082	-0.074	-0.069	-0.068	-0.055	-0.077	-0.058	-0.055
Feedstock costs	0.879	0.948	1.080	1.621	0.593	0.824	0.625	0.597
Processing costs	0.113	0.111	0.110	0.117	0.088	0.072	0.065	0.067
Energy costs	0.057	0.058	0.060	0.065	0.085	0.116	0.136	0.150
Net costs, total	**0.967**	**1.043**	**1.180**	**1.735**	**0.711**	**0.935**	**0.768**	**0.759**
Net price gasoline	**0.293**	**0.396**	**0.466**	**0.512**	**0.293**	**0.396**	**0.466**	**0.512**
% Feedstock costs	0.909	0.909	0.915	0.934	0.833	0.881	0.814	0.787
Net costs - net price gas	0.674	0.647	0.715	1.223	0.418	0.538	0.302	0.247

(Source: Own elaboration and adapted from http://www.sourceoecd.org/9789264045903, accessed on 13/06/2009)

Table A-3: Cost breakdown for EU ethanol (based on wheat), period 2004-2007.

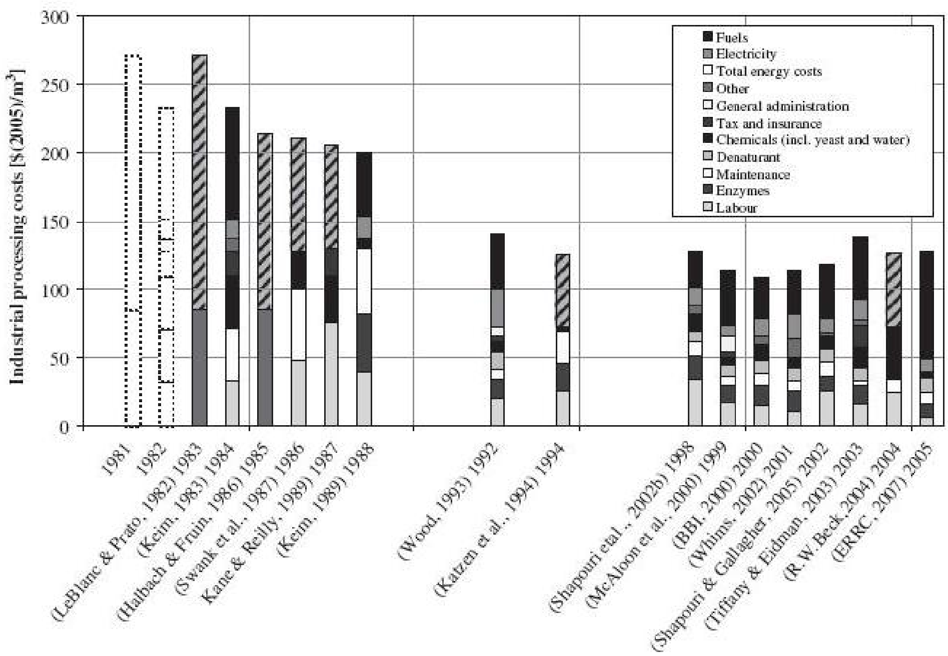
	EU Wheat Ethanol			
Cost breakdown	**'04**	**'05**	**'06**	**'07**
Co-product value	-0.147	-0.162	-0.204	-0.286
Feedstock costs	0.597	0.589	0.760	1.215
Processing costs	0.221	0.228	0.245	0.236
Energy costs	0.085	0.115	0.135	0.149
Net costs, total	**0.756**	**0.770**	**0.936**	**1.314**
Net price gasoline	**0.293**	**0.396**	**0.466**	**0.512**
% Feedstock costs	0.790	0.765	0.811	0.925
Net costs - net price gas	0.463	0.374	0.471	0.801

(Source: Own elaboration and adapted from http://www.sourceoecd.org/9789264045903, accessed on 13/06/2009)

Appendix B US Ethanol Production costs –industrial developments

The following figure presents the industrial developments. The processing costs are categorized into different categories, namely: general farm overhead, custom operations, repairs, labour, chemicals, seed, fuel, lube and electricity, fertilizer, taxes, insurance and land rent and capital recovery including interest. The 'processing costs mainly include costs for energy, enzymes, labour, maintenance and chemicals. Costs for corn and capital are not assessed in this section.

