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Biofuels in the EU - a premature decision: Sustainability of the biofuel production for transportation in Europe

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Preface and Acknowledgements

I would like to express many thanks to my parents for their support and encouragements throughout my studies and writing this work. My special thanks to my father who gave me the idea and direction for my work.

I am grateful to my supervisor, Professor Hans Puxbaum, for his advice and guidance.

Contents

List of abbreviations

EU	European Union
Toe	Tonne of oil equivalent unit
UK	United Kingdom
US	United States of America

Abstract

This work examines different aspects the current use of biofuels in the EU transportation sector. It focuses on the sustainability aspects and examines different influences, which biofuels have on the humankind, nature and the environment. The production process of biofuels has several effects on sustainable future of the mankind such as the increase of food prices, deforestation or depletion of the ozone layer.

In addition, biofuels have proven to be not greenhouse-gas neutral, as it was claimed at the beginning of their production. There are three main groups of factors which have influence on the greenhouse-gas emissions of biofuels: indirect land use change, use of fertilizers and other factors. When all these factors are considered in the Lifecycle analysis, the greenhouse-gas emissions of biofuels are approximately 245 per cent higher than emissions of fossil fuels.

1 Introduction

Every day, transportation plays a crucial role in lives of all citizens of the European Union (EU) even when they are not owners of a car or use public transportation. Transportation is affecting their lives from morning till evening. Coffee they drink, bread they eat, television they watch or hot water in their bathtub caries traces of transportation. The entire production process of these goods depends on transportation of supplies from producer to a factory, goods from the factory continue further until they reach consumers. Every good went through its own journey during the transportation process. Every product has its own carbon footprint which has effect on the environment, the future of the current generation and future of the next generations. Nowadays, 13 per cent of greenhouse-gas emissions are produced in the transportation sector and transportation is responsible for 23 per cent of CO2 emissions produced globally. Transportation is the fastest developing sector and the percentage of CO2 emissions represented by transportation are estimated to increase by 57 per cent in the period from 2005 to 2030. (Ricardson, et al., 2011) This will further increase the impact of transportation on planet Earth and accelerate the effects of climate change.

From the end of the 1970s, the climate change has been recognized as a serious threat to the planet Earth and development in recent years has revealed more scientific evidence that climate of the planet is changing much faster than ever before. It is believed, that no action, even the most radical one, will not stop climate change and these changes to the climate are claimed to be irreversible. Nowadays, discussion is not about whether it is possible to stop or reverse climate change but how to slow down the process of climate change and mitigate its impact on the planet. The change of climate will include lives of every human being on the planet. Climate change has an impact on animals as well as plants. The increasing possibility of droughts and floods will destroy tones of agricultural crops and lead to decrease of agricultural production. Impact of climate change is already clearly noticeable. In the north, we can observe melting of Antarctica. 'Antarctica has been losing more than hundred cubic kilometres I(24 cubic miles) of ice each year since 2002.'(Conway, 2010). In the south, desertification of land is spreading as a consequence of severe droughts. Moreover, the loss of biodiversity is the problem threatening the whole planet. Some life forms are more vulnerable to a climate change than others. However, the loss of one form of life can easily lead to extinction of other organisms or the entire ecosystem because they are often co-dependent. Many ecosystems are highly vulnerable to a change and may be easily irreversibly destroyed.

It is general consensus in the scientific community that Climate change is caused by increase anthropogenic activities which leaded to increase of greenhouse-gases in the atmosphere. The greenhouse gases include water vapour, ozone, carbon dioxide CO2, nitrous dioxide (N2O) and methane (CH4). (Withgott, et al., 2010) The most significant attention is currently paid to CO2 emissions. The CO2 emissions represent a significant increase from the beginning of the 19th century. The increase is caused by industrialization of the production of goods and increased use of fossil fuels in the production process. The figure 1.1 shows steep increase of the CO2 emissions after the industrial revolution as well as increase of global average temperature. The greenhouse-gas emissions have to be managed in a sustainable way in order to mitigate the consequences of further climate change. (Lyon, 2008)

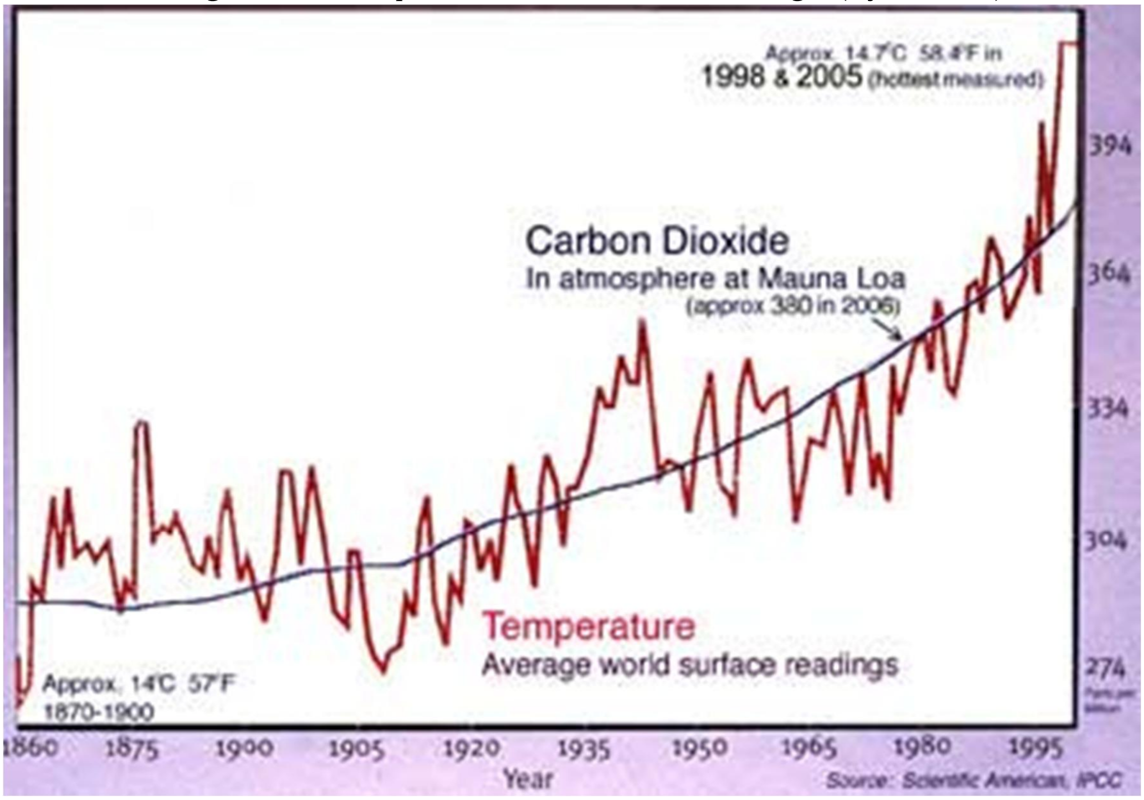


Figure 1-1 Global average temperature and the CO_2 emissions (Lyon, 2008)

1.1 Sustainability

For the first time, the concept of sustainable development was used in the 1987 report of the World Commission on Environment and Development also called the Brundtland Commission. In the Brundtland report was introduced the first definition of the term sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs.’ (World Commission on Environment and Development, 1987) According to this definition, the development has limits based on environmental capacity and current generation have to use resources in consideration with needs of future generation. Since the 1980s, governments of different counties all over the world started to use the term sustainable development in their development policy paper. In addition, states have experienced more pressure from development assistance agencies and various NGOs to use their natural resources in a sustainable manner.

However, the concept of sustainable development was introduced before by scholars and statesman such as Malthus, Roosevelt or Pigou. Malthus believed that the planet has only limited capacity of production and that it will not be able to produce enough food in the future. There are limits on availability of agricultural land, and it will not be able to satisfy the demand for food in the future. The use of crops in order to gain energy would be unthinkable at that time. In 1909, the president of the United States Theodore Roosevelt wrote into the invitation for the North American Conference to the prime minister of Canada and the president of Mexico that ‘It is evident that natural resources are not limited by the boundary lines which separate nations.’(quoted by Pearson, p. 472). This statement was a significant step forward because Roosevelt had officially recognized limits of environment and responsibility for environmental protection shared between different states. In 1970s, Erick Eckholm moved the debate about sustainable development away from developed countries. As a consequence of the first oil crises, energy prices increased, and led to an increase of population growth, which improves of sanitation in developing countries. However, the reduction of mortality rate, as a result of improved sanitation system, increased demands of population for food and other resources in developing countries. According to Eckholm, this may lead to an agricultural crisis with devastating consequences. Furthermore, developing countries will be trapped in vicious circles where they need to improve their productivity in order to get more food supply which leads to deforestation, soil erosion and decrease of production.

Deforestation is one of the main consequences of unsustainable development in many countries. In most of the developed countries deforestation has undergone decades or even centuries ago and forest are representing only small part of their land. In contrast, in many developing countries are still preserved original rainforest, which are hundreds of years old. Rainforests such as Amazon are often called the lungs of the world and are one of the main sources of oxygen on the planet. Moreover, rainforests are also valuable as CO2 sinks, and they are also necessary for preservation of unique and sensitive ecosystem. As the proportion of rainforest on the planet is reduced every day, various ecosystem are disrupted, which leads to irreversible loss of diversity. The only way to reduce the impact of these practices is to create and enforce development policies, which contains elements of sustainable development in both developed and developing countries.

1.2 Methodology and assumptions

The paper examines the sustainability concept of biofuel production for the EU market. It uses the life cycle analysis method and evaluates the impact of production processes, products, side-products and pathways of life cycle of biofuel production in Europe as well as importing countries. It examines different research paper, books, official EU community papers and newspaper articles in order to obtain a full picture of the production. The research is done by quantitative research means and data comparison from different sources. The research is supported by demonstration of found data by a set of tables, figures and graphs which help to demonstrate the full picture and interdependence of certain factors on each other. The research has done the life cycle analysis on Well-to-Tank system, which takes into consideration different factors from the which have influence over the production of biofuels but does not further examines the use of biofuels in the combustion engines. The side-products of the biofuels produced during the use are mentioned, but their influence on the sustainability is not considered in the results.

Despite the fact, that research is the focus on the EU market it takes in to consideration emissions connected to production of fuel used in the EU marked despite the fact that some of these emissions were produced outside of the EU borders. Moreover, the sustainability concept acknowledges that environmental and sustainability problems caused by biofuels have global impact. Therefore, even when the emissions or other consequences of biofuels production are created in the EU these problems have sometimes trans-boundary character, and they can have an impact on other often less well-off regions due to these environmental problems which are often leading to economic impact on these regions.

1.3 Overview

The research discusses and examines the claim that the first generation biofuels which are currently used for transportation in the EU can be proclaimed as a sustainable alternative to fossil fuels. It focuses on the examination of several aspects of connected to the production and use of biofuels. The research exams biofuels direct effect on environment, human health and animal population. Furthermore, research exams indirect effects, which biofuels has on the environment as a consequence of their production and consumption which lead to release of greenhouse-gases in the atmosphere.

