Indirect Land-Use Change from Biofuel Production

- Uncertainties and Policymaking from an EU Perspective

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Uncertainties and policymaking from an EU perspective

Master thesis in Sustainable Development
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Indirect Land-Use Change from Biofuel Production. Uncertainties and policymaking from an EU perspective

TANIYA OFFERGELD

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Abstract: Due to the continuous extensions of biofuel production, indirect land-use change (iLUC) has come under particular scrutiny in the past years, raising sparked interest in EU policy-making and science. Green house gas (GHG) emissions from iLUC are generally not denied. The debate about iLUC is rather concerned in how far these emissions influence the climatic performance of the biofuel’s production life cycle. It seems to be clear that GHG emissions from iLUC are significant, though there is much scientific uncertainty in determining the estimation of emissions from iLUC. Thus EU policy makers are challenged to design appropriate policy frameworks in order to deal with iLUC emissions within the presence of scientific uncertainty. On top of this, policy makers are pressured in different directions by stakeholders. Generally speaking, NGO demand strict regulation on iLUC, while biofuel industry opposes such regulations.

The aim of this thesis is to investigate how EU biofuel policymakers can handle the iLUC issue, given the scientific uncertainty and the involvement of stakeholders. The main issue discussed in this paper is how to design policy regulations for iLUC without an established reasonable degree of certainty. The uncertainty lies in modelling of iLUC but also within the difficulties of including iLUC emissions in Life Cycle Assessment (LCA).

Therefore, the first part provides a sound and theoretical background and aims to explain how greenhouse gas (GHG) emissions are induced from iLUC. Also, main methodological features of LCA are presented. Furthermore, this chapter guides through the EU biofuel policy landscape to show recent enacted legislations associated to iLUC.

The second part of this thesis contains an analysis, demonstrating why it is challenging to model iLUC and to include this phenomenon into LCA. Additionally, within this chapter it is analysed how EU policy regulators deal with this range of scientific uncertainty to design an appropriate policy framework.

Followed by a discussion, the paper evaluates results, proving that setting policy decisions on iLUC in the presence of scientific uncertainty potentially runs the risk of limiting the attractiveness of the EU biofuel market. Alternatively, the inclusion of iLUC in EU policy could develop new opportunities to differentiate and promote the production of the most sustainable biofuels regarding their GHG emission performance. The importance of including stakeholder in decision-making processes is outlined. The issue around iLUC requires a holistic perspective in order to design regulations to reduce emissions most efficiently to achieve overall goals of the EU biofuel policy.

This thesis finds out that the EU has not made any clear decisions which leads to investment insecurity in biofuel technology. As biofuel technology plays an important part to reach overall environmental EU goals, there might be a risk of not fulfilling them. The EU hesitates to make a decision on iLUC due to the pressure, coming from the biofuel industry and NGOs. The rather vague scientific evidences on iLUC has influenced the debate among EU policymakers.

Past studies, research and policy papers have been done on published LCA studies and models to quantify GHG emissions from iLUC and therefore literature review is chosen as method for writing the present thesis.

Keywords: biofuels, indirect land-use change (iLUC), Life Cycle Assessment (LCA), EU biofuel policy, Sustainable Development

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Summary: Currently scientific practices for quantifying indirect land use change (iLUC) due to biofuel production rely heavily on global economic models that fail to give specific answer about the amount of GHG emissions from iLUC. Even though there is a general consensus within the biofuel science community that GHG emissions from iLUC are potentially important for the biofuel's climatic performance, EU policymakers have not decided yet whether and how to design legal frameworks for biofuels.

Achieving a low carbon based energy transport system rather a petroleum dependent one, the EU relies on biofuels as part of the solution. Potential environmental and climatic benefits of biofuels justify their industry extensions and the substitution of fossil fuels. If, however, iLUC emissions are significantly high the question whether promoting biofuels is an opportunity or even a danger for a low carbon future becomes controversial.

Catalysed by several iLUC modelling methodologies and studies, recently published, in the EU and the US, the topic around iLUC has gained attention among EU policymakers and within the scientific- and biofuel community. Here, this paper mainly investigates how the large scientific uncertainty on accounting GHG emissions from biofuels can be explained and how the EU’s policy landscape has been influenced under these conditions. The challenges that EU policymakers and regulatory agencies encounter when they are confronted to act on GHG emissions from biofuels and then dealing with the controversy about iLUC are presented.

This literature review finds out that if EU regulators decide to consider GHG emissions from iLUC due to biofuel production in any ways without changing overall goals for the transport sector where biofuels play a crucial role, the biofuel industry and investments are possibly going to decline. Thereby, a risk of not reaching the overall goals to a low carbon society arises. Setting and implementing policies for a sustainable future in the transport sector seems to be challenging within the context of scientific uncertainties and balancing various interests put additional pressure on the policy outcomes.

Keywords: biofuels, indirect land-use change (iLUC), Life Cycle Assessment (LCA), EU biofuel policy, Sustainable Development

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1 Introduction

Increasing energy use, global warming and an increase of carbon dioxide (CO$_2$) emissions from fossil fuels within the transport sector promote low-carbon technologies like biofuels. Most commonly used sorts of biofuels nowadays are bioethanol and biodiesel (Schmitz 2009).

Several studies and researches have shown that biofuel production reduces carbon emissions and has large climate benefits compared to fossil fuels (Kim & Dale 2005). However, monitoring greenhouse gas (GHG) reductions of biofuels and estimating their substitution efficiency to fossil fuels is subject to significant methodological uncertainty, inaccuracy and insufficient data. In how far the production of biofuels can save carbon emissions is therefore currently a controversial area among scientists. Recently, indirect land-use change (iLUC) GHG emissions due to the extension of biofuel cultivation have triggered a vivid discussion among scientists, politicians and the media. The debate is mainly concerned about in how far these negative effects$^1$ influence the climatic performance of biofuels. ILUC effects, particularly GHG emissions, are generally lacking in Life Cycle Assessment (LCA) studies, an internationally renowned method for evaluating the environmental performance of a product. Due to the insufficient inclusion of iLUC emissions in LCA results, there is a risk of producing misleading results regarding biofuel’s climatic performance. Thus an urgent need for a generic way of integrating iLUC in LCA studies is required.

Though it is generally acknowledged that iLUC emissions from biofuels may be significant, scientific evidence for estimating emissions from iLUC from both, biofuels and gasoline, is still in its infancy (Liska & Perrin 2009). Scientific uncertainty puts regulatory agencies and policymakers under pressure and confronts them with a dilemma whether to consider iLUC emissions from biofuels and how to calculate them. Policy regulators naturally look to science for guidance, but the presence of scientific uncertainty makes it difficult to formulate policies to avoid potentially extra emissions associated with iLUC.

In the past years the European Union (EU), a supranational institution for 27 member states which makes intergovernmental decisions based on negotiations of the member states, is constantly working on certain policy legislations and regulations due to fundamental uncertainties of iLUC related effects from biofuels. The European Directive on renewable energies (RED) published in 2009, is fundamental for the EU biofuel market as it addresses EU member states to produce at least 20 % of energy consumption from renewable sources by 2020 (Directive 2009/28/EC 2009). For reasons of standardisation, calculation rules and specific allocation methods for LCA regarding main- and co-products are stated in the RED, allowing better comparability between results of LCA studies. Here, the RED defines a certain lifecycle method to account the GHG emissions from biofuels. The questions, however, whether and under which circumstances the inclusion of GHG emissions from iLUC into LCA is possible, are addressed in this paper.

Despite numerous scientific studies and negotiations about scientific uncertainties, the European Commission (EC) has steadily delayed and postponed final legislative conclusions on iLUC.

1.1 Definitions

Land use change simply describes a transforming action that is carried out on a unit of land. This action is basically characterised by a diversity of change trajectories which are depended on the local conditions, regional contexts and external influences (Verburg 2009). Most terrestrial land-use changes influence the vegetation and soil of an ecosystem. Thus the amount of carbon sequestered in a hectare of land is affected.

Within this chapter, basically, two main land-use concepts, namely direct land-use change (dLUC) and indirect land-use change (iLUC), will be defined and related to the feedstock of biofuels.

Direct land-use change:

Direct land-use change (dLUC) occurs when biofuel feedstock (e.g. wheat for bioethanol or soybean for biodiesel) displaces a prior land-use such as forest land, grassland and native ecosystems. Thereby, possible changes of the carbon stock of plants and/or soils are generated. Energy crops for biofuels production cause land conversion from carbon storage to cultivated land for biofuels production. If there is no consideration of previous carbon storage, the

$^1$ ILUC may also have positive effects such GHG emission offsets due to by-products. By-products occur during the production process of biofuels and may lead to carbon net gain. These by-products may be processed and used as feed production (e.g. Dried Distillers Grains with Solubles) or for further electricity and heat production within combined heat and power ethanol plants (CHP) or for external electricity provision systems (Malins 2011).
reduction of GHG emissions of the biofuel chain will be overestimated (Gnansounou 2009). Contrary, dLUC also concerns the case when feedstock production on degraded soil contributes to the improvement of the soil carbon storage balance. Therefore, the choice of the previous state of land-use system can influence the GHG balance of the biofuel significantly (Gnansounou 2009). DLUC is included in the EU renewable energy directive, and carbon stock changes from dLUC must be accounted for in biofuels GHG emission performance.

Indirect land-use change:

Compared to dLUC taking indirect land-use change (iLUC) into consideration is subject to more complexity as the indirect conversion of arable land is related to global and dynamic spheres which make it difficult to draw accurate connections to biofuel production (Pandey 2011). It describes a displacement of current land-use to cultivate energy crops for biofuels which generates more land-use elsewhere (Gnansounou et al. 2008). This type of land-use change occurs if a different use such as food and/or feed production took place on land-used for energy crop cultivation and has therefore been displaced somewhere else. To a certain extent the demand for food or feed that has been produced previously remains and therefore its production is likely to be shifted elsewhere. As a result production of existing cropland might be intensified or further land is converted to cropland and/or pastureland. These emissions generate substantial CO₂-emissions, particularly if additional arable land is converted to cropland that had previously large carbon stocks such as forests, peat- and wetlands (Schubert et al. 2010). Environmental effects of iLUC are known as leakage (Croezen 2010). Even though the emissions arise somewhere else, they were mainly caused by energy crop cultivation. Consequently this type of land-use change is named indirect as changes do not take place at the biofuel production site itself, but rather elsewhere triggered through events at the production site. ILUC follows the main logic that the biofuel production competes for agricultural resources. This competition leads to an increase in prices of agricultural goods, causing additional land conversions of grasslands and forests to cropland. Additional land conversion promotes the loss of carbon that has been previously sequestered in grassland and forest ecosystems. In terms of a strict definition, iLUC applies for all biomass feedstock from any land that has been previously used for food/feed or fibre production, or even from land that has the potential to be used for food/feed/fibre production. Here, the underlying hypothesis is that any arable or pasture land has the potential to be used for food/feed/fibre production, so that the application of biomass feedstock production would reduce its opportunity value (Fritsche et al. 2010). Figure 1 below demonstrates one possible pathway of iLUC, exemplified on the U.S. market. Here, the global perspective of iLUC and its non-locality due to the non-locality of global commodity markets become clear.

Figure 1: One Pathway for Indirect Land Use Change
(Zilberman et al. 2010)
1.2 Aims and Objectives
The current debate about iLUC makes clear that negative effects of iLUC exists, but whether and how to incorporate them into LCA results and choosing appropriate accounting methodologies contains no scientific consensus. This leads to difficulties in policy implications to regulate iLUC and biofuels (Howes 2009). Avoiding under- and overestimation of iLUC GHG effects remains a major challenge for the EU biofuel policy; an incorrect policy could lead either to an expansion or to a decline of biofuels leading to suboptimal greenhouse gas emissions (IEA Bioenergy 2009).

