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# The production of scientific evidence on indirect land use change and its role in EU biofuels politics

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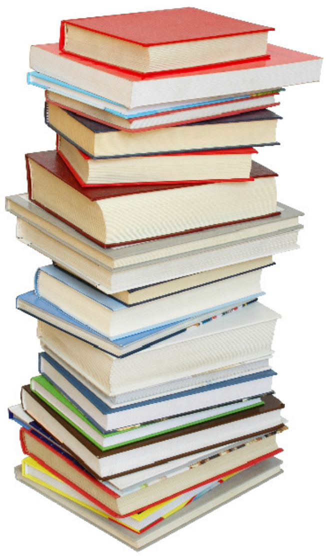

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# Abstract

One of the most heatedly debated aspects of EU's policy on biofuels in recent times concern indirect land use change (ILUC) induced by the production of biofuels. However, when the EU Renewable Energies Directive (RED) adopted in 2008, regulating ILUC was not considered for the time being. Ever since, the fundamental conflicts on biofuels regarding their social and ecological effects crystallize in the debates on ILUC, which is underpinned by the wide range of results of scientific research on the topic.

Starting from explaining the concept of ILUC and from conceptual considerations regarding new ways of knowledge production and its use in the policy process, we firstly trace the policy process on biofuels' ILUC with a special focus on the actors and their stances in this context. Subsequently, mainly by document analysis, we give a detailed overview of the research on biofuels' ILUC, focusing on which actors are related to the various ILUC studies and on what the relationship between these actors and the studies' orientations (methodologies, etc.) and outcomes is.

The analysis shows how the increase in ILUC research and its characteristics can be related to the societal problems arising from biofuels production, to the actors involved in it, and to their stakes in the issue. This points to the social embeddedness of ILUC research into societal as well as political practices and therefore – at least partly – qualifies it as a new mode of knowledge production. Furthermore, it points to special role scientific evidence plays regarding the policy process on the regulation of ILUC in the EU. In this respect, our observations suggest that, on the one hand, the scientific evidence on biofuels' ILUC as well as the uncertainty and complexity has been well perceived and taken up in the policy process. On the other hand, however, its role has eventually been reduced to an instrumental one, serving to legitimize and rationalize decisions agreed upon elsewhere beforehand.

# Contents

# 1 Introduction

One of the most heatedly debated aspects with regard to the European Union's (EU) biofuel policy concern indirect land use changes (ILUC) and their impact on the carbon footprint (CFP) of biofuels. The aim of greenhouse gas (GHG) emissions reduction has been an important driver for promoting biofuels consumption within the EU due to two reasons: Firstly, the EU is committed to reduce the GHG emissions economy wide about 80 to 95% until 2050 and, secondly, the mobility sector has been identified as one of the most relevant sectors for GHG reduction (EC 2011). This has led to a 10% renewable energies quota in the mobility sector to be achieved by 2020, according to the Renewable Energy Directive (RED). Given that the range of renewable energy technologies available in the mobility sector is rather small, the EU has focused its GHG saving efforts in the mobility sector on biofuels (see EP und EC 2009).

To ensure that biofuels actually achieve a significant reduction in GHG emissions, the current RED requires the CFP of biofuels to be at least 35% lower as compared to the CFP of fossil fuels; otherwise, biofuels will not be counted towards attainment of the quota (EP und EC 2009). This comparative value will rise up to 50% in 2017, and up to 60% in 2018. The objective of saving 35% of GHG emissions compared to fossil fuels are met by most of the biofuels if ILUC are not considered (Fritsche, Hennenberg, et al. 2010). However, it worsens significantly when taking into account these ILUC induced GHG emissions ( Fritsche, Sims, et al. 2010). As a consequence of these scientific findings, stakeholders mainly from Non-Governmental Organizations (NGOs) but also from the scientific community have repeatedly questioned whether biofuels actually save GHG emissions compared to fossil fuels and thus whether they are a proper measure to decrease GHG emissions in the mobility sector.

Since 2008 stakeholders have repeatedly called the European Commission (EC) to introduce a political regulation that reduces the ILUC risk of biofuels. At the same time stakeholders from the biofuels sector have frequently pointed out that the scientific knowledge does not provide a sufficient basis to derive a political regulation. An evaluation of these different opinions is difficult insofar that the quantification of ILUC itself is still controversial. While there is a recognized method for the calculation of GHG emissions from direct land use changes (DLUC), approaches to quantify ILUC have only been developed and tested within the last five years. In order to build a solid scientific knowledge base on ILUC the EC itself and other stakeholder commissioned several studies on ILUC quantification and mitigation. Still, an agreement on the EU level on how to deal with the ILUC risk of biofuels could not have been reached so far.