At first, the research is focused on examination of historical and legal development connected to the idea of biofuel used for transportation. The historical use of biofuels for transportation goes back to the beginning of the 20th century, and this idea was suppressed as an alternative fuel source after the end of the Second World War until the 1970s when the question of the alternative fuels source was open for discussion again. Afterwards, the first section discusses the legal bases for the EU level and the consequences for the member states. Secondly, the research presents different types of biofuels available for consumption based on different types of combustion engines. The different types of classifications of biofuels are listed later on in the research. The following section illustrates the current state of the EU biofuel market. The production focuses on the production needs in the EU and the necessary import from the other regions in the world. Forth section is focused on environmental effects of biofuel. It illustrates different impact and their consequences on nature, humans and environment in general. The next section examines the concept of greenhouse-gas neutrality of the production of the first generation of biofuels. It illustrates how different factors reduce the greenhouse-gas savings and dismisses the concept of greenhouse-gas neutrality of the first generation. Finally, the research different option illustrates how it is possible to achieve of greenhouse-gas reduction of the biofuels is used in transportation. It illustrates possible reduction of greenhouse-gas emissions of the first generation biofuels by using different production methods and it also present the reduction which can be achieved by the use of the second and third generation biofuels but also problems connected with their production.

2 Historical and legal development

2.1 Historical perspective

It is common believe that use of biofuels for transportation purposes is a new trend of the last four decades which was triggered by two main factors. On the one hand, 1970s oil crises had brought a large discussion about the necessity of decreasing independence on import from the Middle East. On the other hand, the rising awareness about climate change put pressure on politicians, producers and consumers to seek different fuel alternatives in order to reduce greenhouse gas emissions. Nevertheless, the history of biofuels use to power combustion engines reaches far back in the past. The idea to use biofuels as a supplement for fossil fuels was there almost from the beginning of the combustion engine production. The famous inventors, such as Rudolf Diesel and Henry Ford, saw biofuels potential to replace fossil fuels and believed that biofuels will be an essential part of fuel industry. Rudolf Diesel stated already in 1912 that '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.' (Wood, 2008) Henry Ford has expressed his faith in biofuels in 1925 during his interview for New York Times when he called bioethanol "the fuel of the future." (Kovarik, 1998)"

AUTO CLUB AROUSED OVER ALCOHOL BILL

Governors Will Request Senate to Remove the Duty.

SUBSTITUTE FOR GASOLINE

Manufacturers Experimenting with the New Fuel for Motors—Believe Success Is Assured.

Figure 2-1 New York Times article headline (Anonymous, 1906)

The use of biofuels was well established already in the beginning of the 20th century. In 1906, the New York Times published an article called "Auto Club Aroused Over Alcohol Bill" which describes the first signs of competition between the two different types of fuels: the petroleum and bioethanol. (Songstad, et al., 2010)The article shows, that many cars manufactures, and engineers at that time believe that bioethanol presents a promising substitute for petroleum as a transportation fuel in the future. The president of the Automobile Club of America stated in the article, that "Gasoline is growing scarcer, and therefore dearer, all the time… Automobiles cannot use gasoline for all time, of that I am sure, and alcohol seems to be the best substitute that has yet appeared." (Anonymous, 1906) The idea of biofuel use in transportation was important, however, because the use of fossil fuels was possessed a economical and more efficient possibility, the use of biofuels did not developed significantly for another few decades.

Figure 2-2 April 1933 a bioethanol fuelling station (Kovarik, 1998)

The idea to use biofuels as a substitute for fossil fuels was revised in 1970s. The first event, which leaded to a new biofuels revolution was without no doubt the Arab oil embargo in 1970s which caused an increase of oil prices across the world and caused severe economic problem. The price of oil on the international market nearly quadrupled and reached nearly US$12 per barrel of oil. The high price of oil cause shortages of fuel supplies and effected economies of many countries in the Western Europe, the United States and the rest of the world. The crisis highlighted the dependency of the oil prices on the will of small group of states united in the Organization of Oil Exporting Countries (OPEC). Despite the fact, that the prices have returned to their levels before the period of Arab oil embargo in 1980s biofuels production did dropped but remained constant at approximately 15 billion litres. The main reason behind this new trend was the increased awareness of the common people who started to fear for their jobs and demanded an immediate and long-term measure after the Arab oil embargo. The response was the new political rhetoric – need to reduce dependency on import of fossil fuels. Government representatives have presented to the public the idea of energy independence, which shall be achieved by obtaining of combustion engine fuels from domestic resources by use of biofuels. The idea to use biofuels in transportation was resurrected. (Langeveld, 2010) The increasing level of biofuels will allow the EU to decrease dependency on fossil fuel import. The import of fossil fuels into the EU has experienced several difficulties in last few years. The one of the main factors influencing import of fossil fuels into the EU is the political situation in the Middle East. The Middle East has the largest fossil fuel reserve, and will play the crucial role in the oil export in the future. Other important actor in the

EU fossil fuel import is without no doubt Russia. Russia is currently the largest importer of the fossil fuels to the EU. However, the high dependency on the Yamal-Europe pipeline has proven to be a risk for the EU energy security. The control over the energy resources gives Russia power over the EU which Russia is willing to use to its advantage. This statement was confirmed by events in January 2009 when Russia stopped to supply a large part of the EU, living millions of the EU citizens without fossil fuel supplies during winter, under the excuse of problems with Ukraine and in January 2007 was a similar situation with Belarus. (Anonymous, 2007; Kramer, 2010)

The second cause of increased use of biofuels was for environmental reasons rather than economic. In the mid-1980s, the concern about negative effects of climate change reached an international level. The awareness of scientific, and the general public became more aware of climate which leaded to calls for an action in order to stop or mitigate the consequences of global change. Scientific community presented evidence of rising amount of greenhouse gases, which are believed to be the main cause of global change. As the large number of greenhouse gases is produced in transportation by fossil fuel and one of the main greenhouse gases is proven to be the carbon dioxide (CO2) scientists offered a solution in what they believed to be carbon neutral biofuels. According to this assumption, the amount of carbon dioxide produced by consumption of biofuels is consumed by crops from the atmosphere during the production process.

2.2 The EU legislation

For decades, the EU has played the leading role in climate change mitigation. Since the beginning of the 1990s, the European Community was closely evaluation available possibilities of reduction of carbon dioxide, which is produced within its territory and possible use of biofuels for this purpose. The ratification of the Kyoto Protocol accelerated the need of the EU to accommodate appropriate greenhouse-gas emission reduction policies to secure compliance with the goal set by the Kyoto Protocol. The reduction of greenhouse-gas emission in transportation is essential. ‘In the EU, transport is responsible for an estimated 21per cent of all greenhouse-gas emissions that are contributing to global warming, and the percentage is rising.' (European Communities, 2006)

The use of biodiesel for transportation was introduced in Directive 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport. Nevertheless, the targets set in this directive are not legally binding for any Member State. In the title ,of the treaty is used the word 'promotion' which suggest, that Member States should encourage the use of biofuels for transportation ,but the EU does not force its members to do so. For that reason, this directive is serving as a recommendation or guideline for the Member States, how much biofuels they should use in the diesel blend to contribute to mitigation of a climate change and fulfil their mitigation obligations. Despite the fact, that this directive is not binging the targets on the use of biofuels has been set up. Member States shall be using the blend with 2 per cent of biofuels content by 31 December 2005, and further increase shall be achieved by 31 December 2010 which shall increase the percentage of biofuels in the blend to 5.75per cent. All Member States shall be evaluated by the European Commission on their progress in biofuel promotion every two years. Additionally, the directive admits a possibility that if the Member States are not reaching the targets of the directive without justifiable reason, the mandatory targets may be established. (European Communities, 2003) As a result of the directive, the majority of the member states have set target for level of biofuels used in transportation in their national level. In the new Directive 2009/28/EC which is amending and repealing the Directive 2003/30/EC, the new mandatory are adopted by the EU and all member states have to comply with this targets. This directive establishes the mandatory target of minimum of 10 per cent of fuels use for transportation shall be represent by biofuels by 2020. However, the Directive 2009/28/EC did not enter into force and will enter in effect from 1 January 2012. (European Communities, 2009)

The Directive 2003/30/EC is not only calling for the increase of the biofuels for a purpose of climate change mitigation but has mentioned the necessity of sustainable development principles. The Directive 2009/28/EC states that certain necessary sustainability standards must be met in order to be taken into account towards biofuel targets of individual Member States. According to sustainability criteria, at least 50 per cent of greenhouse-gas reduction shall be achieved in comparison to use of fossil fuels by 2017. By 2018, 60 per cent of greenhouse-gas reduction shall be met from new developed production facilities from 1 January 2017. The assessment of biofuels sustainability shall be done in order to identify its effect on food prices, social sustainability and other development issues. Moreover, the Directive 2009/28/EC identifies different environmental aspects of land use in biofuels production and states that land of peat lands with high biodiversity value or high carbon storage capacity may not be used. (Smyth, et al., 2010; European Communities, 2009; Bringezu, 2009)

An important part in biofuels policy also plays the Common Agricultural Policy (CAP) which is responsible for the agricultural production in the EU including the biofuels and promotes the biofuels production. Under CAP, every EU farmer gains benefits from the EU funds in the form of subsidy payment for not using 10 per cent of their land for crops production. However, CAP allows farmers to use this 10 per cent for energy crop production such as oilseed for production of biofuels. (Smyth, et al., 2010)

National biofuels targets vary from one member states to another. Some of the EU Member States have limited agricultural production capabilities than other. Based on these limits, biofuels does not require to be produced directly from this countries or regions but can be imported from other parts of the world. However, all Member States should reach the minimal, but not yet mandatory EU targets.

Table 2-1 Minimum incorporation targets for EU Member States in place in Summer 2010. (Strategie Grains, 2010)

Member Countries	Ethanol	Biodiesel	Total
Germany	2.80%	4.40%	6.25%
Belgium	4.00%	4.00%	4.00%
Luxembourg			2.00%
Denmark	5.00%		5.75%
Spain	3.90%	3.90%	5.83%
France	7.00%	7.00%	7.00%
Greece			5.75%
Ireland			4.00%
Italy			3.50%
Netherlands	3.50%	3.50%	4.00%
Portugal			7.00%
UK			3.50%
Austria	3.40%	6.30%	5.75%
Finland			4.00%
Sweden			5.75%
Poland			5.75%
Hungary	5.75%	5.75%	5.75%
Czech Rep.	4.10%	6.00%	
Estonia			
Latvia	5.00%	5.00%	
Lithuania	5.00%	5.00%	5.75%
Slovenia			3.00%
Slovakia			5.75%
Cyprus			2.50%
Malta			
Romania	4.00%	4.00%	
Bulgaria			5.75%

Note: Shaded cells are indicative, others are mandatory.
Belgium, Denmark, Ireland, The UK, Czech Republic, Lithuania and Romania targets are set for volume. Others are expressed as energy equivalents.

In addition, Germany has increase the biofuels content in fuel mixtures to 10 per cent in 2011.

3 Biofuels

The increase of fossil fuel prices and the impact of fossil fuels on climate change forced states over the world to search for alternative sources of energy. Biofuels are certain types of solid, liquid and gaseous fuels, which are derived from bio-renewable and combustible renewable feedstocks. ‘Biofuels are ultimately based on the ability of photosynthetic organisms to use solar irradiation for the conversion of CO2 into glucose (C6H12O6) and subsequently into biomass; the overall reaction for conversion into glucose usually being:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$ ‘

(Reijnders, et al., 2009,p. 3)

Liquid petroleum based biofuels offer a possible substitute for fossil fuels, which are nowadays most commonly used in transportation. The most significant difference between biofuels and fossil fuels is the different level of oxygen concentration in the substances. Concentration of oxygen in biofuels is between 10 to 15 wt. per cent while fossil fuels oxygen content is basically none. The difference in oxygen content leads to different chemical properties of biofuels from fossil fuels. (Demirbas, 2009) Nevertheless, the ability of biofuels to reduce greenhouse gas emissions is questionable.