The aim of this thesis is to investigate how EU biofuel policymakers can handle the iLUC issue, given the scientific uncertainty and the involvement of stakeholders.

The following research questions will be investigated:

- How is iLUC related to biofuel’s climatic life cycle performance?
- What are the major challenges to model iLUC and to include its emissions in LCA, leading to scientific uncertainty?
- How has the presence of scientific uncertainty influenced the EU policy design on biofuels so far?
- Who are the major stakeholder groups, and what influence do they have on the policy making process?

In order to answer the above questions the first part of this study describes main feature of LCA as technique to assess environmental impacts of a product and explains the relation between GHG emissions caused by iLUC from biofuels. Furthermore, the EU biofuel policy landscape is presented by reviewing past policy processes on iLUC. Also, relevant and significant documents such as legislations, studies and policy papers are addressed.

The second chapter of this thesis deals with an analysis on major challenges to model iLUC and its inclusion in LCA, following the questions why it is difficult to consider iLUC in LCA which leads to large scientific uncertainty of biofuel’s climatic performance.

Within the next chapter, the essay will conclude with a final discussion, analysis and evaluation of the main results. Here, the question in how far the issue on iLUC presents a dilemma for EU policy regulators of whether and how to calculate iLUC emissions in order to tackle unwanted side-effects. A brief look at the American legislations on biofuels and iLUC is presented to show how countries outside the EU approach and regulate the dilemma.

1.3 Limitations
Effects iLUC due to biofuel productions contain a broad spectrum of different environmental, social and economic impacts. Within this paper social and economic impacts from iLUC are left out.

In order to narrow down the environmental impact of iLUC and to reach the paper’s objectives, I paid particular attention to GHG balance, particularly carbon dioxide (CO₂), induced from iLUC impacts, leading to changes in the carbon balance of the soil. However, several studies have also highlighted that iLUC negative effects from biofuel cultivation affect other impact areas such as food-security, water quality and biodiversity (Dunkelberg et al. 2011). Also pressure on local water resources, disturbance of local land rights, impacts on food prices are indirect effects that have increasingly gained attention in science and the media. However, this paper pays less attention to these negative effects as most of the reviewed literatures provide reliable data mainly on GHG emissions from iLUC. The current debate about iLUC is heavily focused on GHG balance only which serves as guiding indicator in this paper.

2 Methodology
Literature review is chosen as methodology for the first part of his thesis. Recently, numerous scientific studies, anthologies and monographs have been published on the current debate about iLUC impacts from biofuel productions (Fehrenbach et al. 2009). Peer-reviewed research has been increased over last couple of years, providing information and thought-provoking impulses. Literature review allows systematic selecting, organising, summarising and synthesising main arguments, proceedings and circumstances of the current debate on iLUC (Fehrenbach et al. 2009). A detailed insight of the current EU policy discussion and opinions on how to include iLUC in LCA and options to deal with scientific uncertainties, constrained to the paper’s research questions, are provided. Here, I
would like to stress that the debate about whether and how to account GHG emissions from biofuel production and to construct policy frameworks accordingly is presently still heavily debated within the EU and this paper tries to consider and analyse the most recent events within EU policy and science.

The present work is heavily based on scientific articles, policy papers, LCA studies, case studies and technical journals. Researchers that mainly determine the current iLUC debate are e.g. Adam J. Liska, Timothy D. Searchinger, Seungdo Kim, Bruce E. Dale and E. Gnansounou. Not only these authors play significant roles within the thesis, also studies from the Institute for Energy and Environmental Research (IFEU) and from the Öko-Institut (Institute for Applied Ecology) based in Germany are essential for composing this paper. Especially, a controversial scientific paper which was published in 2008 by Timothy D. Searchinger and his team from the Woodrow Wilson School at Princeton University about the inclusion of iLUC effects in LCA studies has lead to continuous intense discussions about iLUC in public and science.

Policy papers, legislations and studies commissioned by the EU are significant literature sources for composing this thesis.

Most of the literature reviewed is written in English, only marginal parts, particularly research studies, are written in German where English translations have not been available.

3 Background

This chapter provides the theoretical background for the following analysis and discussion in order to meet the paper’s objectives. The first part of this chapter presents information about LCA and iLUC GHG emission from biofuels, while the second part gives an overview of the EU biofuel policy landscape on what has been done so far to deal with iLUC of biofuel policies.

3.1 Life Cycle Emissions from Biofuels

Emissions from land-use change caused by biofuel production have become an important and controversial issue of biofuel policy. Even though numerous studies were conducted that biofuel’s life cycle and to model iLUC effects have been made, there is still no sound and scientific consensus about a methodology to take iLUC GHG emissions into account (Yeh & Witcover 2010).

To understand why the inclusion of iLUC in LCA is subject to scientific uncertainty, leading to difficulties in designing policy frameworks for iLUC, this subchapter, belonging to the background part, introduces basic features of LCA and how land-use change (LUC) from biofuels triggers GHG emissions.

3.1.1 The concept of LCA and biofuels

LCA as a specific elaboration of a generic environmental evaluation framework is constantly gaining more attention from policy-decision makers. Most LCA studies provide guidelines for action and support negotiations and setups for political targets. In order to reach the paper’s main objectives this subchapter lays down a theoretical background on LCA which is regarded as one of the most appropriate and widely-used analytical tool to evaluate the GHG emissions from the biofuel production and use pathway (Gnansounou et al. 2008). The following introduction on LCA is essential to discuss the dilemma of EU biofuel policy later, facing a debate on science versus regulations:

LCA has been created as important and comprehensive method to analyse the environmental impact of products and services. It serves as tool for developing a quantitative assessment of materials, energy flows and environmental impacts of products, services and technologies. The result of an LCA allows comparisons between alternatives. LCA can be regarded as engineering tool that focuses on the studies on technical systems and their potential changes. The method has been voluntarily used to ensure that industrial systems do not exceed certain environmental thresholds.

The ISO2 14040-series provides an international standard for LCA, setting guidelines for evaluating environmental performances of products or services. This series of standards have been composed from 1997 and updated in 2006 and serve umbrella documents for defining the procedure of performing an LCA study:

“LCA is a technique for assessing the environmental aspects and potential impacts associated with a product, by

2 ISO stands for International Standard Organization.
• compiling an inventory of relevant inputs and outputs of a product system;
• evaluating the potential environmental impacts associated with those inputs and outputs;
• interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.”(ISO 2006)

This standard also mentions that within an LCA study the complete industrial system of a product or service is described, including stages like production, use and waste management. It means that LCA focuses on the evaluation of environmental load during their entire life cycle from cradle to grave. This implies that a product is followed from its initial stages where its raw materials from natural resources are extracted through its production-, use- and disposal processes. General categories of environmental impacts that require consideration are resource use, human health, and ecological consequences (ISO 2006). The ISO standards lay the foundation for the key features of the LCA methodology. This includes the following aspects that frame an LCA study:

• “LCA studies should systematically and adequately address the environmental aspects of product systems, from raw material acquisition to final disposal.
• The depth of detail and time frame of an LCA study may vary to a large extent, depending on the definition of goal and scope.
• The scope, assumptions, description of data quality, methodologies and output of LCA studies should be transparent. LCA studies should discuss and document the data sources, and be clearly and appropriately communicated.
• Provisions should be made, depending on the intended application of the LCA study, to respect confidentiality and proprietary matters.
• LCA methodology should be amenable to the inclusion of new scientific findings and improvements in the state-of-the-art of the technology.
• There is no scientific basis for reducing LCA results to a single overall score or number, since trade-offs and complexities exist for the systems analysed at different stages of their life cycle.
• There is no single method for conducting LCA studies. Organizations should have flexibility to practically implement LCA as established in this International Standard, based upon the specific application and the requirements of the user.”(ISO 2006)

Furthermore, the ISO 14040 explains the main phases of an LCA procedure: goal and scope definition, inventory analysis, impact assessment and interpretation of results:

![Life cycle assessment framework](image.png)

Figure 2: Life cycle assessment framework (ISO 2006)
Figure 2 does not only demonstrate the main stages of an LCA study, but also points out to the LCA’s applications like identification of improvement possibilities, decision making, market claims and choice of environmental performance indicators. All applications aim to change or improve, either directly through decision making procedures or more indirect ways such as influencing market behaviour or through improvement possibilities (Baumann & Tillman 2004).

Within the goal and scope of an LCA the product is defined and the purpose of the study is made clear. The intention of the study is included, providing the reason for carrying out the study and to whom the results will be are communicated with. The so called system boundaries are essential within this stage of the LCA as these boundaries govern the flow model of the life cycle stages, showing what processes are included and which are left out. The goal can possibly be process design-, operation- or policy-oriented, while the definition of the system is rather detailed regarding design or operation improvement. The system boundaries define the purpose of the study. For instance, the intent might be a comparison of various pathways of the same biofuel (e.g. bioethanol, biodiesel). Here, a so called Well-to-Tank (WtT) LCA is appropriate because the pathways do not affect the performance of the fuel combustion in the vehicle’s engine. However, if the LCA intends to compare selected biofuels with their fossil substitutes e.g. bioethanol blends vs. gasoline or when different kinds of fuels and blends are compared, the utilization stage plays an important role, because the energy that is required in the vehicle tank for a certain service (e.g. 100 veh. km) is dependent on the combustion performances, varying from one blend to another (Gnansounou 2009). Additionally, within the same step the functional unit is introduced, which serves in quantitative terms as a reference for inputs and outputs and enables a comparison of two different systems.

The second important step of an LCA is the inventory analysis where a model is created according to the goal and scope definition (Baumann & Tillman 2004). This model is often designed as flow model of a technical system that requires data retrieval and calculations to fulfil the functional unit. The impact assessment as the next step in an LCA study aims to describe the environmental loads that are quantified in the inventory analysis. Here, potential environmental impacts are evaluated and environmental aspects, including e.g. local air pollution, acidification, eutrophication, land use, ozone depletion etc, are analysed in detail. Finally, conclusions are drawn based on results gained in the previous steps and make recommendations according to the scope and goal definition.

An LCA study is based on (mathematical) models, displaying industrial systems, to analyse environmental impacts. Models within an LCA are often applied or accordingly modified to generate an emission inventory of the production life cycle and to enable accounting of the total GHG intensity of biofuels (Joseph Fargione et al. 2008).

Among the scientist community there is a broad consensus that LCA is one of the best methodologies to evaluate environmental burdens associated with biofuel production (Sanz Requena et al. 2010; Gnansounou et al. 2008). Emissions from biofuel production and processing have been analysed by several LCA studies (Ravindranath et al. 2009) and present that, except for maize ethanol grown in energy intensive processing systems in the USA, most biofuels have a GHG saving amount of about 20% till 80% compare to fossil fuels. However, these results do not include emissions form LUC, which may have significant influences on the net climate benefit of biofuel production and use. Here, the next subchapters are connected by introducing how GHG emissions from LUC, dLUC and iLUC are related to the increasing crop cultivation of biofuels.