Figure B-1: Breakdown of ethanol processing costs between 1980 and 2005. Engineering studies of 1981 and 1982 are assumed to represent actual costs for 1983 and 1984. Note that different studies use different cost structures (LeBlanc and Prato, 1983; Keim, 1983; Halbach and Fruin, 1986; Swank et al. 1987; Kane and Reilly, 1989; Keim, 1989; Wood, 1993; Katzen et al. 1994 Shapouri et al. 2002b; McAloon et al. 2000; BBI, 2000; Whims, 2002; Shapouri and Gallagher, 2005; Tiffany and Eidman, 2003; Beck, 2004; ERRC, 2007).



(Source: Hettinga et al., 2008)

Appendix C EU&US biodiesel costs and overview of 1993-2010 of several studies

Table C-1: EU&US biodiesel costs review on various studies.

Year	**Author**	**Reference**	**Country**	**Feedstock**	**Total production cost /litres**
1993	Weber	Bender (1999)	Nav	Soybean	$0.30
				Canola	$0.40
				Sunflowers	$0.63
				animal fats	$0.44
1993	Nelson & Schrock	Bender (1999)	US	animal fats small industry	$0.37
				animal fats large industry	$0.32
1993	Reed	Bender (1999)	US	waste grease	$0.26
				waste grease impure	$0.34 - 0.42
1994	American Biofuels Association and Information Resources	Bender (1999)	US+EU	vegetable oil	$0.54 - 0.62
1994	American Biofuels Association and Information Resources	Haas (2005)		Soybean	$0.70
1995	National Renewable Energy Laboratory	Bender (1999)		biodiesel US small markets	$0.79
				waste grease	$0.38
1996	National Renewable Energy Laboratory	Bender (1999)		Soybean	$1.00
				waste grease (NOPEC)	$0.53
				soybean (forecast)	$0.66
1996	Noordam and Withers	Bender (1999)	US	Rapeseed	$0.69
1998	Graboski and McCormick	Haas (2005)	Nav	Nav	$0.57
1999	Bender (Europe+US)			oilseeds/animal fats	$0.30 - $0.69
				vegetable oil	$0.54 - $0.62
				waste grease	$0.34 - $0.42
2001	Canakci & van Gerpen	Sharma et al. (2008)	nav	Soybean	$0.42
2002	Coltrain (US)			soy bean	$0.48 - $0.73
2003	Zhang (2003)	Sharma et al. (2008)	nav	Biodiesel	$0.50
2004	Ryan et al (2006)		EU -15	oil seeds	€0.945
			EU -15	used oil/fat	€0.454
2004/2005	Nas and Berktay (2007)	Sharma et al. (2008)		Soybean	$1.41
				yellow grease	$2.54
2004	OECD agricultural outlook (2008)	OECD-FAO (2008)	EU	Rapeseed	€ 0.97
2005	OECD agricultural outlook (2008)	OECD-FAO (2008)	EU	Rapeseed	€ 1.04
2005	Haas (2005)			Soybean	$0.53
2005	Pimentel (2005)		USA	Soybean	$0.84
			USA	Sunflower	$1.53
2006	Randelli (2008)		USA	oil seeds	$0.69
			EU-15	oil seeds	$0.66
2006	OECD agricultural outlook	OECD-FAO	EU	Rapeseed	€ 1.18

	(2008)	(2008)			
2007	OECD agricultural outlook (2008)	OECD-FAO (2008)	EU	Rapeseed	€ 1.74
2010	Ryan et al. (2006)			Oilseeds	€0.888
				Used oil/fat	€0.395

(Source: Own elaboration, primarily based upon Bender (1999), Sharma et al. (2008) and various OECD-FAO studies)

The above table indicates that there are many different costs prices given on the different types of feedstock used throughout the years. Prices differ from each other. The exact reason for this is most often not clear as studies use different cost calculation methods. Moreover, the details on costs are neither always clear. As opposed to the chapter currencies are here not converted, information is provided as-it-is.

Appendix D Progress in the use of biofuels in the Member States, 2003-2005

Table D-1: Progress in the use of biofuels in the Member States, 2003-2005.