3.1 Types of Biofuels

There can be distinguished a three main types of biofuels used for transportation purposes in Europe: bioethanol, bio-Ethyl-Tetrio-Butyl-Ester (ETBE) and biodiesel. Bioethanol and bio-ETBE is used as a substitute for petrol in an internal combustion engine with spark-ignition. On the other hand, biodiesel is used as a substitute for diesel in compression-ignition engine. (Demirbas, 2009)

3.2 Bioethanol and Bio-ETBE

Ethanol or ethyl alcohol is the oldest manufactured synthetic organic chemical and belongs between the most significant chemicals. Bioethanol is not only used in transportation, but for many years, it is used in pharmacy and cosmetic manufacturing. Bioethanol is produced by fermentation of sugars, starch or cellulosic biomass. Fermentation is an abiotic biological process during which sugar is processed by microorganisms such as yeast. (Demirbas, 2010)

The sources of sugar based biofuels are mainly sugarcane and sugar beet, starch is obtained commonly from corn and wheat, and cellulosic biomass is produced, for example from grass, straw or wood. Around 60 per cent of bioethanol production is from sugar crops. Substantial part of the production around 10 per cent is represented by corn. (Demirbas, 2009; Demirbas, 2010) In the EU most common feedsctock for bioethanol production is sugar beet.

Bio-ETBE is a type of ethanol produced by fermentation of starch or sugars and isobutylene in a catalytic reaction.

3.3 Biodiesel

(Origins from Greek - bio = life + diesel - type of fuel named after inventor Rudolf Diesel) Biodiesel is defined as the mono-alkyl esters of fatty obtained by trans-esterifying on vegetable oil or animal fat with an alcohol. (Knothe, 2010) The trans-esterifying process leads to lower viscosity and oxygen content of the vegetable oil which allows the use of these biofuels in diesel combustion engines. Biofuels are commonly produced from soybeans, palm oil or rapeseeds. The most commonly used in the EU is rapeseed.

3.4 Classification of biofuels

Nowadays we can distinguish tree main types or generations of biofuels based on their production technologies: the first, the second and third generation biofuels. Biofuels of the first generation are produced from agricultural feedstock such as palm oil or rapeseed. In contrast, the second and third generation biofuels, so called advanced biofuels, are produced from resources which are not in direct competition with food crops and does not have a direct influence on food prices. The first generation biofuels are in direct competition with food crops. Farmers often decide to plant energy crops instead of the food crops as energy crops offer a higher profit. This situation leads to higher food prices due to the shift of supply towards the energy crops and decrease of availability of food crops. According to the World Bank's food price index, the increase of the total commodities prices by 25-30 per cent and 70-75 per cent increase of the prices of food commodities are caused by biofuel production during the years of 2002 to 2008. (Mitchell, 2008)

4 Biofuels production

Nowadays, biofuels production is starting to play a crucial role in transportation across the EU. Most of Member States have developed and started the process of implementation of national biofuels policies which are the response to the directives set in by the EU. The compliance of the individual member states with the biofuels directive and their national targets differs and some states take the implementation stricter than others as the EU targets are not obligatory yet. There can be distinguishing different biofuels mixes based on the level of biofuels and fossil fuels content. The most common mixes are B2, B5, B10, and B100 for biodiesel which indicates that the B5 blend has 5 per cent of biodiesel in diesel. For ethanol, blends come in two mixes: E5 and E85 and again the number are indicating the percentage of bioethanol in the blend. In recent years, production of biofuels within the EU has expanded rapidly, and the EU is the world's largest producer of biodiesel. (Zhou, 2009; Amaya, 2009)

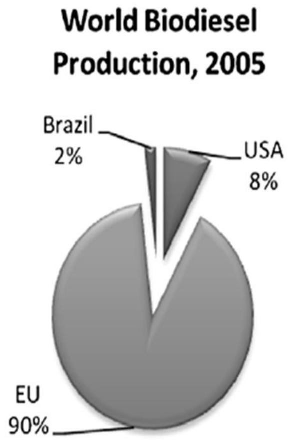


Figure 4-1 Global biodiesel production by source (Zhou, 2009)

In 2006, the EU produced around 90 per cent of world biodiesel. (Zhou,2009) On the EU level, the production is dominated by biodiesel, which represents 80 per cent of all biofuels in the EU. Only 20 per cent of biofuel production is represented by bioethanol. Since 2006, the production of both biofuels grown rapidly, however, biodiesel remains the dominate biofuel type used in the EU. This corresponds with the consumption of fossil diesel fuel which is nearly 45 per cent higher than gasoline consumption. Despite the fact, that in other parts of the world, such as Brazil or the United States, bioethanol is produced in a large amount, the EU is just a minor producer, and bioethanol remains the secondary biofuel type in both production and consumption. (Flach, et al., 2010)

The important factor of the biofuel production is the tonne of oil equivalents (toe) unit which varies throughout regions and different crop types. "The productivity per land area is, it the EU, in the order of 1-2 toe ethanol/ha for cereals as feedstock and 2-3 toe ethanol/ha for sugar beet… The biodiesel productivity per land area from different oil-seed crops in the EU amount to 0.8 to 1.2 toe biodiesel/ha."(SETIS, 2011)

In 2009, the EU produced in total 3 480 millions of litters of bioethanol and 9 610 million litters of biodiesel. However, as it is shown in Table 4-1 the gasoline demand in the EU is 105 647 Ktoe which means that the EU is only able to cover 3.3 per cent of the gasoline supply from the bioethanol production. The diesel consumption is even higher than gasoline consumption. In 2009, the consumption of diesel fuel was 194 942 Ktoe from which biofuels represent 4.9 per cent.

Table 4-1 Road Transportation Fuels Consumption (Ktoe) (Flach, et al., 2010)

Calendar Year	2006	2007	2008	2009	2010	2011
Bioethanol	880	1380	1790	2210	2560	3070
Biodiesel	4110	5960	7490	8820	10630	10460
Total Biofuels	4990	7340	9280	11030	13200	13550
Gasoline	109829	106071	105647	105224	104803	104384
Diesel	183702	189596	192250	194942	197671	200438
Tot. Fossil Fuels	298251	300481	304387	308344	312353	316413
Actual Blending	1.65%	2.38%	2.96%	3.45%	4.05%	4.11%
Goal EU	2.75%	3.50%	4.25%	5.00%	5.75%	-

For example, Germany is currently the largest producer of biofuels in the EU. Germany is also the largest producer of biodiesel and the second largest producer of bioethanol. Germany is also by far the most efficient and most advance in its biofuel policy. This year Germany has introduced a 10 per cent bioethanol blend called E10 on its market. This step, clearly shows the Germany leading position in promoting of biofuels as it is the first and currently the only country in the EU which introduced the E10 blend on its market. Based on this fact, the demand for biofuels has increased recently. In addition to the recent increase of bioethanol increase, Germany has adopted regulation on the sustainability of biofuels. Based on this sustainability regulation, companies producing biofuels must prove that their production is sustainable in order to apply the tax deduction on theirs products. Other countries are following the German footstep and developing their own national sustainability requirement and criteria. Many countries, such as Austria or the Czech Republic already set the required amount of biofuel in the blend to 5.5 level and plans for further increase are subject of heavy discussion. (Germany, 2010; Austria, 2010; Czech Republic, 2010; Bringezu, 2009)

4.1 Land use

Production of the biofuels in Europe has grown rapidly in last two decades. It expected to satisfy needs for the goals set by the EU which should serve the purpose of fulfilling the EU obligation made by ratification of the Kyoto protocol and avoid irreversible changes in the environment. However, the land suitable for growing crops is scars all over the planet and the EU is not an exception. It was acknowledged that already in these days some EU Member States, such as Malta, do not possess enough arable land to satisfy biofuel demand from national production. Currently, the amount of land used for agricultural production is around 178,4 million of hectares.(Eurostat, 2010) This area includes is „the total arable land, permanent grassland, land used for permanent crops and kitchen gardens. The utilised agricultural area excludes unutilised agricultural land, woodland and land occupied by buildings, farmyards, tracks, ponds, etc." (Eurostat, 2010, p.14)

According to report for the House of Lords in the UK (2006) and Smith, et al. (2010), in order to achieve the targets establish by the EU on the biofuels consumption in transportation 13.6 million hectares will be required for biofuels production in 2010. The increase of space necessary for production is rapid. Nowadays, the EU has approximately 130 million hectares of arable land.(Eurostat, 2008; Smith, 2010) However, 13.6 million hectares represents roughly 10.5 per cent of arable land in the EU. The land use for biofuels production is supposed to be from the set aside land which represents 10 per cent of arable land. In order to achieve the sustainable requirement and avoid the pressure on the food market, which would lead to further increase of food prices, and have a high impact on poor people mainly in developing parts of the world where food usually represents, the highest part in spending. This means that the EU reached the limit of land arable, which should be available for production and has not enough arable land to meet 10 per cent of biofuels in transportation. With further increase of biofuels content on the EU market, it will be impossible to meet by sustainable way with the use of the first generation biofuels. The table 1, presents different possibilities of biofuels blend, and how much it arable l and would be necessary if the biofuels should be supplied from the EU internal market with the use of agricultural feedstock such as rapeseed which is currently the most feedstock used in biofuel production in the EU. It shows that it is impossible to produce enough biofuels in order to satisfy the demand in transportation in the EU purely with biofuels and the EU would have to have three times large arable land than it has today. If the EU decides to increase the share of biofuels to 53 per cent in the blend with fossil fuels, it will mean that the EU needs to use all its arable land just for the production of biofuels if all the biofuels production will be supplied by the first generation feedstocks.

Table 4-2 Table shows the arable land demand for different biofuel mixes for the production from the EU domestic sources. (Source: own creation, based on data from Eurostat, 2008; House of Lords, 2006; Smith, et al., 2010)

Percentage of biofuels in the blend	Potential use of arable land in hectares	Use of arable land in percentage
5.5%	13.6 million	10.5
10%	20.3 million	15.6
20%	40.6 million	31.2
53%	130 million	100
100%	247,3 million	190

In order to, meet the requirement content of biofuels the EU will have to import a significant amount of biofuels from other regions. Nevertheless, the import of biofuels from outside the EU areas will make it nearly impossible for the EU to control the sustainability of these products. In addition, the biofuels will be most likely imported from developing countries, which have traditionally lower requirements for sustainability. Lower productivity and household income in developing countries lead to lower environmental standards as these countries do not have resources for more environmental friendly technologies when developing countries act in unsustainable way the comparative advantage gained at the beginning by lower standards and in many cases a large number developing states tend to unexploited natural resources which leads to diminishment of environmental problems increase and cause severe disruptions in production. Moreover, the exploitation of natural resources in unsustainable way leads to a wasting of natural resources and decrease of profit. The policy of sustainable development in one region can lead to increase of unsustainable practices and environmental degradation in other regions.

4.2 Import of biofuels

Demand for biofuels is rising globally. In the EU is this increase driven by domestic consumption aiming to fulfil the EU Member States targets. The EU is producing the majority of biofuels used in transportation. However, demand for biofuels in the transportation sector will influence import in the future even if the EU will be able to satisfy the increase in the future which is according to the land availability land highly unlikely with the first generation biofuels the EU may experience the increase of biofuel import. The increasing use of biofuels in transportation influences the market with biofuels in other sectors such as pharmaceutical or food industry. Transportation sector will lead to shortages of supply and these other industries will have to seek new suppliers outside the EU. (Jank, 2007) The import of biofuels will increase despite the fact that biofuels are not always used for transportation, transportation sector have an indirect effect on this changes as it forces other sectors to seek biofuel market outside the EU. Even, if all biofuels use for transportation will be produced within the EU borders, the shift will indirectly decrease the sustainability of biofuels as their production will most likely occur in developing countries that will not comply with the sustainable requirements. Moreover, as these biofuels will not be used in the transportation sector, the sustainability requirements of the EU Directive 2009/28/EC will not apply.