### 3.1.2 GHG emissions from Land Use Change

Soils and plant biomass are known as the world largest biologically active storages of terrestrial carbon, containing about ~2.7 times more carbon than the atmosphere (Joseph Fargione et al. 2008). Biosequestration serves as a natural and biological process that implies the capture of CO$_2$ by photosynthesis and the sequestration of it in plants and soils. If native ecosystems are converted into cropland CO$_2$ is released, because of burning or microbial decomposition of organic carbon stored in plant biomass and soils. Fire that is used to clear the land or from decomposition of leaves and fine roots lead to a period where GHG are released during the decaying or burning process of coarse roots, branches, wood products. Therefore, land-use change (LUC) seems to be a significant large source of carbon emissions. LUC contributes to one third of the anthropogenic GHG emissions since 1750 and one-fifth of GHG emissions during the 1990s (Liska & Perrin 2009). If the current deforestation rate continues, the Amazon rainforest is predicted to decrease down to 40% by 2050, which would release around 32 billion metric tons of carbon (PgC) into the atmosphere (Liska & Perrin 2009). For 2100 it is estimated that globally 130 Pg of terrestrial carbon will be emitted due to LUC.
3.1.3 GHG emissions from direct Land Use Change

To produce biofuels farmers can directly remove more forests and grasslands. This action, implemented through fire or decomposition, releases carbon that has been previously stored in plants and soils (Searchinger et al. 2008). If the previous land cover is changed to the biofuel crop itself dLUC occurs. This leads to losses of the soil’s sequestration capacity and therefore additional GHG emissions are released.

GHG emissions from dLUC can be determined from the carbon balances of the previous land use and the land use for biocrops. The above-ground carbon content of existing vegetation (if any) and the below-ground (soil) soil carbon content need to be considered for GHG emission calculations. Each balance may be positive or negative.

The amount of CO\(_2\) that is released during that processes in the first 50 years is called carbon depth of land conversion (Joseph Fargione et al. 2008). Carbon debt can be understood as the time that is necessary to counter the balance of the amount of CO\(_2\) emissions released by the conversion of native ecosystems. According to scientists like Joseph Fargione biofuels from converted land can repay the carbon debt by having a less GHG emission loaded production and combustion than fossil fuels. However, until this carbon debt is repaid by biofuels, they have a larger GHG impact than fossil fuels have which they are supposed to replace (2008). This assumption is based on calculations on product demand, concessions and examples of different cases of native habits such as Brazilian Amazon to biodiesel, Malaysian lowland tropical rainforest to palm oil diesel and U.S. central grassland to corn ethanol. For example, the conversion from peatland to palm oil releases about 3452 tCO\(_2\)/ha which would require 423 years to repay the carbon debt. Together with his colleagues Fargione’s analysis suggests that biofuels that are produced on converted land are likely to have a larger GHG impact than fossil fuels over long periods of time. The EU renewable energy directive includes dLUC, so that carbon stock changes caused by dLUC must be accounted for in the biofuels GHG.

3.1.4 GHG Emissions from indirect Land Use Change

In contrast, defining and measuring GHG emissions from iLUC is more controversial (Liska & Perrin 2009). Within the context of biofuel production, iLUC follows the main logic that biofuel production competes for agricultural resources which leads to price increases in agricultural products. These price increases boost additional conversions of native habitats to cropland. ILUC is therefore likely to be triggered through higher crop prices and farmers respond accordingly by clearing more forest and grassland to replace crops for feed and food (IEA Bioenergy 2009). However, a general understanding of the exact causes of LUC is still scientifically not determined due to the complexity of driving forces, distant and social influences (Liska & Perrin 2009). For example, tropical deforestation is caused by more than 16 different drivers such as agricultural expansion, wood extraction or infrastructure development lead by several different underlying causes such as demography, economics, technology or politics.

There is a large variety of different models to quantify land use induced by biofuel crops. Two main, opposing model approaches, namely complex economic models and simplified models, can be identified that are often applied to track the GHG emissions from biofuels, particularly to calculate iLUC emissions (Fehrenbach et al. 2009). The estimated GHG emissions from iLUC induced by expansion of biofuel crops vary according to different models that are applied for quantification.

The complex approach comprises economic models which simulate the market mechanisms in numeric terms using multilayered models. Models such as equilibrium models that focus on the macroeconomy or the global economy and look for simultaneous equilibrium on all relevant markets belong to the complex approach. The Global Trade Analysis Project (GTAP), Dynamic Applied Regional Trade (DART) or Forest and Agriculture Sector Optimization Model (FASOM) are worth mentioning as examples for equilibrium models.

The simplified approaches cover many different types of models rather refer to models. The model described in Bauen et al. (2010), e.g., uses a causal descriptive approach where land use scenarios are formed by a reference expert group. Others use statistics of past land-use to predict future land use changes (e.g., Fritsche et al., 2010; Tipper et al., 2009).

Figure 3 (Berndes et al. 2011) gives an overview of different studies that have been conducted on iLUC GHG emissions from biofuels. Each study that is given in the figure below is either named after their founding researcher or according to their research institute where it has been developed. They all apply a different model to quantify. Therefore the result regarding the g CO2eq/MJ varies significantly between the studies. All studies amortise over 30 years of production for comparison and any value is normalised to 20 years.
Not only does the application of various models lead to different amount results of GHG emission of iLUC, but the actual amount is also heavily dependent on where and how agricultural activities expand or intensify. For example, the conversion of tropical rainforests and peatlands to agricultural land release large amount of carbon that could possibly take decades or centuries to offset with the carbon benefits connected to the consumption of biofuel (CBES 2009). Around a third of the total carbon in the world’s soils is stored in different types of peatlands. This is more than half of the current atmospheric stock of CO$_2$ (Rydin & Jeglum 2006).

Some models used to quantify iLUC give answers in terms of number of hectares. This requires biophysical models to derive the corresponding GHG emission balance. So, the calculation of GHG emissions from iLUC requires the coupling of economic and biophysical models (Fritsche et al. 2010), which adds another factor of uncertainty to the end results.

### 3.2 Characterisation of the EU biofuel policy landscape

After introducing LCA as quantitative assessment tool for environmental impacts of products and reviewing the relation between GHG emissions and iLUC due to biofuel production, this subchapter lays the theoretical foundation for the EU biofuel policy landscape. In line with the research questions, the following characterisation is done by explaining the evolution of the EU biofuel policy process and by reviewing most important policy documents, affecting iLUC regulations, in more detail.

#### 3.2.1 Key developments of the EU biofuel policy from 2000 onwards

The increasing production, share and consumption of biofuels, biodiesel and bioethanol, in the European Union (EU) mainly aim to secure energy supply within the transport sector. Biodiesel is the main biofuel that is used for the EU road transport with a biofuel market share of 80% in 2009 (8,820 ktoe), while bioethanol, mainly made out of wheat, sugar beet, corn and rye, accounted for 20% (2,210 ktoe) market share in the same year (Flach et al. 2010). The reason for the relatively low market volume of bioethanol is due to the so far less developed second generation of
cellulosic bioethanol, which is expected to develop progressively in the coming years (Flach et al. 2010). The total biofuel consumption in 2009 was around 11,030 ktoe. Biofuels are widely considered as an essential step to lower carbon emissions of transport (Ernst & Young 2011). Boosting the decarbonization of transport fuels, diversifying fuel supply sources and developing long-term replacements for fossil fuels are central goals within the EU biofuel policy (Schnepf 2006). In response, the European Commission (EC) has developed certain criteria and minimum GHG thresholds for biofuels which are particularly manifested in the Biofuel Directive (Directive 2003/30/EC), the Renewable Energy Directive (RED; 2009/28/EC) and the revised Fuels Quality Directive (FQD; 2009/30/EC).

The Biofuel Directive, published in 2003, sets a minimum percentage of biofuels to replace fossil fuels such as diesel and petrol within the transport sector in each Member State of the EU (Directive 2003/30/EC 2003). Here, the reduction of particularly emissions such as CO\(_2\) (carbon dioxide), CO (carbon monoxide), NO\(_x\) (nitrogen oxides), VOC (volatile organic compounds) is centred. EU Member States are addressed to ensure a minimum share of biofuels of 5, 75% that is sold on their market by 2010 (a reference value of 2005 lies at 2%). All Member States have to report their progress annually and if any Member State sets lower objectives and does not reach the target by 2010 justification of actions in front of the EC is required. However, the biofuels target is not mandatory, so no penalty for non-compliance is involved. All Member States are free to set higher standards. As a result, the degree of participation varies across EU Member States (Schnepf 2006).

The RED and revised FQD have both come into force in 2009 and regarding on energy in transport include the following targets that should ideally be reached by 2020:

- 10% of energy used within the transport sector to be renewable
- a minimum reduction in GHG emissions from road transport of 6%

Using today’s technology biofuels as renewable energy in transport seem to be a primary mechanism for meeting the EU’s 2020 (Ernst & Young 2011). The RED also includes certain calculation rules and a specific allocation method for LCA in order to standardise and make results from other life cycle analysis principles comparable. RED defines a certain lifecycle method. Based on this methodology, the EC presents calculated default emissions for different biofuel production pathways (Directive 2009/28/EC 2009). The basic LCA calculation for emissions is stated in the Annex V of the RED as follows:

\[ E = eec + el + ep + etd + eu - esca - eccs - eccr - eee \]

The calculation rules for LCA in RED enable better comparability between results of LCA studies, but also constrain other calculations methods and provide less interpretation freedom than the standardised LCA method, rooted in ISO 14040.

Additionally, the RED concretised the above targets by defining environmental sustainability criteria that for EU Member States that need to be followed in order to be eligible for financial support for the consumption of biofuels and bioliquids and contribute to the 10 % goal (Directive 2009/28/EC 2009). These sustainability criteria, serving as standards, refer to environmental and land protection and point out e.g. that the net increase in demand for crops caused by the promotion of biofuels lead to a net increase in the cropped area. As a result this could affect high carbon stock land and lead to high carbon stock losses. GHG savings from biofuels compare to fossil fuels plays a central role within the sustainability criteria catalogue. One criterion requires a reduction of at least 35 % GHG emissions of biofuels in comparison to fossil fuels. By the year 2017 biofuels need to save 50% less GHG emissions and by 2018 60%. RED and FQD currently refer that GHG emission from dLUC need to be taken into account. How to account iLUC remains unconsidered or only marginally touched upon. In order to support the implementation of the sustainability criteria the EC approved seven voluntary certification systems in July 2011:

1. ISCC (International Sustainability and Carbon Certification)
2. Bonsucro EU

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3 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; eee = emission saving from excess electricity from cogeneration (Directive 2009/28/EC 2009)
3. RTRS EU RED (Round Table on Responsible Soy EU RED)
4. RSB EU RED (Roundtable of Sustainable Biofuels EU RED)
5. 2BSvs (Biomass Biofuels voluntary scheme)
6. RBSA (Abengoa RED Bioenergy Sustainability Assurance)
7. Greenergy (Greenergy Brazilian Bioethanol verification programme)

The recognition of the above voluntary schemes applies directly to all 27 EU Member States. With the help of these certification systems distributors of biofuels can prove that their products meet the sustainability criteria, framed in the RED, and can be counted to the 10% goal.

3.2.2 Key developments of the EU biofuel market situation from 2000 onwards

The mentioned EU legislations affect among other forces the EU biofuel demand, production and consumption (Flach et al. 2010). Especially over the last ten years the biofuel industry has experienced a rapid growth. Driven by the EU Member States domestic consumption, the EU biofuel production has increased steadily during 2006 and 2008. But the yearly growth rate for biodiesel in the EU has been declined in mid 2008 due to low crude oil prices, high vegetable oil prices increasing biodiesel imports and the financial crisis (Flach et al. 2010). The bioethanol production, however, benefited from low feedstock prices and showed an increase in its yearly growth rate from 2008 to 2009.