Member State	Biofuel share 2003 (%)	Biofuel share 2004 (%)	Biofuel share 2005 (%)	National indicative target 2005 (%)
Austria	0.06	0.06	0.93	2.50
Belgium	0.00	0.00	0.00	2.00
Cyprus	0.00	0.00	0.00	1.00
Czech Republic	1.09	1.00	0.05	3.7024
Denmark	0.00	0.00	no data	0.10
Estonia	0.00	0.00	0.00	2.00
Finland	0.11	0.11	no data	0.10
France	0.67	0.67	0.97	2.00
Germany	**1.21**	**1.72**	**3.75**	**2.00**
Greece	0.00	0.00	no data	0.70
Hungary	0.00	0.00	0.07	0.60
Ireland	0.00	0.00	0.05	0.06
Italy	0.50	0.50	0.51	1.00
Latvia	0.22	0.07	0.33	2.00
Lithuania	0.00	0.02	0.72	2.00
Luxembourg	0.00	0.02	0.02	0.00
Malta	0.02	0.10	0.52	0.30
The Netherlands	0.03	0.01	0.02	2.0025
Poland	0.49	0.30	0.48	0.50
Portugal	0.00	0.00	0.00	2.00
Slovakia	0.14	0.15	no data	2.00
Slovenia	0.00	0.06	0.35	0.65
Spain	0.35	0.38	0.44	2.00
Sweden	**1.32**	**2.28**	**2.23**	**3.00**
UK	0.02626	0.04	0.18	0.1927
EU25	0.50%	0.70%	1.0% (estimate)	1.40%

(Source: Biofuels Progress Report, 2007)

Only the countries Sweden and Germany were able to achieve the target value of 2%. For practical reasons they are presented by a bold lettertype in the table above.

Appendix E National indicative targets for the share of biofuels, 2006-2010

Table E-1: National indicative targets for the share of biofuels, 2006-2010.

%	2006	2007	2008	2009	2010
Austria	2.50	4.30	5.75	5.75	5.75
Belgium	2.75	3.50	4.25	5.00	5.75
Cyprus					
Czech Republic	1.78	1.63	2.45	2.71	3.27
Denmark	0.10				
Estonia	2.00				5.75
Finland					
France			5.75		7.00
Germany	2.00				5.75
Greece	2.50	3.00	4.00	5.00	5.75
Hungary					5.75
Ireland	1.14	1.75	2.24		
Italy	2.00	2.00	3.00	4.00	5.00
Latvia	2.75	3.50	4.25	5.00	5.75
Lithuania					5.75
Luxembourg	2.75				5.75
Malta					
The Netherlands	2.00	2.00			5.75
Poland	1.50	2.30	28	29	5.75
Portugal	2.00	3.00	5.75	5.75	5.75
Slovakia	2.50	3.20	4.00	4.90	5.75
Slovenia	1.20	2.00	3.00	4.00	5.00
Spain					
Sweden					5.75
UK			2.0030	2.8031	3.5032
EU					5.4533

(Source: Biofuels Progress Report, 2007)

Appendix F Share of renewables in 2005 and share of renewables required by 2020

Table F-1: Share of renewables in 2005 and share of renewables required by 2020.

Member State	Share of Renewables in 2005 (%)	Share renewables required by 2020 (%)
Austria	23.3	34
Belgium	2.2	13
Bulgaria	9.4	16
Cyprus	2.9	13
Czech Republic	6.1	13
Denmark	17	30
Estonia	18	25
Finland	28.5	38
France	10.3	23
Germany	5.8	18
Greece	6.9	18
Hungary	4.3	13
Ireland	3.1	16
Italy	5.2	17
Latvia	32.6	40
Lithuania	15	23
Luxembourg	0.9	11
Malta	0	10
The Netherlands	2.4	14
Poland	7.2	15
Portugal	20.5	31
Romania	17.8	24
Slovakia	6.7	14
Slovenia	16	25
Spain	8.7	20
Sweden	39.8	49
UK	1.3	15

(Source: Biofuels Progress Report, 2007)

Appendix G List of figures and tables

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Chapter 3

Chapter 4

Chapter 5

Appendix A

Appendix B

Appendix C

Appendix D

Appendix E

Appendix F