There can be distinguished to different biofuel markets. One is focused on bioethanol, and the other one is specialized on biodiesel. The division between the exports of biofuel crops is caused by the necessity of exporting countries to specialize in that biofuels crop, which is more suitable for their conditions. This allows exporting counties to maximize their profits.

The main importer of bioethanol in the EU is Brazil, however, Brazil has recently reduced its import in the EU by nearly half. As a response, to this decrease the import from other countries, mainly Guatemala, Nicaragua and Costa Rica has increase. The main EU Member countries importing bioethanol for their national markets are the UK, Sweden and the countries of Benelux. The import of the bioethanol in the EU is handled through the port of Rotterdam. (Flach, et.al, 2010) 'During the 2002-04 period, about 64% of EU ethanol imports entered under preferential trade arrangements including the Generalized System of Preferences (GSP), the Cotonou Agreement (ACP), Everything But Arms (EBA) initiative, and others. Pakistan, with a 20% share of EU ethanol imports, is the largest ethanol exporter under preferential trade arrangements. Nevertheless, availability of bioethanol on global is decreasing." (Flach, et.al, 2010)

The import of biodiesel is primarily dominated by Argentina, Malaysia and Indonesia. Argentina has a strong position on the EU marked which is caused by different and lower export taxes on biofuels export compare to higher export taxes on soybeans and soybean oil. Malaysia and Indonesia have also extremely strong position as they are currently the world's largest palm oil exporters and they production is continuing to rise. In Indonesia, the area on which is produced oil palm has increased from 54,000 hectares in 1960 to 4.05 million hectares in 2005, reflecting a compound annual growth of 10.06%. Production increased from 94,000 tonnes in 1960 to 15 million tonnes in 2005, or by almost 160 times within 45 years – this represents a compound annual growth of 11.93% per year. (Basiron, 2007) However, Malaysia and Indonesia are no longer producing biofuels only for the export but they also see biofuels as an important source of energy security. From 2006, Indonesia is no longer self-sufficient in fossil fuel production and has to import oil from other countries because of that Indonesia has been decreasing its export of biofuels. (Zhou, 2009)

5 Environmental Effects of Biofuels

5.1 Atmospheric emission reduction

The promotion of biofuels in the EU is primarily based on the argument that biofuels can be used as an alternative source of energy and help to reduce the greenhouse-gas emissions. Therefore, biofuels play a crucial role in the EU climate change mitigation policy. The Direction 2009/28/EC states that:

‘The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, and with further Community and international greenhouse gas emission reduction commitments beyond 2012.‘

(European Commission, 2009)

The ability of biofuels to reduce the greenhouse gas emissions is based on the assumption that biofuels, unlike fossil fuels, are carbon neutral. Biofuels are called carbon neutral because it is assumed that the amount of CO2 emissions produced during the use of biofuels is extracted by biofuel crops from the atmosphere during its production process. In 1990s, it was argued that biofuels offer the possibility of 65 to 90 per cent reduction of CO2 emissions in comparison to fossil fuels. The carbon neutrality is represented as the main environmental benefit of biofuels as it is expected to reduce the amount of greenhouse-gases produced in transportation and should help the EU to fulfil its obligation and targets for climate change mitigation set by the Kyoto protocol.

In addition, the use of biofuels can also improve the quality of urban air and lower the negative impacts of emissions produced by the transportation sector on human health. The use of biofuels in conventional combustion engines can decrease some levels and toxicity of tailpipe emission. The biofuels are biodegradable, which means, that in case of accidental leakage, it does not put high pressure on the environment. The urban air pollution plays a crucial role in everyday lives of millions of people in the EU. The use of bioethanol can help to decrease the carbon monoxide emissions which may significantly endanger human health and even lead to death. On the other hand, biodiesel does not only reduce the carbon monoxide emissions, but it also has a positive effect on reduction of particulate emissions of diesel combustion engine. The exposure to particulate emissions leads to increase the risk of lung and heart diseases. (Duffield, et al., 2006) Biodiesel is reducing the possibility of exposure to carcinogens in emissions. (Ma, et al., 1999)

5.2 Indirect land change

For several years, the EU has been increasing the level of biofuels used for transportation. The change of market demand shifts the production and causes a higher amount of biofuels crops produced by farmers in the side as well as outside the EU. As a result, the shift towards the biofuels crops agricultural sector underwent significant changes in the land use.

The effects of indirect land used caused by biofuels can be traced all over the planet. Everyday rainforest is destroyed and converted into agricultural land. The rising prices of energy crops are presenting an attractive way how to increase the income mainly for developing countries and provide an opportunity for their citizens to improve their standard of living. In addition, developed countries such as the EU member states are promoting the plantation of biofuels on the set aside land in order to decrease their import needs also energy dependency on other countries. Nevertheless, this opportunity has many negative consequences on the environment especially in tropical regions.

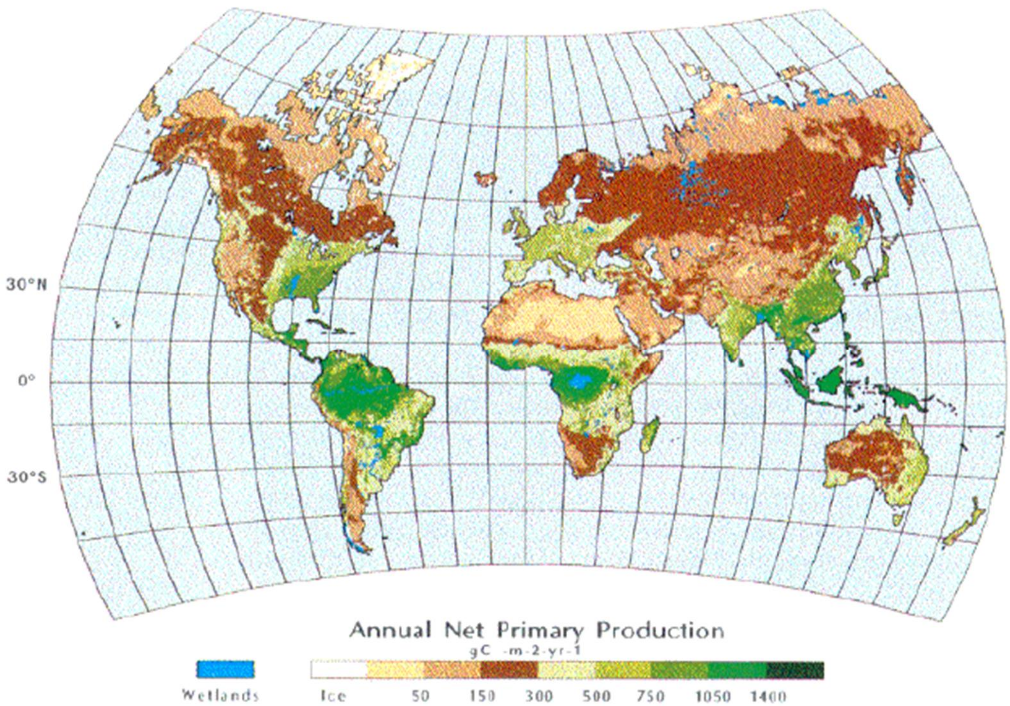
The CO2 produced due to indirect land changes need to be taken in to consideration while the carbon neutrality of biofuels. It would in correct to estimate the percentage of different feedstock reduction capacity without taking in to consideration the effects of indirect land change caused by an increase in production of biofuels. The amount released from indirect land change needs to be reduced from greenhouse-gas savings of biofuels so the proper comparison with fossil fuels can be made.

Indict change of land causes an unintentional release of greenhouse-gas emissions, mainly CO_2, from plants in the atmosphere. The capacity of plants to store CO_2 is varying according to different types of vegetation and different regions. Moreover, the amount of CO_2 emissions released depends on the age of the vegetation. The atmospheric CO_2 gases are consumed by plants during the photosynthesis process. As a result of photosynthesis process, plant consumes atmospheric CO_2 and water and produces cellulose and oxygen. The cellulose is used as a storage space for carbon and oxygen is released back in the atmosphere. If some land is cleared in order to make space for an agricultural production, it leads to realise of CO_2 which was previously stored in the bodies and roots of plants. Realise is most likely occurring during decomposition or incineration of these plants. As a consequence of the indirect land change, there is an increase of greenhouse-gas emissions in the atmosphere.

The ability of the plant to store carbon is measured by the net primary production rate. The net primary production is the ratio between the amount of chemical energy produced by plant and energy lost during the respiration process. It is measured in combination of units of mass / area / time and provides the amount of biomass carbon produced in different ecosystems or individual plants.

There are significant differences in plants storage capacity in different regions and types of ecosystems so that the temperate mixed forest has a different carbon storage capacity then tropical evergreen forest, short grassland, or wet moist tundra. This is caused by the amount of light is available for the plants in these regions. Moreover, the type of vegetation has also impact on the storage capacity. The tropical deciduous forest have a much higher carbon storage capacity then tropical evergreen forest which is caused by different time of vegetation and their ability to absorb the CO_2 emissions during photosynthesis process. The tropical evergreen forest has the highest carbon storing capacity, and its net primary production is around 1400 g $C/m^2/yr$ whereas the lowest net primary production is estimated for 50 g $C/m^2/yr$ in a polar desert ecosystem. The figure 5-1 demonstrated the differences in net primary production which is decreasing with the growing distance of ecosystems from equator. However, there are some exceptions so the desert has a low net production system despite the fact that it is located close to the equator but the amount of vegetation is low so it there is a limited storage capacity. “Over half of the global annual net primary production occurs in the tropics between the latitudes of 22.5° S and 22.5° N.The most of this productivity is attributable to tropical evergreen forest which accounts for 35.9 per cent of the net exchange CO_2 between terrestrial vegetation and atmosphere, although it covers only 13.7% of the terrestrial land surface.” (Mellilo,et al., 1993)

The tropical evergreen rainforests are offering an opportunity for expansion of



production as there are millions of hectares of land available and suitable for an agricultural production. Nevertheless, the land gained from rainforest can be use for a production only for a short period of time. The fertile land of rainforests is losing its vitality quickly. Moreover, the monoculture plantations are lacking diversity of rainforest’s original flora and fauna and this causes even faster deterioration of land. The lack of nutrition in the lands forces farmers to use heavy fertilizers in order to increase the productivity of plants and sustain their production as long as possible. The use of heavy chemical based fertilizers leads usually to serious damage of the environment due to unsustainable use of land. As a consequence, the income of many people starts to decrease with a decrease of plantation’s production and after some time they are losing their source of livelihood completely.

The government of Indonesia is planning to convert 5.25 million hectares of unused land into an oil producing plantations. The unused land in Indonesia which is suitable for an agricultural production is in majority hidden under rainforests. The Borneo Island is the third world largest island on the planet with large and dense rainforests. However, the large areas of this island's rainforests have been cut down because of the economic interests of the Governments of Indonesia and Malaysia. Over the last two decades, the proportion of rainforests on Borneo has decreased significantly. Only 25 year ago, Borneo was covered with 73.7 per cent by rainforest. Nevertheless, in 2020, rainforest should cover only one-third of Borneo's surface. This is caused by geographic location of this island which offers a unique climate for palm oil cultivation.

5.3 Deforestation

In contrast, many developing state are facing another significant problem caused by unsustainable development in biofuel production. The indirect land change in the form of deforestation has a significant impact on welfare of their people. Governments of developing countries are cutting down millions of hectares of tropical evergreen rainforest in order to increase their biofuel production. The Government of Indonesia is planning to convert 5.25 million hectares of unused land into an oil producing plantations. The unused land in Indonesia which is suitable for an agricultural production is in majority hidden under rainforests. The Borneo Island is the third world largest island on the planet with large and dense rainforests.