Figure 4 shows the market development of biodiesel and bioethanol regarding their consumption, production and import from 2006 till 2011. Because the bioethanol production in the EU has started to establish recently in the past years, it is assumed that so far not all production facilities have reached full production capacity (Flach et al. 2010). However, the United States Department of Agriculture (USDA) predicts an increase of bioethanol production in 2011 as particularly the United Kingdom and the Benelux-countries aim to expand their bioethanol production facilities (2010). Most imported bioethanol reach the EU through Scandinavian countries such as Sweden, the United Kingdom and the Benelux-countries, coming mostly from Brazil, and according to the above figure imports of bioethanol rather tend to decline from 2008 onwards. The declining import and the growing production volume of...
bioethanol lead to the assumption that the bioethanol trade within the EU is likely to increase in the coming years (Flach et al. 2010).

Germany, France and Spain are countries within the EU that produce and consume the most amount of biodiesel. Figure 3 clearly demonstrates that the biodiesel production capacity is expected to stagnate, though biodiesel demand is likely to be the higher than bioethanol and has a market share of 80 % within the biofuel market (Ernst & Young 2011). Possible reasons for this current stagnate development are e.g. impacts of the financial crisis, growing imports from South-America and insolvency of some biodiesel operating companies in the United Kingdom, Austria, Germany and the Benelux-countries. Through figure 3 it becomes obvious that the EU biodiesel consumption is continually higher than the production. An increase in production capacity would cover the demand. Since mid-2009 the biodiesel import seems to rise which is possibly due to a sales volume increase of cost-saving Argentinean biodiesel on the European market. As a result, the European biodiesel production, involving higher costs, is constrained and also the capacity utilization is kept low (Flach et al. 2010).

Due to the rapid expansion of biodiesel in Europe in the recent years, producers face significant challenge of overcapacity. As a result, several biodiesel plants are shut down. Particularly, in Germany overcapacity is becoming and acute issue, where a biofuels tax has had the undesirable effect of causing demand to fall rapidly. During 2010, Germany, Europe's largest, operated at only about 50 % of capacity (Hunt & Hogan 2010). More than half of the 49 German biodiesel plants were not working at all and most operational plants were producing under full capacity. Also in the UK the biodiesel industry is also running at about half capacity and companies have recently cut back on production.

4 Analysis

Within this chapter past theoretical information will be critically analysed to investigate the ILUC uncertainty context and the dilemma for EU policy regulators in order to reach the aims and objectives of this paper.

4.1 A critical perspective on modelling ILUC and its incorporation in LCA

The question dominated in public debate and research related to ILUC is whether biofuels provide significant GHG reduction in comparison to fossil fuels if potential GHG emissions of ILUC are taken into account. Data gaps and significant scientific uncertainty are wide, making a clear answer to this question difficult and challenge EU policy regulators to deal with future promotion or reduction of biofuel regulations in order to minimize the risk of GHG emissions increase. The lack of scientific provisions to account GHG emissions from ILUC has developed significant loopholes in current EU biofuel legislations. This subchapter demonstrates why it is challenging to take emissions into account and why their incorporation in biofuel’s LCA is subject to scientific uncertainty.

4.1.1 Challenges of modelling GHG emissions from ILUC

The potential climatic impact of ILUC if included in biofuel’s life cycle is still scientifically controversial. One reason why the estimation of GHG emissions for ILUC is subject to significant uncertainty and research gaps is that ILUC can not be observed and ILUC correlations exist on a global level. Therefore, models need to make assumptions about future impacts and interactions between different input parameters (Ernst & Young 2011). Modelling helps to develop biofuel policy roadmaps, aiming to minimise GHG emissions from ILUC, and can be incorporated in LCA.

General challenges to calculate GHG emissions from ILUC are described are listed below.

- Effects of ILUC are regionally independent and their impacts are sensitive to complex mechanisms of the agricultural markets (Fehrenbach et al. 2009).4
- The use of one hectare of land for biofuel crop cultivation does not automatically relate to the same amount of hectare of further land that will be processed for the displaced food/feed and fibre. It is assumed that the potential crop yield per hectare of land is not fully exploited (Fehrenbach et al. 2009).

4 It needs to be kept in mind that certain researchers stress that ILUC can also be strongly influenced by regional and local drivers. Particularly, policy decisions on the regional agricultural sector, local infrastructure, geophysical suitability and pricing have impacts on ILUC on a global scale (Delzeit et al. 2011)
Generally, statistical data and monitoring data on iLUC is lacking. Also, there are large research gaps regarding the potentials beneficial impacts of arising by-products.

As a result most models to quantify GHG emissions of iLUC are complex constructed and lead to wide ranges of uncertainties.

As mentioned in chapter 2.1.4 iLUC there are currently two main, opposing method approaches to construct iLUC modelling, namely the complex approach and the simplified approach. This chapter has a closer look on models that can primarily be classified under the complex method approach, because those have been mainly used in decision-making processes in the EU and the US. Over the last decade, especially global economic models are grouped under the complex approach. Economic models, used to simulate the economic impacts of political decisions, are mainly subdivided between general equilibrium model and partial equilibrium model. While general equilibrium models\(^5\) rather focus on the macro economy as a whole, partial equilibrium models\(^6\) emphasise the individual market. Economic models provide estimates of what crops are likely to be substituted by using trade data and in which regions these commodities are traded. Key economic tools that influence biofuel policy in the US and EU are e.g. the Global Trade Analysis Project (GTAP), FAPRI (the Food and Agricultural Policy Research Institute) and FASOM (Forest and Agricultural Sector Optimisation model). These models have been applied in association with various LCA models such as GREET\(^7\).

According to many scientists like Adam J. Liska and Richard K. Perrin from the University of Nebraska especially economic modelling of iLUC contains uncertainties at every stage of modelling (Liska & Perrin 2009). Here, uncertainties are mainly found in the biofuel demand on world prices and agricultural commodities, responsiveness of crop yields and consumption and most of all land conversion due to price increases in certain ecological sensitive regions. The following study example demonstrates the nature of significant uncertainties of economic modelling of iLUC:

Together with his research team Timothy Searchinger, a researcher and lecturer in Public and International Affairs at Princeton's Woodrow Wilson School, published the first study of global iLUC from US ethanol production in 2008 and estimated that over a period of ten years 12.8 Mha of corn for bioethanol in the US would lead to over 10.8 Mha of new cropland around the world (Searchinger et al. 2008). ILUC GHG emissions are quantified in relation to an assumed US corn consumption of 56 billion litres up to the year 2016. The conversion of native ecosystems would release of further 3.8 billion tons of CO\(_2\) equivalent (CO\(_2\)e) emissions into the atmosphere over a time of range 30 years. As a result emissions due to iLUC alone added up to 104 gCO2eMJ\(^{-1}\) attributable to ethanol, which is higher than estimated emissions from gasoline that it is supposed to replace (Searchinger et al. 2008). Within this study Searchinger and his co-authors apply a set of partial equilibrium model, non-spatial economic models which are developed at the Centre for Agricultural and Rural Development (CARD) and the Food and Agricultural Policy Research Institute (FAPRI) of the Iowa State University. To measure world agricultural prices and land allocation the GREET model is used. The GREET model includes GHG emissions due to LUC into LCA. Furthermore, it contains assumptions and default values of GHG emissions of LUC depending on plant types and market shares of ethanol feedstock. Searchinger’s results have sparked a vivid discussions about the estimation and attribution of iLUC within the science community. However, critics argue that the applied model does not contain specific land supply structure for several countries (Sylvester-Bradley 2008). The overall model approach taken by Searchinger can generally be regarded as highly limited as it may not be feasible to model world economics at a level of precision that lead to quantifications of secondary or even tertiary iLUC effects embedded in a global, rather complex system. Furthermore, Searchinger et al. basically modelled forces of free market economics, policy instruments such as certification, tax rebates or investment in research as accompanying effects of biofuel incentives are marginally analysed. The study considers policy and regulatory conditions in the US, but differences between US bioethanol and EU biofuel initiatives are not being focused on. Prospects of policy and regulatory interventions arising from biofuel initiatives elsewhere outside the US are ignored. Additionally, trade effects such as a proportion of ethanol spike through imports from countries such as Brazil are not considered (Tan & Mathews 2009). The question whether and to what extent iLUC should be attributed to biofuels GHG performance requires consideration of interacting effects on policies relating to energy, development, conservation and other ecosystem services.

\(^5\) Typical general equilibrium model are GTAP – Global Trade Analysis Project and DART – Dynamic Applied Regional Trade.

\(^6\) Typical partial equilibrium models are FASOM – Forest and Agriculture Sector Optimization Model or CAPSIM – Common Agricultural Policy Simulation Model.

\(^7\) GREET stands for Greenhouse gases, Regulated Emissions, and Energy use in Transportation model. This model is commonly used lifecycle analysis of GHG emissions of the different stages from biofuel and gasoline production.
There are other economic model alternatives to Searchinger’s study. However, the general criticism on all economic models centres on their complexities which hardly enable transparency:

- The broad variation in the results of economic models make an application of their results for legislative purposes difficult (Kim & Dale 2011)
- There is still a wide range of data uncertainty, particularly on the increase of GHG emissions due to the amount and type of ecosystem such as forest and grassland that is converted by iLUC (Kim & Dale 2011)
- Another critique is that economic models also do not consider market distortions enough (e.g. custom duties) (Fehrenbach et al. 2009)
- The large variety of input parameters used in economic models lead to complexities (Fehrenbach et al. 2009)
- Due to the high complexities there is a lack of traceability in economic models (Fehrenbach et al. 2009)
- The large quantity of input data and high degree of model development expertise make it hard for policy-makers and people who are not deeply involved in the model development to understand the results (Kim & Dale 2011)
- At the same time the complexity of economic models is not sufficient to include all relevant factors to calculate GHG emissions from iLUC (Fehrenbach et al. 2009)

While Searchinger et al. explains that about 9.1 ha or natural resources ecosystems are converted to croplands for one terajoule (TJ) of bioethanol, the US Environmental Protection Agency (US EPA) developed a methodology, involving a serious of relevant models, that estimates the same amount of bioethanol 4.4 ha/TJ (Kim & Dale 2011). The California Air Resource Board (CARB) applies the Global Trade Analysis Project (GTAP) model and estimates a conversion of 5.1 ha of natural ecosystems to croplands for one TJ bioethanol. However, the GREET model, an LCA model applied by Searchinger et. al., shows a conversion of 1.6 ha/TJ bioethanol. These models plus the GREET model demonstrate that chosen assumptions and parameters such as size, types and locations of the converted natural ecosystems lead to divergent results.

The detailed table shown in figure 6 provides an overview of various economic models and how they differ significantly in their results regarding LUC impacts from biofuel demand. Here, the range in results can partly be explains by significant properties that need to be included in the models such as land-expansion and agricultural expansion.
4.1.2 Limitations of LCA to incorporate iLUC: A problem of scope

Not only the modelling to compute iLUC presents a scientific challenge to include iLUC in LCA studies, but also the definition of the system boundaries and the reference system make the inclusion of iLUC in LCA studies critical and challenge biofuel regulations. Policy regulations that promote biofuels such as RED require GHG emissions reporting through LCA studies or similar calculation guidelines for accountancy, ensuring that biofuel lead to a GHG emission reductions relative to fossil fuels. Often these policies tend not to distinguish between two different LCA approaches, namely attributional LCA (ALCA) and consequential LCA (CLCA), which lead to misinterpretations of results and no clear comparisons between results derived from different LCA type can be made (Brander et al. 2009).
Attributional LCA (ALCA) provides information about input and output physical flows of products, showing their impacts of the production processes, their consumption and disposal. The flows of the production system are based on average data and with the help of ALCA information on the average unit of product is provided. This LCA approach is rather static and therefore dynamic processes are not considered. Price variations, changes in demand or technological improvement are not accounted by static modelling.