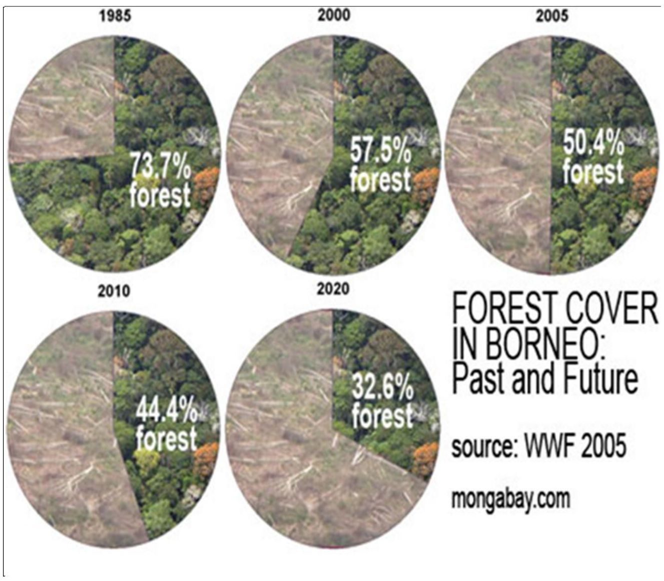


Figure 5-1 Development of deforestation in Borneo (Butler, 2005)

However, the large areas of this island's rainforests have been cut down because of the economic interests of the Governments of Indonesia and Malaysia. Over the last two decades, the proportion of rainforests on Borneo has decreased significantly. Only 25 year ago, Borneo was covered with 73.7 per cent by rainforest. Nevertheless, in 2020, rainforest should cover only one-third of Borneo's surface. (see figure 5-2) This is caused by geographic location of this island which offers a unique climate for palm oil cultivation.

Rainforests offer millions of hectares of land suitable for an agricultural production. Nevertheless, the land gained from rainforest can be used for a production only for a short period of time. The fertile land of rainforests is losing its vitality quickly. Moreover, the monoculture plantations are lacking diversity of rainforest's original flora and this causes even faster deterioration of land. The lack of nutrition in the lands forces farmers to use heavy fertilizers in order to increase the productivity of plants and sustain their production as long as possible. The use of heavy chemical-based fertilizers leads usually to serious damage of the environment due to unsustainable use of land. As a consequence, the income of many people starts to decrease with a decrease of plantation's production and after some time they are losing their source of livelihood completely.

Moreover, the plantation of palm oil seeds in tropical areas leads to increase of greenhouse gasses in the atmosphere. This is caused by their mono-cultural nature because mono-cultural biofuel crops can provide only extremely limited amount of nutrition and this leads to the use of chemical based fertilizers. 'The extensive use of chemical-based fertilizers, resulting in the release of nitrous oxide which is a greenhouse gas that is about 300 times stronger than carbon dioxide in terms of greenhouse gas potential. It is also known that nitrogen-based chemical fertilizers have a greenhouse gas potential of 10 – 100 times more in tropical climates than temperate climates.' (Zhou, 2009) Based on these facts, the use of biofuels is ineffective strategy for mitigation of climate change. Despite the fact that the EU does not use biodiesel from Malaysia or Indonesia directly for mitigation of climate change, it is still more harmful to use biofuels for global climate than not to use biodiesel at all and use instead fossil fuels. The EU use its own oil seeds for its biofuel production, but the EU still need to use import biodiesel from Indonesia, and

Malaysia in order to satisfy demand in other industry areas. The biodiesel, which would normally be used in the food industry is now used for transportation and because of that biodiesel from outside of the EU with exceedingly high carbon footprint must be used in other industries. In addition, deforestation leads to reduction of natural carbon dioxide sinks. That means that the EU is not only importing a biodiesel which production was highly intensive on realise of greenhouse gasses, but they are indirectly supporting other governments in deforestation of their countries in order to gain access to biofuels which should mitigate climate change but ignores the fact that because of their production important carbon dioxide sinks where cut down. This means that the footprint of this biodiesel is even larger.

Additionally, deforestation causes another serious problem for the environment. Deforestation leads to the loss of biodiversity due to cutting down of forest for the palm oil plantation. The tropical rainforests are home for thousands of different species of plants and animals. The ecosystems are often extremely fragile and extinction of one or two species may destroy symbiotic life circle and leads to destruction of the whole ecosystem. The biodiversity on plantations is reduced significantly as in tropical rainforests in Malaysia lives nearly 80 mammal species but on palm oil plantation the number of mammal species which are able to live there drops down to only 11or 12. (Clay, 2004) Some species are already on the list of endangered species such as orangutans, tigers, Sumatran rhino or Asian elephants.

The population of orang-utans is decreasing rapidly. The current population of orang-utans is around 40 thousands and according to the World Wildlife Fund every year one thousands of orang-utans are killed which represents about 2.5 per cent of the entire population. Orang-utans are often victims of fires set to clear space for oil plantations or many orang-utans are poisoned after eating heavily fertilized crops. Deforestation leads to a severe loss of biodiversity and in many cases this loss can be already irreversible but even if there is still some hope to save these rare and endangered species without serious steps towards conservation made by governments this species will soon be extinct or will live only in the protection of zoos. Unfortunately, nowadays is protection of this species ineffective.

Last but not least, deforestation is one of the main reason of soil erosions and the deterioration of water quality in many river systems in Malaysia and Indonesia. The unsustainable development will lead to exceptionally serious consequences in the future because the soil is a scarce natural resource and its erosion will impact on agriculture. The agricultural production will be decreasing due to unsuitable use of land and monoculture plantation. Soil erosion will lead to a more devastating impact on Malaysian and Indonesian economies.

5.4 The use of fertilizers

The use of chemical fertilisers is a common practice in agricultural production all over the world. Since the 1960s, total use of fertilizers has risen sharply. Nowadays, the amount of fertilizers used in agricultural production reached nearly 150 million metric tons used every year. The only exception to these practices is the production of organic agricultural products which can only use the fertilizers based on organic material without the use of chemicals. The fertilizers are used to increase the productivity of arable land and to increase the strength of crops. Fertilizers provide nutrients necessary for growth of plants and increase fertility of the soil. Use of fertilizers is commonly used in biofuel production in order to secure a sufficient amount of biofuels mainly in tropical regions where soil after deforestation of rainforest losses the vitally and mineral in contained in soil after the shorter period of time then it would lose it in temperate regions. However, the use of fertilizers in agriculture has a negative impact on the environment.

Fertilizers are commonly passed on phosphorus and nitrogen bases which leads to several environmental problems connected with these agrochemicals. Agricultural N and P are transported by leaching and surface flow to surface, ground, and coastal waters causing eutrophication, loss of biodiversity, and elevated nitrate and nitrite in drinking-water wells. (Hill, et al., 2006) Damage caused by fertilizers has devastating consequences on the environment. Eutrophication causes serious damage to water bodies due to increase growth of algae in the water. A large amount of algae leads to the depletion of oxygen and the loss of biodiversity in this water body. In addition, use of fertilizers can lead to contamination of ground water. The contaminated ground water is transported into wells where it is used for human consumption. The use of contaminated ground water can lead to serious health problems (such as cancer) or even death. (Withgott, 2010)

The use of nitrogen fertilizers in agricultural production leads to the formation of N2O emissions. The emissions of N2O are produced by bacteria which are naturally occurring in soil and water. After fertilization of soil, the amount of N2O emissions rises significantly and increases the amount of greenhouse gases in the atmosphere.

Moreover, N2O emissions do not only have a negative effect on climate change but also cause the depletion of the ozone layer. According to Ravishankara, et al. (2009) N2O emissions are currently the main factor influencing the condition of the ozone layer as it is currently the main source of NOx which functions as a catalyst during the destruction of ozone in the stratosphere. "By comparing the ozone depletion potential –weighted anthropogenic emissions of N2O with those of other ozone-depleting substances, we show that N2O emission currently is the single most important ozone-depleting emission and is expected to remain the largest throughout the 21st century." (Ravishankara, et al., 2009) Despite the fact, that increase of N2O emission is caused by anthropogenic behaviour the Montreal Protocol on Substances That Deplete the Ozone Layer does not impose limits on their production N2O emission. However, N2O emissions are limited to a certain extant in Kyoto Protocol but only from climate change point of view. N2O emission share many similarities with chlorofluorocarbon which is recognized as the most common ozone depleting substance. Both of these substances are stable in the troposphere, but after the stratosphere to they release chemicals and act as a catalyst ,which results in disruption of the ozone layer. The increase of N2O emissions in the stratosphere is causing the depletion of the ozone layer and slowing down its recovery. As a result of the ozone layer depletion, the ultraviolet radiation has a negative effect on human health and can lead to cancer. Moreover, there had been reported cases when sheep close to Antarctica went blind due to exposure to ultraviolet radiation. (Ravishankara, et al., 2009)

5.5 Direct land changes and food prices

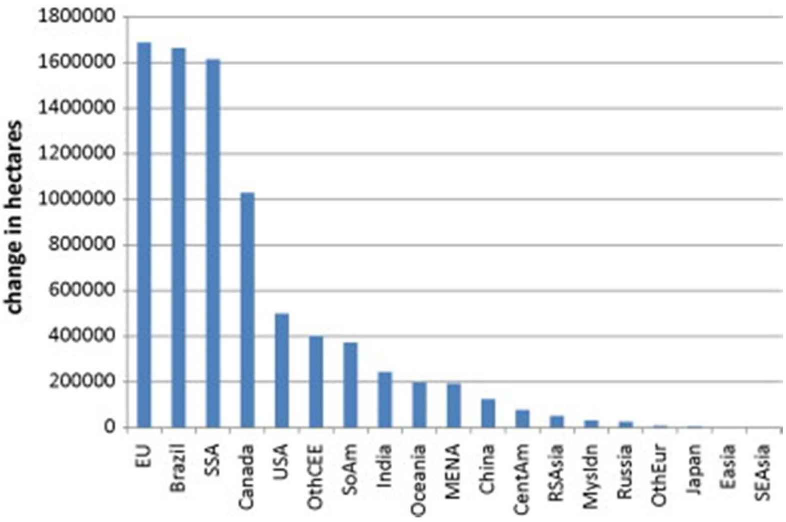


Figure 5-2 Impact of biodiesel expansion on cropland cover (ha) (Britz, 2009)

As a direct land use change we identify the situation when agricultural crop producer decides to plant a different type of seed than he was planting previously. For example, on a field where was previously produced a potatoes producers are now planning rapeseeds for biofuels oil production. Lange areas of land have been directly converted biofuel plantation. (see Figure 6-2) The largest are converted into biodiesel from the cropland was in the EU and represents over 1.7 million hectares. (Britz, 2009)The shifts towards the different type of seeds do not have effect on carbon neutrality of biofuels oils but it may be unsustainable and influence lives of millions of people.

Despite the promising planes created by the governments, the increase of living standards may not occur if the government will not take into consideration the necessity of sustainable development. The advantages of higher income in households may be diminished by the higher cost connected to unsustainable policies. The increase of biofuels production has a significant impact on food prices. The first generation biofuels such as palm oil are often planted by food producers instead of food crops because crops used for biofuel production can be sell with higher profit. This puts food in direct competition with biofuels and leads to increase in food prices. The food prices have been rising over the year but since the introduction of the EU biofuel policy the food prices have increased more rapidly than in previous years. (see Fig. 5-4) However, the food prices are rising all over the world and cannot be influence by the single government policy.

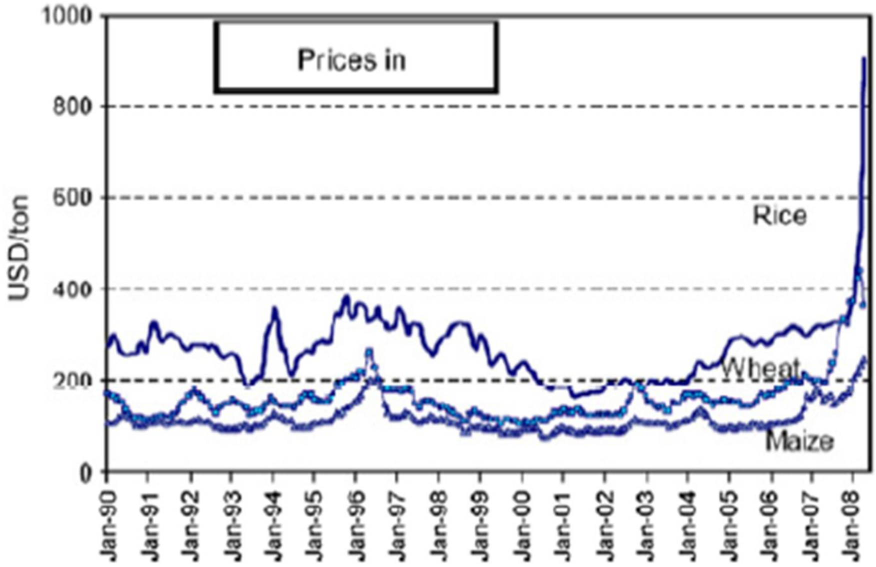


Figure 5-3 Fig. 4: Price of food crops from 1990 to 2008 (used in Zhou, 2009)

6 Greenhouse gas neutrality of biofuels

Since the recognition of climate change as a serious environmental problem which will influence the lives of millions of people all over the planet biofuels importance increased significantly. At the beginning of climate change talks, it was determined that CO_2 emissions are the main cause of the climate change. The political community did not pay much attention to other greenhouse-gases and focused primarily on the CO_2 emissions. Therefore, policies which were developed for mitigation of the climate change are focused on reduction of CO_2 and does not take into account other greenhouse-gases produced during the production process of biofuels.

The EU Directive 2003/30/EC, which is focused on the promotion of biofuels and currently in force, is a clear example of the carbon oriented legislative. Despite the fact that this legislative is focus on greenhouse-gas reduction in general it is clear that CO_2 emissions are the only one of the greenhouse-gases considered. The impact of the other greenhouse-gases produced during the biofuel production process is not mentioned in the EU Directive 200/30/EC and there are no indications that they were taken into an account by the EU Commission.

Biofuels were in the initial phase of their promotion seen as a carbon neutral. It was assumed that CO_2 produced during the use of biofuels were previously consumed by plants from which was the biofuels made during growth of crops. Plants need CO_2 in order to grow and store the carbon in their bodies. Based on this assumption, all the CO_2 emissions produced during the use of biofuels were consumed by the plant during its growing phase which should mean that use of biofuels do not produce any additional CO_2 emissions during the consumption process. However, the production process of biofuels is complex system. This process involves many side-products and creates many co-dependencies which also need to be considered in order to achieve more accurate result and determine actual impact of biofuels on our planet.

During the production process, there can be identify several different sources of greenhouse-gas emissions which are responsible for the reduction of greenhouse-gas savings. In the table 5-1, there are presented different sources of the greenhouse-gas emission during the production process. The table considers processes which have influence on the greenhouse-gas emissions from change of land until distribution on the EU market in the form of biofuel blend.

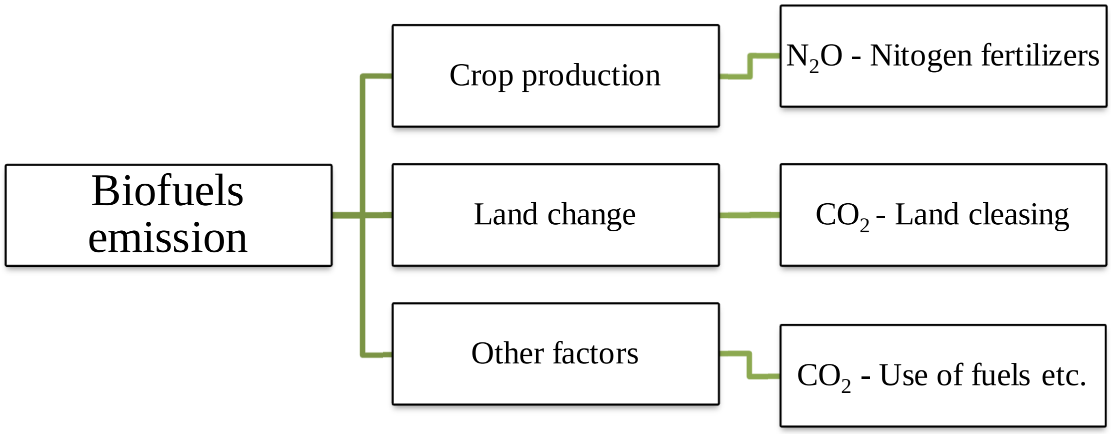


Figure 5-1 The three main factors negatively influencing the greenhouse-gas neutrality of biofuels (Source: own creation)

The life cycle of biofuels can be divided into three different production factors. Each production factor contributes to different extend and has different impact on greenhouse-gas neutrality of biofuels. The first of the factors occurs during the agricultural production of biofuel production and is primarily caused by the use of fertilizers which produce a substantial amount of laughing gas – N_2O. The second factor starts to have influence on greenhouse-gas neutrality before the actual production of the biofuels and is focused on the land changes done in order to satisfy the demand for the land on which is biofuel crop planted. The last factor influencing the greenhouse-gas emissions is the use of machinery during the production process which requires use of energy.

The calculation of the greenhouse-gas neutrality of biofuels it is important to take into consideration not only greenhouse-gas emissions released directly by biofuels but also biofuels occurring during production process. Furthermore, it is important to recognize different heat capturing capacities of different greenhouse-gases. The unification of these differences is necessary because of that greenhouse gas emissions are converted into the CO_2 emissions equivalents in order to achieve accurate results. Currently, emissions for biofuels are expressed. The official recognized CO_2 equivalent by the EU is expressed in terms of grams of CO_2 per MJ of fuel. (Commission of the European Communities, 2009)

In addition, the EU established a formula for calculation of greenhouse-gas emissions in the Directive 2009/28/EC. „Greenhouse gas emissions from the production and use of transport fuels, biofuels and bioliquids shall be calculated as:

$$E = eec + el + ep + etd + eu – esca – eccs – eccr – eee,$$

Where

E	=total emissions from the use of the fuel;
eec	=emissions from the extraction or cultivation of raw materials;
el	=annualised emissions from carbon stock changes caused by land-use change;
ep	=emissions from processing;
etd	=emissions from transport and distribution;
eu	=emissions from the fuel in use;
esca	=emission saving from soil carbon accumulation via improved agricultural management;
eccs	=emission saving from carbon capture and geological storage;
eccr	=emission saving from carbon capture and replacement; and
eee	=emission saving from excess electricity from cogeneration.“

(Commission of the European Communities, 2009)

The official formula to calculate the greenhouse-gas savings of biofuels set by the EU is important and necessary step forward in the future. This formula will allow obtaining more accurate results and revealing more relevantly the actual impact of biofuels on climate change.

6.1 Crop production

The emissions produced during the growing phase of biofuel crop are important factors which have a significant influence on the greenhouse-gas neutrality of biofuel production. They represent an important part of emissions produced and need to be taken in to an account. The use of nitrogen fertilizers for biofuel production increases the amount of greenhouse-gases in the atmosphere. The concept of carbon neutrality does not get influence as the main emissions produced are N_2O gas emissions also known as laughing gas but the greenhouse-gas neutrality is significantly changed. This is due to the fact that N_2O is one of the main greenhouse-gases. Moreover, N_2O has significantly higher ability to trap heat inside the atmosphere than CO_2. The impact of one molecule of N_2O is 296 times higher than impact of CO_2 molecule. (see Table 5-1) Due to the fact that the CO_2 equivalent of N_2O is significantly higher even the small amount of this gas causes a large reduction of greenhouse-gas emissions savings. According to Cherubini, et al. (2009) it is established that the amount of 1.325 per cent of N in synthetic nitrogen fertilizer is released in the atmosphere as N in N_2O.

Table 6-1 Global warming potentials of Greenhouse-gases (Withgott, 2010)

Greenhouse-gas	Relative heat-trapping ability (in CO_2 equivalents)
Carbon Dioxide	1
Methane	23
Nitrous oxide	296

In addition, the calculation of greenhouse-gas savings needs to distinguish many different factors. “Emissions from fields vary depending on soil type, climate, crop, tillage method, and fertilizers and manure application rates.” (Cherubini, 2009, p. 436) The highest amounts of emissions are produced in the tropical regions with high rainfall, such as evergreen rainforest biospheres. The cause of the increased gentrification in this environment is due to the low amount of oxygen in moist soil which provides good conditions for formation of N_2O gas. As the EU is importing the part of its biofuels from the regions outside its territory and the EU main importers are Brazil, Indonesia or Malaysia, which are all located in tropical regions with tropical evergreen forests, the amount of N_2O emissions produced during the biofuel production is significant. Figure 5-1, compares a different regions and different crops. Despite the temperate climate in Europe, figure 5-1 shows that maize and rapeseed produce more than 5 kilogram of N_2O-N ha^{-1} y^{-1}. The emissions by rapeseed are representing a serious problem as the rapeseed crop is the main source of biodiesel production and the most common biofuel crops produced in the EU.

Figure 6-1 N_2O emissions due to energy crop production and from the reference land-use systems cropland, grassland, natural vegetation and zero N input for the year 2000 (in kgN_2O-N ha 1 y 1). (Smeets, et al., 2010)

In the EU, the use of nitrogen fertilizers has increased in recent years as a result of biofuel production. On the one hand, the organic fertilization of soil by manure has slightly decreased by 5 per cent. On the other hand, the use of inorganic nitrogen based fertilizers has increased by about 1.4 per cent which resulted in increase of the level of nitrogen in soil by 0.5 per cent. (Britz, et al., 2009) These changes are significantly influenced by indirect but more importantly direct land use change. The Figure 6-1 shows a significant difference in emissions released between the wheat and rapeseed production. The rapeseed is currently the main crop used for biofuel production. As a result of this dominance, rapeseed desirability is replacing certain the attractiveness of wheat crop production and leads to the direct land change from wheat crop to rapeseed crop production and further leads to increase use of inorganic nitrogen fertilizers on these fields. In the EU, the wheat crop produces at least 1 kilogram of N_2O-N ha $^{-1}$ y $^{-1}$ less than rapeseed crop for biofuel production. When the emissions of N_2O released in the atmosphere during biofuel production are taken into an account, the levels of greenhouse-gas savings of biofuels compare to the fossil fuels are only around 43 per cent. (Smeets, et al., 2010; Biomass energy centre)

6.2 Impact of indirenct land use change

The impact of indirect land change on the greenhouse-gas neutrality of biofuels has not been in the attention of scientific and political community up until recently. Only in last few years, did started to raise the concern about the effects greenhouse-gas emissions released during indirect land change and put it into the centre of attention. Recent studies have brought significant results. Indirect land use change put the greenhouse-gas neutrality of biofuels into question. Many researchers has discovered shocking results and concluded that biofuels cannot be viewed as greenhouse-gas neutral. It is possible that the first generation biofuels not only do not reduce the greenhouse gas emissions in comparison to fossil fuels but as a consequence of indirect land use changes their use is actually producing more greenhouse-gas emissions and increasing the greenhouse gas emissions in the atmosphere accelerating the climate change.