In contrast, consequential LCA (CLCA) evaluates changes that are produced by the studied system, based on a system-wide approach where system boundaries are expanded to consider the impacts of influenced activities (Gnansounou et al. 2008). Information about emissions both inside and outside the life cycle of the product is provided. CLCA is therefore appropriate to study iLUC as it seeks to inform policy makers on the broader impacts of policies, intending to change levels of production.

ALCAs enable results with certain levels of accuracy and precision. CLCAs, however, are highly dependent on economic models representing relationships between demand for inputs, prices elasticities, supply, and market effects of by-products (Gnansounou et al. 2008). Such models, proven formerly in this paper, are subject to inaccuracy or less precision and therefore should be interpreted with caution.

Figure 7, take from the technical paper of Brander et al. 2009, below summarises main key differences between both LCA approaches:

<table>
<thead>
<tr>
<th>Question the method aims to answer?</th>
<th>Attributional LCA</th>
<th>Consequential LCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the total emissions from the processes and material flows directly used in the life cycle of a product?</td>
<td>ALCA is applicable for understanding the emissions directly associated with the life cycle of a product. ALCA is also appropriate for consumption-based emissions accounting.</td>
<td>CLCA is applicable for informing consumers and policy-makers on the change in total emissions from a purchasing or policy decision.</td>
</tr>
<tr>
<td>Application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Boundaries</td>
<td>The processes and material flows directly used in the production, consumption and disposal of the product.</td>
<td>All processes and material flows which are directly or indirectly affected by a marginal change in the output of a product (e.g. through market effects, substitution, use of constrained resources etc).</td>
</tr>
<tr>
<td>Market Effects</td>
<td>ALCA does not consider the market effects of the production and consumption of the product.</td>
<td>CLCA considers the market effects of the production and consumption of the product.</td>
</tr>
<tr>
<td>Time scales, means by which change is promoted, and magnitude of the change</td>
<td>ALCA aims to quantify the emissions attributable to a product at a given level of production at a given time.</td>
<td>CLCA aims to quantify the change in emissions which result from a change in production. It is necessary to specify the time-scale of the change, the means by which the change is promoted, and the magnitude of the change.</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>ALCA has low uncertainty because the relationships between inputs and outputs are generally clear</td>
<td>CLCA is nearly always highly uncertain because it relies on models that seek to represent complex socio-economic systems that include feedback loops and random elements.</td>
</tr>
</tbody>
</table>

Figure 6: Key differences between ALCA and CLCA (Brander et al. 2009)

ALCA compares the emissions from the production processes of various products and enables opportunities for reducing emissions within the life cycle by recognizing improvements in production and processing efficiency and/or
new technologies that can be applied. Regarding iLUC however, ALCA is not suitable for assessing changes in
emissions which result from changes to the output and even other life cycle stages of a product. These impacts are
outside the scope of an ALCA. Presently, CLCA is adopted as appropriate method for quantifying GHG emissions
from iLUC as an output of a product, in this case biofuel production. Taking into account both, direct and indirect
effects may therefore be according to Brander et al., specialists of Ecometrica, of higher importance to policy makers
than ALCA (Brander et al. 2009). Past LCA studies show that recently CLCA has already been applied to assess
iLUC caused by corn production for bioethanol purposes in the USA to evaluate GHG emissions from iLUC due to
crops consumption (Kloverpris et al. 2009). The EU RED is however largely consistent, except for the treatment of
excess electricity from co-generation, with ALCA. If the EU manages to find appropriate methods to account effects
of iLUC the application of CLCA will be inevitable. Here, the results from CLCA and ALCA, created for the RED
approach, need to be analysed and used separately and not summed up together, because the suggested result would
neither show absolute emissions from the production of biofuels, nor the explain relative changes in emissions due to
changes in the level of production.

4.2 Analysis of the EU biofuel policy landscape: Regulations within
the context of scientific uncertainty

“Policymakers cannot afford the luxury of ignoring the many impacts of their actions, for it is the
summed impacts, intended and unintended, that determines whether a regulatory intervention has
advanced, or even retarded, the approach toward sustainability.”(Allenby 1999)

The above quotation clearly demonstrates that policymakers are increasingly more aware of the importance of
environmental impact assessments for their legislative actions and also points out that there is often range of
scientific uncertainty involved when it comes to policymaking. In the previous chapters the scientific uncertainty of
modelling of GHG emissions from iLUC has been shown, provoking an ongoing and controversial debate about
whether and how to include a policy framework for this issue. This subchapter, therefore, presents how the scientific
uncertainty of iLUC is reflected in EU biofuel regulations and what the outcome means for policymakers.

EU GHG emissions targets within the transport sector will heavily depend on the promotion of biofuels until the year
2020 at least. The uncertainties about iLUC GHG emissions, analysed previously, lead to difficulties to find out to
what extent and through which instruments iLUC related regulations can be established. In terms of iLUC policy
decision makers are currently dealing with a dilemma as the nature and scale of GHG emissions from iLUC is
scientifically disputed. Under the conditions of uncertainty the iLUC dilemma for policy makers is shown in the
figure 8 below:

To see how the EU tries to overcome this dilemma it is worth to have a closer look how effective policy changes
have been in the past.

One way of dealing with the dilemma is that the EU intensively has recently intensively invested in research on
iLUC and biofuels. In response to RED and FQD which promote the expansion of biofuel use within the EU and
growing concerns about the climatic impacts of biofuels, the EU launched several studies and literature reviews
about iLUC in 2009, 2010 and recently in 2011. To model and analyse iLUC and provide respective quantitative
estimates of its effects various research services commissioned by the EC substantially contributed to carry out the

<table>
<thead>
<tr>
<th>iLUC hypothesis is true (iLUC is relevant)</th>
<th>Take iLUC into account in bioenergy policies (do not reject iLUC hypothesis)</th>
<th>Neglect iLUC in bioenergy policies (reject iLUC hypothesis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ok (error of misestimation persists)</td>
<td>Incorrectly reject the hypothesis</td>
<td>Type II error i.e. too little or “wrong” structure of bioenergy</td>
</tr>
</tbody>
</table>

Fig. 7: The iLUC dilemma (Gawel & Ludwig 2011)
four investigations. Here, the EC’s Joint Research Centre (JRC), the Institute for Environment and Sustainability (IES), the Institute for Energy (IE) and the Institute for Prospective Technological Studies (IPTS) are worth mentioning, playing a major role in composing the studies on iLUC. Centrally for the published studies in 2009 and 2010 (except the literature review study) is to find out appropriate calculation tools to model and measure iLUC with its effect:

- The IFPR applies a modified MIRAGE model together with 2 alternative policy scenarios and 5 biofuel incorporation scenarios. MIRAGE is regarded as computable general equilibrium model for trade policy analysis.

- JRC and the IPTS test a variety of different partial equilibrium models on iLUC such as AGLINK, ESIM and CAPRI (DG-AGRI & JRC 2009).

- JR and ISPRA composed a study that includes comparisons between partial and full equilibrium models (e.g. AGLINK-COSIMO from OECD, CARD from FAPRI-ISU, IMPACT from IFPRI and G-TAP from Purdue University) to model two different EU biofuel scenarios (Edwards et al. 2010).

The fourth study, a literature review, examines the impact of the EU biofuel policy and possible changes in EU biofuel trade policies on global agricultural production and environmental performance due to RED (Al-Riffai et al. 2010). This report which was in March 2010 is called Global Trade and Environmental Impact Study of the EU Biofuels Mandate and summarises main findings of the three modelling studies in order to present a clear comparison between different models to measure iLUC and possible scenarios. Together with the Imperial College of London the following table 8 on the next page gives an overview of the comparison between the models used in the studies from 2009 and 2010:
<table>
<thead>
<tr>
<th></th>
<th>IFPRI-MIRAGE</th>
<th>JRC-IPTS AGLINK-COSIMO</th>
<th>JRC-IPTS ES III</th>
<th>JRC-IPTS CAPRI</th>
<th>FAPRI-CARD (as used in JRC-IE)</th>
<th>IMPACT (as used in JRC-IE)</th>
<th>GTAP (as used in JRC-IE)</th>
<th>LEITAP (as used in JRC-IE)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model Type</strong></td>
<td>GE</td>
<td>PE, dynamic recursive</td>
<td>PE, comparative static</td>
<td>PE, comparative static</td>
<td>PE</td>
<td>PE</td>
<td>GE</td>
<td>GE</td>
</tr>
<tr>
<td><strong>Regional</strong></td>
<td>All</td>
<td>52 countries</td>
<td>EU27, Turkey, USA</td>
<td>EU27 + 33 non EU</td>
<td>All</td>
<td>All</td>
<td>All, in 87 regions</td>
<td>All</td>
</tr>
<tr>
<td><strong>Crops</strong></td>
<td>VQ, PO, SC, SB, WT, SD, PO</td>
<td>WT, VO, MA, SC, SB, OS, VQ, WT, MA, SB</td>
<td>WT, MA, OC, OS, VO, SB</td>
<td>Amble crops, SC, SB, WT, MA, other cereals</td>
<td>WT, MA, SC</td>
<td>VO, WT, MA, SC, SB</td>
<td>WT, MA, SC</td>
<td></td>
</tr>
<tr>
<td><strong>Disaggregation of oilseed crops</strong></td>
<td>Yes, (rape, soy, palm, sunflower) – see p. 89</td>
<td>No (P.23)</td>
<td>Yes, 3 individual oilseeds (P. 101)</td>
<td>Yes, 2 individual oilseeds (P. 161)</td>
<td>Yes (P. 29)</td>
<td>No (P. 37 of GE Literature Review)</td>
<td>No (P. 37 of GE Literature Review)</td>
<td></td>
</tr>
<tr>
<td><strong>2G Biofuels</strong></td>
<td>Yes, exogenous</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Co-products</strong></td>
<td>Yes (but not glycerol from biodiesel) – see p. 89</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Co-product protein content modelled?</strong></td>
<td>Yes for molasses [p. 89]</td>
<td>No for DDGS (modelled by energy content – p.50)</td>
<td>Yes, but for DDGS assumed exogenously (P.25)</td>
<td>ILxvell &amp; non-nutrients treated separately (P.25)</td>
<td>No (P. 81)</td>
<td>Yes (P. 29)</td>
<td>No, co-products not modelled</td>
<td></td>
</tr>
<tr>
<td><strong>Yield growth modelled as a function of demand growth?</strong></td>
<td>Yes (see P. 33)</td>
<td>Yes (P. 58)</td>
<td>Yes (P. 61)</td>
<td>Yes (P. 73)</td>
<td>No (Lywood 2009), with some modification of yield for crops (ADDG UK 2009)</td>
<td>Yes (P. 58)</td>
<td>Yes, using yield-price elasticity of 0.25 in all regions</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Idle land modelled separately or as part of forest/grassland?</strong></td>
<td>Idle land not modelled – externalisation assumed to be in forest or pasture (P.56)</td>
<td>Idle land not modelled – externalisation of cropland into pasture not modelled in EU15 (P.100)</td>
<td>Idle land not modelled – externalisation of cropland into pasture not modelled in EU15 (P.100)</td>
<td>Idle land not modelled (see <a href="http://www.capi-model.org/fm4_e.html">www.capi-model.org/fm4_e.html</a>)</td>
<td>No specified. In EC reports</td>
<td>Idle land modelled separately (P. 58)</td>
<td>Not specified. In EC reports</td>
<td>Not specified. In EC reports</td>
</tr>
<tr>
<td><strong>Source of historic trend data</strong></td>
<td>GTAP-7 which is based on FAO for crops (P.20)</td>
<td>FAO for crops (P.22)</td>
<td>Not specified. In EC reports</td>
<td>FAPRI (see <a href="http://www.capi-model.org/fm4_e.html">www.capi-model.org/fm4_e.html</a>)</td>
<td>FAPRI (see <a href="http://www.capi-model.org/fm4_e.html">www.capi-model.org/fm4_e.html</a>)</td>
<td>GTAP-E</td>
<td>Not specified. In EC reports</td>
<td>Not specified. In EC reports</td>
</tr>
<tr>
<td><strong>Impact of extensification modelled endogenously?</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Emissions from fertilizer use modelled?</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>GHG emissions from land conversion modelled?</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Via IMAGE</td>
</tr>
</tbody>
</table>