In recent years, the phenomenon of indirect land use change is occurring more of often due to the increasing demand for biofuels which forces the agricultural production to intensify in order to achieve a desirable amount needed to satisfy market demand. The demand of the EU market is currently supplied by domestic production and imported biofuels mainly from Brazil, Argentina, Indonesia or Malaysia. The production of biofuels in these tropical countries is increasing due to the domestic demand but also the exporting potential which can provide a new source of income and improve their economics.

The biofuel import in the EU from developing countries such as Brazil or Indonesia is the main reason behind the indirect land use change as these countries have large areas of uncultivated areas which can be converted into arable land for biofuels production. The import into the EU has proven to be lucrative business and influenced crop production in many countries. Nowadays, around two-thirds of indirect land change in Indonesia is caused by increasing production of palm oil. Many uncultivated areas in these developing countries are covered by tropical evergreen forests which are hundreds of years and have been covering the land for many centuries. With the increasing age of the forest or any other ecosystem is increasing the capacity and amount of CO_2 emissions stored within this living organism. The ability to store CO_2 emissions is achieved due to the complex system of roots and increased mass of plants' bodies which provide large storage capacities. However, the largest capacity to store carbon has a soil. "Globally, the soil carbon pool is estimated to hold 2500 Gt of carbon, compared with 560 Gt carbon in vegetation and 760 Gt in the atmosphere." (Cherubini, et al., 2009, p. 436) The areas with a large storage capacity of CO_2 are on peat soil in the tropical forest which is causing a particularly large amount of emissions release from this region. The differences in greenhouse-gas emissions released in different tropical regions are presented in Table 6-2. According to the Table 6-2, the amount of the greenhouse-gas emissions released by tropical rainforest is more than six-fold higher than from other ecosystem in the tropical region. On the other hand, CO_2 emissions from the pastures are low. The change of pasture to arable land for plantation of biofuel crop will save a significant amount of CO_2 emissions and increase the greenhouse-gas savings of this biofuel production. However, this savings may be done only ‘cosmetically’ as more evergreen forest can still be cut down in order to make a space for a new pastures. This way producer will be able to prove that his production has a larger greenhouse gas savings and presents its biofuel crop as more sustainable but the practice of land change will continue and release greenhouse-gas emissions indirectly due to the biofuel production. The greenhouse-gas emission will increase despite the fact that pastures have a higher storage capacity than forests, however, they have much lower carbon storage capacity than rainforests.

Table 6-2 Greenhouse gas emissions (in CO2 equivalents) from the clearing of natural ecosystems for farmland, and follow-up emissions from cultivated organic soils (Bringezu, et al. 2009)

Region and event	Ecosystem	Unit	Selected	Min.	Max.
Amazonia: clearing	Tropical rainforest on mineral soils and wood removal before slash-and-burn	Tonnes CO_2 equivalents/ha	600	300	1000
Brazil-Cerrado: clearing	Campo Cerrado	Tonnes CO_2-equiv./ha	65	55	75
Brazil-Pasture: clearing	Grassland-savannah	Tonnes CO_2-equiv./ha	40	20	60
Southeast Asia: clearing	Tropical rainforest on mineral soils and wood removal before slash-and-burn	Tonnes CO_2-equiv./ha	600	300	1000
Southeast-Asia: follow-up emissions	CO_2 emissions from peat soils, plus N_2O emissions from cultivated organic soils	Tonnes CO_2-equiv./(ha·a)	99	21	273

On the global scale, the cropland continuous to expand despite the fact that forest areas has slightly increase due to the high prices of timber. Currently, the largest amount of land converted is from pastures. The land changes from forest to cropland is representing only 1.8 Mha of the 8.2 Mha converted. (Britz, et al., 2009) As shown on Figure 6-2, the indirect land change is occurring throughout regions with some exceptions such as Russia or Thailand where the land is converted back to uncultivated land. The indirect land change in the EU represents around 1.3 per cent of the land and covers 1.69 million of hectares. According to Britz and Hertel (2009) the global increase of emissions due to the increasing use of biodiesel on the EU market is 1472 MMT CO_2. This represents 42.2g/MJ of energy produced by biodiesel. The level of emissions for all biofuels will be even higher as this increase represents only biodiesel production and does not include bioethanol. “By using a worldwide agricultural model to estimate emissions from land-use change, we found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years. (Searchiger, et al., 2008) The change in net greenhouse-gas emissions of bioethanol in comparison to gasoline is between plus 50 to 93 per cent. (Searchinger, et al., 2008)

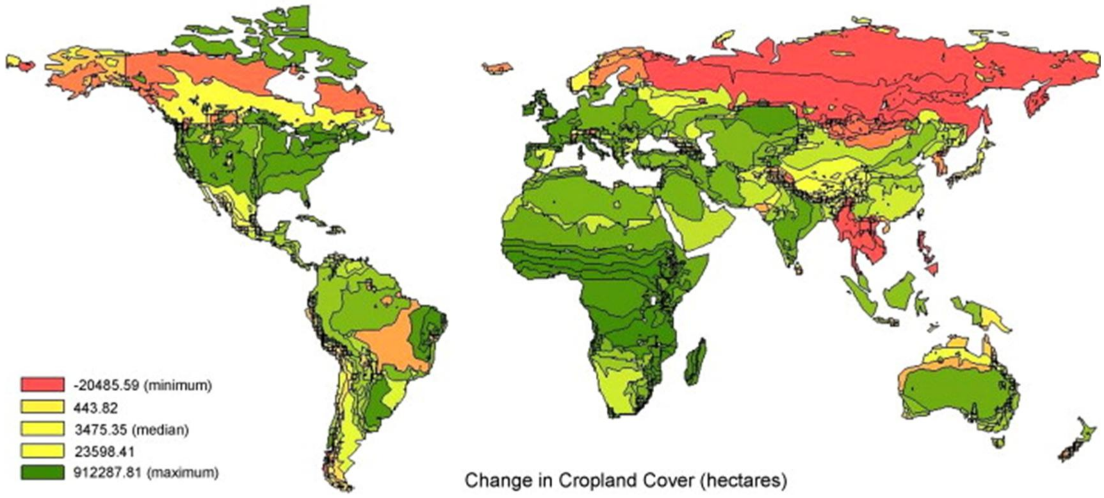


Figure 6-2 Change of cropland cover (Britz, et al., 2009)

6.3 Other factors

Despite the claim that biofuels are carbon neutral already in 1990s it was proven that biofuels are not 100 per cent carbon neutral. The life cycle of biofuel production is consisted of many different factors which reduce the greenhouse gas savings of biofuels. Some factors have a large influence on the greenhouse gas savings such as use of fertilizers or indirect land change with was discussed in previous sections. Other has less substantial influence on the greenhouse gas savings but should not be completely ignored. Between these factors belongs for example fertilization, harvesting of crop, processing, waste treatment or transportation of biofuels. These are some of the factors which have to some extend influence on the greenhouse-gas emissions.

The reason for the decrease of greenhouse gas savings is based on the fact that the use of energy, mostly fossil or fossil plus biofuels is necessary to power the machinery. The logistic represents a 3 to 5 per cent of energy which is necessary during the biofuels production process.(Richard, 793) In order to achieve the most efficient spread of the fertilizers and pesticides the airplanes are often use which leads to use of fossil fuels because biofuels are not available for common air transportation purposes yet. Another important factor is the transportation of biofuels to the market. Unlike with fossil fuels biofuels are not transported by pipelines between importing and exporting countries. Because of that the use of energy has to be provided in order to secure logistic between crop produce, factory and distributors. Despite the fact, that this practices are only representing a small amount of greenhouse-gases produced during the production it is necessary to take them in to consideration to achieve more precise results. When are considered only this emissions the greenhouse-gas produced around 27 grams of greenhouse-gas equivalent per MJ of energy in fuels which gives us around 70 per cent of greenhouse-gas emissions savings in production of bioethanol. (Searchinger, 2008) According to the Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus which was produced by the U.S. Department of Agriculture and the U.S. Department of Energy the life cycle emissions of the biodiesel provide the savings of 78 per cent of greenhouse-gas emissions in comparison to diesel fuel. (Sheehan, et al., 1998) When are considered only this emissions, as they were in 1990s, the greenhouse-gas emission savings are between 70 to 80 per cent. (Searchinger, 2010; Sheehan, et al., 1998)

6.4 Greenhouse-gas emissions in total

To sum up, every phase presented above has a certain impact on the greenhouse-gas neutrality of the first generation biofuels. When put together, these factors are not only greenhouse-neutral but they are in fact greenhouse gas positive in comparison to fossil fuels. The Figure 6-3 presents the increase of greenhouse-gas emissions in different phases of biofuels production. The sum of all greenhouse-gases produced during the production of biodiesel is by 50 per cent higher than diesel emissions. The emission of the bioethanol has even higher increase. In compare to its fossil equivalent the bioethanol realises nearly twice as much greenhouse gas emissions in the atmosphere.

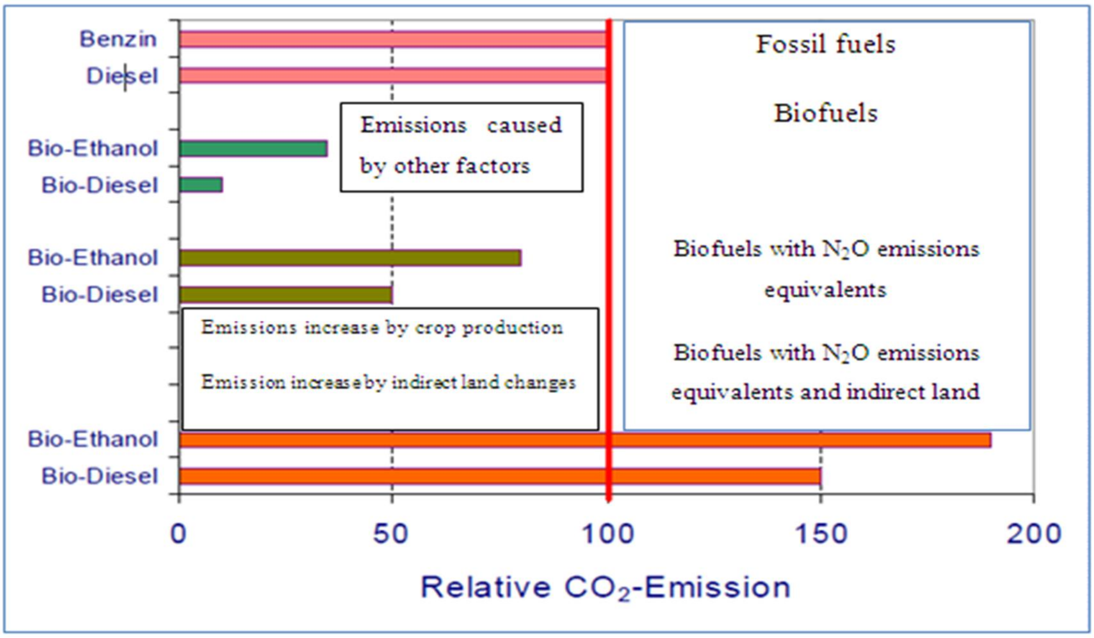


Figure 6-3 Relative CO_2 Emissions during the biofuel production (Privatew communication Puxbaum, 2010 based on Searchinger, et al., Science 319, 2010; Barnett MO, ES&T 44, 2010)

In addition, the table 6-3 presents the different emissions produced and the level of greenhouse-gas emissions their represents. It is clear that the indirect land change presents the largest proportion of the emissions. In total, the greenhouse-gas emissions produced by biofuels can be on average 245 per cent more than the greenhouse-gas emission of fossil fuels.