1. GE: Computational general equilibrium models explain the relationship between supply, demand, and prices across all sectors of the economy and assess the impacts of changes within sectors on the rest of the economy over time. PE: Partial equilibrium models consider only a subset of sectors of the economy (e.g., energy, agriculture, forestry) and model the impacts of changes within these sectors over time.
2. MA: maize; PO: palm oil; CC: oil crops; OS: oilseeds; SB: sugar beet; SC: sugarcane; SO: soy; VO: vegetable oil; WT: wheat.
3. 2G: second generation biofuels.
4. From feedstock production only.

Figure 8: Comparison of General Model Characteristics (Akhurst et al. 2011)
Besides the above comparison the literature review states that iLUC is of serious concern regarding its climatic impacts and that a high degree of uncertainty regarding their measuring effects exists. An administrative agreement on iLUC emissions from biofuels between JRC and the Directorate-General for the Environment (DG-Env) addresses the wide range of uncertainty within the composed studies, commissioned by the EC, as following:

“The JRC has identified in its report on biofuels, that there are significant doubts about greenhouse gas savings from biofuels because of considerable uncertainties including those relating to the indirect effects arising form the displacement of agricultural production.” (JRC 2009)

In 2011 another two more studies have been recently published to improve previous data and to document methodological progresses. One study with the title Estimate of GHG emissions from global land use change scenarios follows the methodology developed by the JRC (2010) for estimating changes in GHG emissions from global LUC due to increased biofuels demand. The methodology for global modelling calculations, run by the International Food and Policy Research Institute (IFPRI), is applied. Compared to the new (2011) study, the previous (2010) analysis provided much higher estimations of LUC due to 8.6% biofuels consumption in 2020 (Marelli et al. 2011). The other study, published in October 2011, is called Assessing the Land Use Change Consequences of European Biofuel Policies, and applies an updated version of the global computable general equilibrium model (CGE), MIRAGE-Biof, as well as a revised scenario describing the EU mandate based on the National Renewable Energy compare to the previous report in 2010 (Al-Riffai et al. 2010). The most important change compared to the previous study is the definition of the scenario considered such as size of the mandate and ratio biodiesel/ethanol (Laborde 2011).

Especially, the sustainability criteria that were fixed in the RED, supported by seven certification systems, are debatable. Though the EU’s sustainability criteria catalogue considers GHG emissions due to LUC and rule out biofuels produced from feedstock grown on certain lands as unsustainable, it is not guaranteed that emissions from iLUC are taken into account (Lendle & Schaus 2010). The criteria within the RED suggest certain minimum reduction values for GHG emissions, but iLUC is not considered when those values were calculated and determined. Despite these objections, coming mainly from NGOs (European Environmental Bureau 2009), the version of the sustainability criteria without taking iLUC into account were agreed due to the lack of scientific certainty including inadequacies in the models, assumptions and data used. Instead the EC aimed to compose a report about iLUC from biofuels. In order to make a policy decision on iLUC the EC gave several studies, introduced in the beginning of this paper, in service and researchers worldwide investigated iLUC intensively. The previous chapters of this paper, however, proved that there are wide variations among the result, making a consistent evaluation and transparency for policy decision-makers difficult. Therefore, the EU was not able to develop policy regulations on iLUC in 2010, but acknowledges that iLUC leads to significant GHG emissions increases:

“[…] the Commission acknowledges that indirect land-use change can have an impact on greenhouse gas emissions savings associated with biofuels, which could reduce their contribution to the policy goals, under certain circumstances in the absence of intervention. As such, the Commission considers that, if action is required, indirect land-use change should be addressed under a precautionary approach.”(European Commission 2010)

At that time a legislative proposal how to consider iLUC in the EU has been shifted to July 2011 as more impact assessments and studies are required. However, the EC formally considers the four policy options that address the regulation of negative effects from iLUC:

1. take no action for the time being, while continuing to monitor
2. increase the minimum greenhouse gas saving threshold for biofuels
3. introduce additional sustainability requirements on certain categories of biofuels
4. attribute a quantity of greenhouse gas emissions to biofuels reflecting the estimated indirect land-use impact

Further studies that have been released by the EC, briefly introduced in chapter 2.1.1, proved that iLUC due to biofuel production leads to a large increase of GHG emissions.

Based on these results the first of the above mentioned policy option seems to be meanwhile unlikely to be favoured as basis for the future EU iLUC policy regulations. Rather the last option seems to be realistic (Vogelpohl et al. 2011).
applying a methodology such as the \textit{iLUC factor} according to the German Oeko-Institut. This methodology allows implementing iLUC mitigation credits, incentives, offsets, penalties or bonus for each biofuel. This policy approach is widely discussed in scientific literature (Ernst & Young 2011) and has already been applied at a federal level of the United States e.g. through California’s Low Carbon Fuels Standard (LCFS).

With the integration of an \textit{iLUC factor} the EC is facing the dilemma that most types of biodiesel would not reach the required CO$_2$ mitigation values due to calculated \textit{iLUC factor} (Vogelpohl et al. 2011). However, biodiesel presents with about 80% the largest share of the European biofuel market and if biodiesel would not be counted as contribution to the 10% goal of the RED the demand decreases. On the one hand the EC is not ignore the significant impacts of iLUC due to large amount of published studies that prove the significant impact of iLUC and on the hand investments of economic actors within the biodiesel sector are affected. As a result investor confidence might decrease. Based on this dilemma a decision to design a policy approach for iLUC has been postponed to the end of 2011. In the meanwhile observations show that the EU tries to combine policy option 2 and 4 in order to overcome the dilemma. Hereby, biofuel specific \textit{iLUC factor} will be introduced in the year 2018 and first, on a short term perspective, increases of CO$_2$-mitigation values are preferred to address the debate about iLUC. The CO$_2$-mitigation values do not include iLUC in their calculation, but here the biodiesel industry is not disadvantaged to other biofuel industries while \textit{iLUC factor} requires higher standards especially for certain biodiesel types than for other biofuels. So the biodiesel industry has time to prepare accordingly till 2018.

4.2 Analysis of the stakeholder debate on EU policy impacts regarding iLUC

The previous subchapter already approached to mention that the EU policy process on iLUC connects to various key stakeholders and experts such as the fuels industry, farmers, governments, NGOs, academic institutions, scientists and consultants that would be affected by legislations and policy instruments. Therefore, relevant stakeholders attempt to influence the outcome of legislations or regulations. As the European Union is continuously growing, the role of lobbying is also about to expand dramatically (Smallwood et al. 2008). This subchapter introduces two opposing, key stakeholder groups, namely the biofuel industry and NGOs, by pointing out their interests and in how far they have been influencing the EU policy making on iLUC. Here, the context in which iLUC policy its scientific dispute must be considered is clearly shown.

The biofuels industry and interest groups that promote biofuels such as the German association for the oil and protein plants, named \textit{Union zur Förderung von Oel- und Proteinpflanzen e.V. (UFOP)}, are major stakeholders in the debate about iLUC and mostly strongly oppose to high iLUC reference values for GHG emissions. Especially the biodiesel industry complains about the EU published studies, introduced in the paper, as according to the industry a very negative image of biodiesel is portrayed in them. Pierre-Antoine Vernon, a project manager of the European Biodiesel Board, states that if the GHG impacts due to iLUC estimated by these studies were calculated into GHG savings currently attributed to biodiesel, it would not be possible for most types of biodiesel to achieve the GHG saving goal of 35% required under the RED, rising to 50% in 2017 (Voegele 2011). Also, Vernon stresses that if the studies iLUC values would be added into the into the GHG calculations for biodiesel, the biodiesel use within the EU would be ruined. At the same time Mr. Vernon predicts that the high iLUC values estimated by the studies will not essentially determine future EU biofuel policy as he complains that the studies and their modelling are still having a shaky scientific basis. A compromise legislative outcome would be more like. Furthermore, voices coming from the biodiesel industry add that iLUC is rather theoretical and by attributing those theoretical GHG values to biodiesel massive economic damage to the European biodiesel industry would be caused. Based on the average biodiesel sales volume in 2008 till 2010, the UFOP even claims investment protection for all existing biodiesel types and production plants, so that economically incentives maintain. Dieter Brauer, UFOP’s vice chairman, strongly opposes the introduction of iLUC factors, based on the EU studies. According to Brauer the study, particularly, carried out by the

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8 The methodology \textit{iLUC factor} according to the German Oeko-Institut has been developed to avoid the complex modelling of agricultural markets. Mainly, they are based on the assumption that additional biomass production leads to additional LUC (Fehrenbach et al. 2009). First this methodology approach has been called \textit{risk adder}, but in 2008 it was renamed to \textit{iLUC factor} (Fritsche et al. 2010). For the estimated calculation simple data and allocated to biomass production are used. The \textit{iLUC factor} follows the idea of presenting sectional average in relation to the respective biomass yield per hectare, while ignoring regional effects. Additionally, the \textit{iLUC factor} methodology assumes that pattern of global trade in agricultural commodities can be derived from observed trade trends. Due to this assumption \textit{iLUC factor} does not consider potential iLUC that occurs within a country, because intra-national trade information is usually not given.
4.4 The US policy design to face GHG emissions from iLUC

The debate surrounding GHG emissions from iLUC has not only increasingly got more attention from science and policymaking in the EU, but also in the USA certain regulatory treatments regarding iLUC and its context of scientific uncertainty have been made and discussed at the same time. This subchapter briefly introduces main landmarks of US biofuel policy and how the iLUC dilemma within the context of scientific uncertainty is tackled. As a result parallels and differences between the US and the EU can be observed and it is made clear in how far EU landmarks of US biofuel policy and how the iLUC dilemma within the context of scientific uncertainty is tackled. As scientific uncertainty have been made and discussed at the same time. This is proved by several stakeholder meetings, workshops and consultations, increasingly organised by the EC. For policymakers it is a balancing act to protect and improve the biofuel’s investor confidence and to make a policy proposal to mitigate the potential, significant amount of GHG emissions from iLUC at the same time, while not setting up ambiguous policy frameworks that include lacks of clarity. This policy uncertainty restrains investments in renewable energies as the uncertainty of how GHG emissions of biofuels are calculated investors have difficulties in determining how the market will react to the GHG performance of a particular biofuel (Ernst & Young 2011). Insufficient investment in current biofuel technologies would implicate difficulties in achieving the volumetric targets mandated in RED and FQD.

By some industrial stakeholders already argue that alone the RED and the FQD, referring to dLUC only, together with their introduction of sustainability requirements have economically negative impacts on feedstock producers. Additional requirements to mitigate potential iLUC would make their compliance more challenging for the biofuel industry and therefore problematic to sell their products into the EU biofuel market (Ernst & Young 2011).

In contrast, NGOs pressure the EC to make a legislative proposal based on the latest scientific results and give each feedstock a specific iLUC factor that reflects their GHG emission values. This statement is made clear in a letter from a network of NGOs, including BirdLife International, ClientEarth, the European Environmental Bureau, Transport and Environment, Greenpeace and Wetlands International, to the former EC president José Manuel Barroso (Wates 2011). The NGOs declare the iLUC issue to be the main obstacle to develop and promote biofuels in order to reduce GHG emission. When the RED was agreed upon in 2008, the EC was asked to solve the problem by the end of 2010, taking the best available science into consideration. However, the policy proposal has always been postponed. The EC has sponsored increasingly research projects to investigate iLUC and renowned scientists from all over the world intensively have started to investigate the GHG emissions from iLUC. The NGOs point out that so far most of the published results go in the direction those GHG emissions due to iLUC are significant. In the letter to Barroso NGOs claim that the latest impact assessment study, published by the EC sadly proves that an increase of iLUC from biofuels will lead to massive destruction of forests, wetlands, grasslands and their carbon stocks plus negative impacts on biodiversity and water are also results. Out of these reasons NGOs urges the EC to take to action and delaying a policy proposal seems to be irresponsible to avoid the mentioned damages. The only credible solution is to put an iLUC factor for different types of biofuels into the upcoming proposal (Wates 2011). However, the EU debates about an introduction of an iLUC factor earliest in 2018, so that especially the biodiesel industry has time to prepare accordingly. Here, environmental NGOs critics that biofuels, having potential high GHG emissions due to iLUC are not considered at first. NGOs state that if GHG emissions from iLUC due to biofuel production are not avoided from the beginning, the dilemma solving is not central in current iLUC policy decision making processes (Vogelpohl et al. 2011).

Both voices, from the biofuel producer’s side and the concerns of the NGOs, have put significant pressure on the EC policy process. This is proved by several stakeholder meetings, workshops and consultations, increasingly organised by the EC. For policymakers it is a balancing act to protect and improve the biofuel’s investor confidence and to make a policy proposal to mitigate the potential, significant amount of GHG emissions from iLUC at the same time, while not setting up ambiguous policy frameworks that include lacks of clarity. This policy uncertainty restrains investments in renewable energies as the uncertainty of how GHG emissions of biofuels are calculated investors have difficulties in determining how the market will react to the GHG performance of a particular biofuel (Ernst & Young 2011). Insufficient investment in current biofuel technologies would implicate difficulties in achieving the volumetric targets mandated in RED and FQD.

4.4 The US policy design to face GHG emissions from iLUC

The Energy Independence and Security Act of 2007, also known as EISA and signed under the presidency of George W. Bush, was a milestone in American biofuel energy policy. Main aims of this act are energy independency and security, the increase of the production of renewable energy fuels and the promotion of research on GHG capture and storage options (EISA 2007). The EISA demands that all transport fuels, sold in the US, comprises a certain amount of biofuels and requires a renewable fuel standard (RFS) that sets an upper limit of GHG emission per unit of various biofuel types. Within the same year the government of California published another major regulation for biofuels, namely the low carbon fuel standard (LCFS). This standard aims to reduce the average GHG emission of fuels by a certain percentage amount each year until the target of 10% reduction is achieved by 2020. The GHG emissions from biofuels calculated in those mentioned regulations are done by the application of LCA. The EISA states that not only GHG emissions from dLUC are to be included in the LCA, but also GHG emissions from iLUC. Here, the dispute...
among scientists is intense as the LCA studies mandated in EISA have their technical requirements that are challenging to implement in order to include GHG emissions from iLUC. Technical challenges already have been introduced in chapter 3.1.2 in this paper and basically deal with questions of allocation and system boundaries. Furthermore, uncertainties of the underlying model studies to account GHG emissions from iLUC have not been fully assessed and research to validate iLUC of biofuels is still going on. Models such as FASOM, GTAP and FAPRI are primarily used for legislation in the US and California.

In 2009 the California Air Resources Board (CARB) approved the LCFS by adopting iLUC factors for biofuels. The CARB created so called lookup tables for the most relevant fuels used in California and the data already include fuel-specific iLUC factors, determined by modelling (California Air Resources Board 2009). A following summary of iLUC factors published in selected lookup tables is given in the figure 9 below:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Pathway Description</th>
<th>Direct Emissions</th>
<th>Land Use or Other Indirect Effect</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>average crude oil delivered to CA refineries, average efficiencies</td>
<td>95.9</td>
<td>0</td>
<td>95.9</td>
</tr>
<tr>
<td>Ethanol from Com</td>
<td>Midwest average 80% Dry Mill, 20% Wet Mill, Dry DGS</td>
<td>69.4</td>
<td>30</td>
<td>99.4</td>
</tr>
<tr>
<td>Ethanol, CA average</td>
<td>80% Midwest average 20% CA Dry Mill, Wet DGS, NG</td>
<td>65.7</td>
<td>30</td>
<td>95.7</td>
</tr>
<tr>
<td>Ethanol from BR sugar</td>
<td>average production processes</td>
<td>27.4</td>
<td>46</td>
<td>73.4</td>
</tr>
<tr>
<td>Diesel</td>
<td>average crude oil delivered to CA refineries, average efficiencies</td>
<td>94.7</td>
<td>0</td>
<td>94.7</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>from Midwest soybeans</td>
<td>21.3</td>
<td>62</td>
<td>83.3</td>
</tr>
</tbody>
</table>

Fig. 9: Selected Life-Cycle GHG Emissions of (Bio) Fuels in the LCFS Carbon Intensity Lookup Tables (Fritsche et al. 2010)
CA = California; DGS = Distillers Grains and Solubles; NG = natural gas; BR = Brazil

The CARB generated these values with a GHG emissions model, namely GREET that has been developed by Argonne National Labs. The LCFS has become operational in 2010 and the data for GHG balances are constantly reviewed and adjusted. Therefore, CARB is cooperation with several expert groups from US EPA (US Environmental Protection Agency) and universities to improve and extend iLUC to biofuel pathways. Other US States have also started to work on iLUC policy regulations similar to the LCFS and most probably will adopt certain GHG values (Fritsche et al. 2010).

Critical voices towards the inclusion of iLUC in LCA determining policy choices explain that there are still large modelling uncertainties. Introducing iLUC in biofuel regulations would cause additional uncertainty, because the performance standards under which biofuel facility and the product’s GHG performance will be judged and controlled by regulations. (Zilberman et al. 2010). Investors in biofuels need to understand what rules and costs are associated with certain policy compliance. Here, uncertainty serves a disincentive for investments. A major critique on adding an iLUC penalty to biofuels is that through iLUC regulations other actors such as the biofuel producers, investors are suppliers are made responsible for actions they do not control and argued to be far outside their responsibility (Zilberman et al. 2010) as GHG emissions from iLUC are likely to occur on a global scale.

According to these policy landmarks it becomes clear that in the US the issue about iLUC has gained much earlier attention in policy regulations though there is still a lack of scientific certainty. Setting regulatory standards and iLUC penalties in the presence of scientific uncertainty, policymakers run the risk of creating counter-productive rules as estimated default values might be not fully scientifically tested (Liska & Perrin 2009). Continuously, the
scientific community elaborates more precise, empirical data, improve modelling tools and get a better insight of how to approach and minimise the uncertainty and complexity involved in iLUC analysis. Here, the advancements in science of iLUC have not yet been reflected by changes in biofuel regulations and include still outdated calculations to estimate iLUC.

Not only the stakeholders, introduced in the previous chapter, influence the policy process, but also 27 EU equal member states follow their own interest likely driven by the motivation of state sovereignty. Finding compromises and a consensus seems to be more challenging than in the US as more actors are actively and equally involved, pressuring rulemaking. Interestingly, the US mainly based its policy regulations on an iLUC factor, while iLUC factor in Europe have not yet been integrated in the policy design. During the 2007, when the RED was developed, some parties and countries proposed to include an iLUC factor into the GHG balance of biofuels, but the final decision of the European Parliament and the Council decided not to do so. Together with the German researche Uwe R. Fritsche and his research team from the Öko-Institut, Energy and Climate Division, it can be stated that in comparison to the Californian LCFS, the EU RED scheme in its present format with regard to favouring an iLUC factor to lower the iLUC risk of biofuels is flawed (Fritsche et al. 2010). Opponents against the application of an iLUC factor warn that it could bring unintended negative consequences for some of the EU’s wider renewable energy goals such as the RED. Recently, the EU has intensively started a debate about an iLUC factor to penalise biofuels that are more environmental harmful. However, it seems there is not consent and that the methodology of iLUC factor stays under discussion (ENDS Europe 2012a)

5 Discussion

After analysing the current scientific context on iLUC and its policy framework related to their methodological and decision-making challenges, this chapter views the findings and critically debates and generates suggestions for conclusions.

The main focus of this paper centres on the question if and whether GHG emissions due to iLUC of biofuels determine the policymaking process of the EU. Hereby, following results can be drawn from the previous investigations:

- Models can serve as helpful tools to derive iLUC. However, the presented challenges show that various models differ significantly in their results and approach to quantify iLUC.

Together with several researchers from the German Institut für Energie- und Umweltforschung Heidelberg GmbH I agree that the broad variation in the results of the models is currently the core problem for their application for legislative purposes (Fehrenbach et al. 2009). The calculation results of the economic models are hardly transparent to those not involved (e.g. policymakers) in their development due to their complex structures and large parameter input. Each of the model, displayed in figure 6, is complex and each one has own strengths and weaknesses. In order to rely on certain models to construct biofuel policy regulations a review of these models is required to understand the wide range of results and what factors the models are most sensitive to, what are the constraints or each model and how accurate each model represents different sectors. Furthermore, the required assessment needs to examine in how far the proposed models could be tailored to biofuels to develop good practice guidance for iLUC modelling due to the extension or reduction of future biofuel production in certain regions. The significant variability not only in the results and the quantity of literature and models that investigate iLUC impacts of different feedstock is likely to be time-consuming and complex for policy makers to gain overviews of the scientific landscape. Conducting a broad literature review is required to enable transparency for EU decision-makers. So far the EU has commissioned several literature reviews in the past, most importantly however is that these need to be continuously updated according to the latest scientific finding on iLUC. As long as accounting methods remain non-transparent there is a lack of being able to create political legitimation.

- The integration of iLUC in LCA poses methodological hinders, and adds to the uncertainty

CLCA seems to be more adequate type of LCA for decision-makers to rely on and seems to be more applicable for counting GHG emissions from iLUC. However, I would like to stress that CLCA has its methodological limitations and is associated to a large range of uncertainties in its results. CLCA includes dynamic, economic concepts like marginal production costs and developments of supply and demand elasticity, leading to conceptual complexities and results are highly sensitive to its assumptions. The last row of figure 6 clearly explains that CLCA is largely based on those economic models, discussed in the latter sub-chapter, which include wide range of uncertainties and data gaps at various stages, leading to a poor analysis. The scientific uncertainty makes CLCA less well defined than ALCA and allows a higher degree of interpretation that can be used to support various viewpoints and interest groups. This means for policy decision-makers that they need to be aware of the intent of published studies and what role certain
interest groups (e.g. the biofuel industry, NGOs and governments) have played in the study’s development and/or results analysis. If iLUC is therefore considered in LCA studies, the results of GHG emissions would be rather uncertain and hard to define.