Emissions	Average of grams of greenhouse-gas equivalent	Percentage in compare to fossil fuels
Indirect land use change	156	170
Use of fertilizers	40	45
Other factors	27	30
Total	315	245
Fossil fuels	92	100

Table 6-3 Amount of emissions in percentage produced by different factors (Source: own creation, based on data from Searchinger, 2010; Sheehan, et al., 1998; Smeets, et al., 2010; Biomass energy centre)

7 Future solutions

For decades, it was recognized that climate change threatens our environment, our lives and lives of the future generation. Because of that it is necessary to take an action which will mitigate the impacts of climate change and help us to deal with problems connected to this problem. Biofuels supposed to be the part of the climate change mitigation precautions and help to reduce consequences. However, the production of biofuels in the last decades has proven to be unsustainable and have a negative greenhouse gas effect. The first generation biofuels which are dominating the current EU market have done more harm than good for the environment. Nevertheless, the biofuels are already introduced into the EU economic and its market and this project cannot be simply abandon. The billions of Euros have already been paid on the promotion of this alternative fuels and billions more will be spent in the next years. Therefore, it is important to present a certain alternatives which will allowed the use of biofuels on the EU market and will reduce the impact of these fuels on the environment. Furthermore, the abandonment of biofuels is not possible because the reserves of fossil fuels are running low and production of alternative fuel will be necessary to establish an energy security and secure economic stability in the future. Biofuels can at least partially help to achieve this important security and stability requirements for the stability of future of current and future generation.

Firstly, as a step towards the elimination of negative effects of biofuel production can be improvement of efficiency of production. The way to decrease the impact of biofuels on food prices is to use double and mix cropping system. In this system we plant two types of feedstocks: food and energy crop. The crops are planted at the same field but are harvested in different time. This mean, that at the same field can be produced rapeseed crop and wheat crop where rapeseed is used for production of biofuels and wheat is used to satisfy the food demand on the market. When used the double cropping system the second crop is planted after the first type of crop is harvested. In the mixed cropping system two different types of crops are planted at the same field simultaneously but the first crop is maturing earlier than the second one which allows the harvest earlier and leave enough space and nutrients for other crop to mature later in the season. (Tilman, 2009)

Secondly, the improvement of sustainability can be done through the crop residues. If the crop residues such as straws from rice or wheat are left on the field they have positive effects on the soil and help to reduce some of the problems connected to unsustainable production. Crop residues are rich on carbon, nitrogen and phosphor which are essential for the fertility of soil, they also lead to improving of carbon storage capacity of fields and minimize the possible soil erosions which often leave the field in devastating conditions and lead to decrease of productivity. (Tilman, 2009)

Thirdly, the use of the second and third generation may lead to mitigation of negative environmental effects of the first generation biofuels. Both generations, the second and third, belong between so called advanced biofuels due to the fact that they can be produced without increasing the pressure on food market and can be produced on the land which is not suitable for the agricultural production. Furthermore, both generation of biofuels have higher greenhouse-gas emission savings due to the fact that during their production is eliminated the main source of greenhouse-gas emissions of the first generation biofuels which are the CO_2 emissions released in the atmosphere by the indirect land change. Both generations are produced without the demand for the use of arable land during their production.

The second generation biofuels are produced from lignocellulosic biomass such as wheat straw, willow, forest residues or various garden wastes. Lignocellulosic biofuels are produced from materials that are easily accessible thanks to their low cost due to their origin from abandon non-food materials. Moreover, the use of fertilizers is not necessary during their production as the main source of lignocellulosic comes from side-products. The material is not gain from focused production of lignocellulosic biomass but is rather gain from timber or food industry which gives away the waste material which is useful for their production but can be used and its producers will be able to earn profit from production of lignocellulosic biofuels. However, this may bring us some limitation on availability of these materials as there will not be a specific amount of material produced for the single purpose of lignocellulosic biofuels but rather will be collected over other productions which may lead to the shortages of supplies. (Richard, 2010) In addition, another obstacle in lignocellulosic biofuel production is connected to the logistics. These materials have considerably lower bulk densities than grains, resulting in significant logistical challenges. ”The transportation fraction of the energy required to grow and deliver energy crops to a bio refinery is only 3 to 5 per cent for grains and oilseeds, but increases to 7 to 26 per cent for lignocellulosic crops such as switch grass, miscanthus, and other forages and crop residues. These transportation costs represent a diseconomy of scale for lignocellulosic biofuels that contrasts with, and at large scales can overwhelm, the economies of scale associated with advanced conversion technologies.“ (Richard, 2010, p. 793) The lignocellulosic production already exists and many resources are invested in the research to improve the production and solve the problems connected to the transportation. Despite these problems, lignocellulosic biofuels are offering one of the promising alternatives for the first generation biofuels and their importance will increase in the future. However, they will not be able to completely replace the first generation biofuels due to availability of lignocellulosic biomass and also the investment which were already done into the infrastructure.

The third generation biofuels are produced from algae or microalgae. So far microalgae are presented as the most promising source for the future production of biofuels. The possibility to produce the biofuels from microalgae is known already for 50 years since the Arab oil embargo in 1970s. The algae biofuels are offering the possibility to replace the first generation biofuels in the future. The main advantage of algae biofuels is due to the fact that algae production does not require arable land and eliminates the emissions caused by indirect land use change. (Wijfels, 2010)

The microalgae store its energy in form of oil which can be converted into biofuel by trans-esterification with short-chain alcohol. In order to produce the algae biofuels, microalgae has to be exposed by certain main inputs which are sunlight, water, CO_2, nitrogen, phosphorus, iron and in some case silicon. (Chisti, 2007; Wijfels, 2010) The commercial production of algae biofuels is commonly using the sea water for the production with supplements of phosphorus and nitrate.(Chisti, 2007) The body of algae is consisted of 7 per cent of nitrogen and 1 per cent of phosphorus. The use of phosphorus and nitrogen nutrients is essential for the production and without these nutrients it would be impossible to obtained desirable results. However, the current production on fertilizers in the EU is not able to satisfy demand. In order to achieve the required amount, the EU would have to produce 25 million tons of nitrogen and 4 millions of phosphorus which is more double amount of nutrients currently produced in the EU. In order to satisfy this demand for the future it will be necessary to recycle as many nutrients as possible. Moreover, this increase demand of nutrients may lead to an increase of prices of fertilizers in the future and lead to the increase of food prices due to the indirect pressure. This indirect pressure may be caused by increased prices of fertilizers which are essential for food production. The higher cost of production will lead to the increase of prices of food crops.

In addition to the possible impact on food prices in the future, the algae biofuels are currently facing another problem which is connected to the high costs of this fuel. The production of algae fuels is based on small scale production so in order to be successful in the future, the infrastructure for production needs to be developed and cost of the production needs to be decreased. „ On practical level, the scale of production needs to increase at least 3 orders of magnitude, with a concomitant decrease of the cost of production by a factor 10.“ (Wijfels, 2010p. 329)

In the future, the production of biofuels will need to consist from different sources. All three generations will play certain role in the production of biofuels in order to achieve the most suitable line between the cost of the production and sustainability. The investments made in to the first generation biofuels are extensive which means that despised their current impact on environment their production is most likely to continue in the future. However, with implication of some measures their sustainability can be improved. The second and third generations are offering the opportunity to satisfy the needs of further increasing demand on the EU market without causing further environmental damage on tropical rainforests and reduce the increase of emissions caused by biofuel production.

8 Conclusion

Despite the good intention which seems to be behind the idea of biofuel use for transportation, the introduction of the biofuels on the EU market was done prematurely. The EU did introduced the biofuels in transportation, invest billions of Euros into the project, promoted biofuels without actual knowledge of the amount of emissions their release and without consideration of how will the increase production of biofuels effect the environment and people all around the world due to rising food prices and deforestation. There is no doubt that the actions are necessary in order to mitigate the threat connected to climate change but this decision have to be make more carefully and cannot be based on precautionary principle. The precautionary principle is important tool which should be used in order to recognize problem and develop solutions. However, it cannot be used in order to implement solution. If there is not enough knowledge about side-productions which may be caused by these solutions we picked because it can be done more harm than good. Biofuels are a good example of such a failure of judgement. The emissions released by biofuel production and consumption can in some cases produce 50 to 100 per cent emissions more than fossil fuels which would lead to increase of greenhouse-gases in the atmosphere not decrease. This will lead to severe environmental problems in the future and negatively influence live of current and future generations. The EU as the leading actor in climate change negotiations and supporter of mitigation practices needs to recognize the failure of the biofuel policy and implement serious steps which will lead to more sustainable production.

The future of biofuels will be closely connected to development of the new practices of production such as double cropping. However, the more important role needs to be played by the second and third generation biofuels which are offering a significant improvement of biofuel sustainability for the future. They will lower the emissions release and avoid several environmental problems. Nevertheless, more attention and resources needs to be invested into a research of this advance generation biofuels. The improvement of infrastructure will be necessary in order to produce the biofuels from these resources and do not increase the prices of biofuels so they will remain a suitable substitute without putting a stress on the EU economy. Furthermore, the EU needs to develop more complex directive which will deal with all generations of biofuels and consider all environmental impacts of their production so the complex picture can be viewed more clearly and the guideline for production is set properly. The biofuels legislative needs to be binding and the EU Member States needs to harmonize their national policies with the EU policies in order to act according to a common interest and implement common approach which will allowed unified standards. Unified standards are necessary due to the international obligation of the EU, such as Kyoto protocol, but they are also important because of the import of biofuels on the EU market. If the EU wants to secure the sustainability of important biofuels the EU and its Member States need to set clear standards for import so no importing country can protest or find the way around the standards.

The demand of the EU for biofuels for transportation purposes has influence on nature and humans in different regions. These regions, such as Southeast Asia, are experiencing more serious environmental problems than does the EU. The production of biofuels in the tropical regions leads to defenestration, loss of diversity and soil erosions. Most of these countries belong between developing countries and traditionally have low environmental standards. However, the higher environmental standards set by the EU on imported biofuels may improve the environmental standards in these countries as they will try to fulfil the new standards set by the EU in order to qualify themselves for import of biofuels in the EU.

In addition, the EU should set stricter standard on use of fertilizers for production of biofuels. The higher restriction on limits of fertilizers in energy crop production will lead to significant decrease of greenhouse-gas emissions and reduce the amount of ozone depleting substances in the atmosphere. Despite the fact, that the reduction of fertilizers would lead to lower production of fields it would be desirable and compensated by environmental gains. The disruption of the production can be than supplemented from the increased production of the second generation biofuels.

To sum up, the first section examines the historical development and circumstances during which were suitability of biofuels for use as a supplement fuel in combustion engines recognize. The significant attention is paid to discussion of development of legislative framework behind the biofuels and their impact on the EU Member States and their domestic policies. Secondly, the research is focused on examination of different available types of biofuels and their categorization. Thirdly, this research examines current production of biofuels in the EU and the possible options of biofuel mixes on the EU market. It discusses the current and future need for biofuel import into the EU from other regions of the world. Following section is focused on effects of biofuel production on environment and the impact of different factors. It discusses environmental problems which occur on the EU level (use of fertilizers), problems outside the EU (deforestation) and problems on global scale (atmospheric emissions). The next section is focused the concept of greenhouse-gas neutrality. It examines three different factors which reduce the greenhouse-gas emissions savings of the first generation biofuels. It identifies different amounts of emissions released this factors. It also recognizes the difference in emission in indirect land change based on the difference in region and type of ecosystem. Finally, the last section is presenting the possible solution of reduction of greenhouse-gases released by biofuels. It discusses two possible ways to reduce the amount of greenhouse-gases released in the atmosphere. The first possibility is to improve the practices of production of the first generation of biofuels and the second possibility is to replace the first generation biofuel with the next generation biofuels.

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