- The so far delaying of EU policy decisions in iLUC leads to uncertainty within the biofuel industry

The recent published studies and literature reviews, mentioned in chapter 2.2.2, on iLUC published by the EC proof that this issue has become a central topic within the EU biofuel policy. Though the results vary from study to study, they mainly show that the amount of GHG emissions from iLUC is likely to be significant. Recently, the EU invested intensively into research and policy analysis on iLUC. A final policy decision on whether and how to regulate iLUC has, however, so far not been undertaken by the EC. It seems that the EC acts careful towards iLUC decisions as the RED’s targets that require a large extent of biofuels for the transport sector are not supposed to be weakened. Endangered by so far not decided iLUC regulations the uncertainty in the biofuel industry sector increases and the investment interests for biofuels are about decrease. A final decision on iLUC policy has been postponed several times, though in March 2012 the EC is expected to comment on further action. Under uncertainty procures the time being need for further research on iLUC accounting seems to be reasonable for the EU to delay legislative actions that are likely to have impacts on the European biofuel markets and on the RED targets. Then the question arises for how long this decision delaying can be continued. As there is currently a vivid discussion about iLUC in the media, among scientists and policy decision-makers, and the biofuel market gets continuously nervous and uncertain about future investments, the EU is pressured to make a clear decision about how to handle GHG emissions from iLUC politically and how to develop further biofuel policy. Not only the scientific uncertainty, but also the uncertainty about the future market situation of biofuels, pressure EU policy makers (Roundtable on Sustainable Biofuels 2010). By steadily delaying clear-cut policy decisions, the pressure coming from the biofuel site increases as the uncertainty and nervousness about policy decisions within the biofuel market also increases. Delaying decisions is therefore not evaluated as a long-term strategy the EU can lean on. Decisions for future actions need to be designed to calm down the biofuel industry.

- At the same time making a policy decision on iLUC and achieving the EU’s RED targets are heavily dependent upon the biofuel industry sector

The previous discussion point states that the biofuel industry and future investments are already uncertain due to the hesitation and delaying actions of the EU. Also, it seems that the targets of the RED are not to be changed or weakened by the EU and so an increase of biofuels is central for the coming years in order to achieve the RED goals. If iLUC regulations would lower the investment interest in biofuels, the achievement of RED targets would be endangered. Making a policy decision on iLUC requires considering possible consequences for the biofuel market and on how overall biofuel policy goals are going to be affected. The strong dependency on certain interest groups raises the question in how far the delaying action of the EU is driven by the level of scientific certainty or lead by interests of the private sector. While writing this paper I realized that results on GHG emissions from iLUC published by certain think tanks, universities and policy consultants are interest motivated. At the beginning of this paper I mentioned that policy makers look at science for guidance, but here I put this statement into perspective and would like to refer to the central and strong role of stakeholder within the European iLUC debate. I agree that there is a certain level of scientific certainty, but the EC has recently invested in far reaching research projects and broad studies to investigate GHG emissions from iLUC and to reduce scientific uncertainty by continuously presenting more accurate results. Therefore, I conclude that there is indeed degree of certainty about GHG emissions from iLUC and so the current scientific uncertainty on GHG emissions of iLUC might be exaggeratedly displayed mainly by the biofuel industry and even politically utilised to influence policy designs, favouring own, mostly economic, interests. Talking about how the EU is trying to overcome the iLUC dilemma makes it challenging to differentiate between what has been said or published from a more impartial science perspective or motivated by stakeholders that usually follow their interests. The debate about how the EU handles the iLUC dilemma has become a not only a question of the scientific certainty standard, but also exemplifies that policy design on particularly scientific controversial issues is subject to the influences of stakeholders that pressure policy makers in order to create a legislative framework favouring their interests.

- Political experiences on iLUC regulations in the US exemplify that if decisions are made at an early state of scientific certainty level, there is a risk of producing rigid legislative frameworks which are not sensitive to legal changes and improvements based on scientific progress.

If iLUC policy regulations and decisions are applied under scientific uncertainty procures misleading, even counter-productive rules the biofuel industry can be economically affected, the climate performance of biofuels is influenced and overall biofuel and environmental related roadmaps are put into question. The US released iLUC regulations at
an early stage of scientific research and by the time GHG emissions values on iLUC have been changed, revised or specified. Model-based accounting on iLUC has been steadily improved and provides more accurate results. However, these results based on the latest findings are not reflected by the US regulations. This example supports the delaying action of the EU in order to avoid misleading results. Here, it seems that waiting for a scientific consensus is a reasonable option to deal with the iLUC dilemma.

Above mentioned findings of the thesis it becomes evident that iLUC from biofuels and tackling the iLUC dilemma within an EU policy perspective needs to be approached holistically. This means that developing accounting models and framing policies always affects the biofuel market, investments and general environmental and sustainability goals. The controversial topic associates various stakeholders that follow their own interests and actively shape policy decisions. The question how the EU is going to tackle GHG emissions from iLUC is not yet decided, though an announcement on this issue is planned to happen in March 2012. The iLUC dilemma and the way the EU reacts politically show that the balancing of different interests under low scientific certainty is challenging. Also the EU has to develop a policy response that fits into the context of existing RED and FQD GHG emissions goals plus as stable support of private sector investment is needed. It appears that fulfilling all these demands for a policy decision in iLUC is impossible. Especially, if the EU decides to regulate iLUC without changing the RED, economical and investment disadvantages for the biofuel industry would be inevitable.

6 Conclusions

The aim of this paper was to investigate the EU policymaking on iLUC within the context of scientific uncertainty and involvement of stakeholder interests. A final policy decision on iLUC has still not been made by the EU. This thesis concludes that delaying the settings of EU regulatory standards in the presence of science is only a transitional solution. Sooner or later the EU has to make a policy decision on iLUC. Forming policy designs for iLUC in line with overall RED and FQD goals, framed by a certain level of scientific certainty and influenced by various interests, is challenging.

It becomes clear that the scientific uncertainty on iLUC leads to hesitation and delaying in EU policymaking which promotes uncertainty and nervousness in the biofuel industry sector and its future investments goals. EU policymakers experience pressure from various sites, especially from biofuel industry, but also NGOs and concerned scientists that call for legislative actions. At the same time, the delaying actions of the EU lead to uncertainties for the biofuel sector. This interplay shows that the two uncertainty challenges are tightly linked with each other.

The iLUC dilemma will not be solved for the EC and taking the iLUC issue seriously, the EC needs to make a clear policy proposal even if parts of the biofuel industry may be negatively affected (Vogelpohl et al. 2011). One policy option that is categorically excluded from the EC is to weaken the target of the RED saying that 10% of energy used within the transport sector to be renewable by 2020 (Vogelpohl et al. 2011). Though this target has started to put pressure on the biofuel industry, the EC seems to be not willing to lower the aim. Lowering this aim would also mean that the debate about iLUC would lose importance. Instead, the latest news show that the yet to be published proposal from the EC to address iLUC due to biofuels is going to be discussed at the ministers’ first meeting on the 9th of March 2012 (ENDS Europe 2012b). Denmark took over the EU rotating presidency on the 1st of January 2012 and hopes that agreement on that day to tackle the dilemma can be made. However, based on past experiences and latest news the expectations need to be kept low. Additionally, usually it takes up to six weeks to finalise an inter-service consultation and a further two weeks of discussion at cabinet level before complete approval. Therefore, the iLUC proposal might not emerge until as late as June (ENDS Europe 2012a).

The problem of balancing interests related to iLUC that underlie overall EU environmental legislations and in a context of controversial scientific certainty level, exemplifies main implementation challenges of sustainability at a various stages. Though many definitions of sustainability have been proposed sustainability conceptualises basically to the equal balancing of economic growth, social progress and environmental protection over long-term conditions (Munier 2005). Sustainability as a vague concept for future decisions in controversially discussed and reflects the harmonization of various interests that seem to be contrarians. The main challenge is to equalise them. This conflict is reflected in the iLUC dilemma and a holistic, multidisciplinary approach is necessary to make policy decisions to analyse the challenge from different perspective and creating solutions that are ideally long-term oriented.
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# 9 Annex

List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ALCA</td>
<td>attributional Life Cycle Assessment</td>
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<tr>
<td>CARB</td>
<td>California Air Resources Board</td>
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<tr>
<td>CAPSIM</td>
<td>Common Agricultural Policy Simulation Model</td>
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<tr>
<td>CARD</td>
<td>Centre for Agricultural and Rural Development</td>
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<tr>
<td>CGE</td>
<td>computable general equilibrium model</td>
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<tr>
<td>GHG</td>
<td>greenhouse gas</td>
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<tr>
<td>CHP</td>
<td>combined heat and power plant</td>
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<tr>
<td>CLCA</td>
<td>consequential Life Cycle Assessment</td>
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<tr>
<td>GTAP</td>
<td>Global Trade Analysis Project</td>
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<tr>
<td>CO</td>
<td>carbon monoxide</td>
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<tr>
<td>CO$_2$</td>
<td>carbon dioxide</td>
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<tr>
<td>CO$_2$e</td>
<td>carbon dioxide equivalent</td>
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<tr>
<td>DART</td>
<td>Dynamic Applied Regional Trade</td>
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<td>dLUC</td>
<td>direct land use change</td>
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<tr>
<td>EC</td>
<td>European Commission</td>
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<tr>
<td>EISA</td>
<td>Energy Independence and Security Act</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>FAPRI</td>
<td>Food and Agricultural Policy Research Institute</td>
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<tr>
<td>FASOM</td>
<td>Forest and Agriculture Sector Optimization Model</td>
</tr>
<tr>
<td>FQD</td>
<td>Fuel Quality Directive</td>
</tr>
<tr>
<td>GREET</td>
<td>Greenhouse gases, Regulated Emissions, and Energy use in Transportation model</td>
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<tr>
<td>ha</td>
<td>hectare</td>
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<tr>
<td>IE</td>
<td>Institute for Energy</td>
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<td>IES</td>
<td>Institute for Environment and Sustainability</td>
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<tr>
<td>IFPRI</td>
<td>International Food and Policy Research Institute</td>
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<tr>
<td>iLUC</td>
<td>indirect land use change</td>
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<tr>
<td>ISO</td>
<td>International Standard Organization</td>
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<td>IPTS</td>
<td>Institute for Prospective Technological Studies</td>
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<td>JRC</td>
<td>Joint Research Centre</td>
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<tr>
<td>LCA</td>
<td>Life Cycle Assessment</td>
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<tr>
<td>LCFS</td>
<td>low carbon fuel standard</td>
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<tr>
<td>LUC</td>
<td>land use change</td>
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<tr>
<td>Ktoe</td>
<td>kilo tonne of oil equivalent</td>
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<tr>
<td>NOx</td>
<td>nitrogen oxides</td>
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<tr>
<td>Pg</td>
<td>metric tons</td>
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<tr>
<td>RED</td>
<td>Renewable Energy Directive</td>
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<td>RFS</td>
<td>Renewable Fuel Standard</td>
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<td>TJ</td>
<td>terajoule</td>
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<td>UFOP</td>
<td>Union zur Förderung von Oel- und Proteinpflanzen e.V.</td>
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<tr>
<td>VOC</td>
<td>volatile organic compounds</td>
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<tr>
<td>WtT</td>
<td>Well-to-Tank</td>
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