The overall aim of this paper is to analyze how scientific evidence on ILUC has been produced in recent years and to analyze its role in EU biofuels politics. Chapter 2 provides theoretical background information with respect to the concept of ILUC and its quantification and with respect to the role of science and scientific evidence in policy making. In chapter 3 we describe the process in the EU towards a political regulation of ILUC and we present the most relevant steps so far, thereby also taking a look at the stances of different stakeholders regarding the debates on this issue. In chapter 4 we will give a review of the production of scientific evidence on ILUC, particularly from 2008 on. In chapter 5, drawing on conceptual work on the science-policy interface in chapter 2, we will evaluate the process of scientific knowledge production on ILUC and the role has played so far regarding the political debates on ILUC regulation in the EU. Chapter 6 concludes the paper by summarizing the main findings.

# 2 Theoretical background

## 2.1 Introduction to the concept of ILUC

ILUC is only one of several possible indirect effects related to biofuel production; such indirect effects can affect the social, economic or environmental performance of biofuels. Indirect effects having early been identified were rising food commodity prices that can negatively affect food security and ILUC that can negatively affect the CFP of biofuels.

Within the context of bioenergy, Ros et al. (2010, 5) defined indirect effects as “effects that are caused by the introduction of a bio-energy product, but cannot be directly linked to the production chain”. Delzeit et al. (2011) emphasized changing market prices of different products to be the link between biofuel promotion and indirect effects; according to this definition, indirect effects are a market effect. This is in line with the ILUC-definition mostly used in science: if biofuel crops are cultivated on agricultural area, the former agricultural production is replaced and the amount of the former product decreases in the world market. Assuming that the demand for this product remains the product’s price will increase due to the reduced supply (Searchinger et al. 2008; Fritsche, Hennenberg, et al. 2010). These higher prices act as an incentive for farmers or companies to create new agricultural area on former natural ecosystems (see Fig. 2.1).

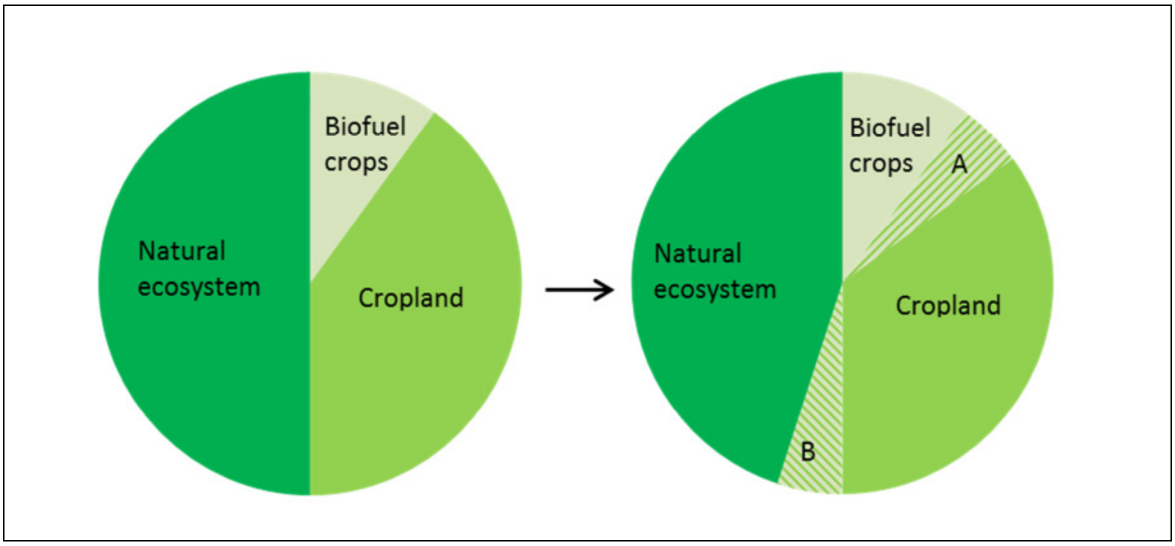


**Fig. 2.1: Schematic diagram describing ILUC. A presents the amount of additional land required due to expansion of biofuel crops, B represents the amount of natural ecosystems converted to cropland as a result of the conversion of cropland to biofuel crops**
Source: Diagram slightly modified from Djomo et al. (2012)

Given that LUC is generally accompanied by considerable GHG emissions if natural ecosystems as primary forest, peat bogs or also managed grassland are transformed to arable land, ILUC is crucial for the CFP of biofuels (Fritsche et al. 2006; Fargione et al. 2008; Searchinger et al. 2008). According to Fargione et al. (2008) the payback time, i.e. the time to repay the biofuel carbon debt, for palm oil biodiesel from former peat land would be over 400 years while the payback time for soy biodiesel from former Brazilian grassland would only be 40 years.

While the quantification of GHG emissions from DLUC is standardized according to IPCC (2006), the quantification of GHG emissions from ILUC has not been standardized yet. To quantify ILUC-induced emissions is a highly complex matter given that ILUC are tied to global market dynamics. Because of increasing global market prices that occur as a consequence of any displacement, ILUC can occur anywhere in the world and not only in the country where biofuels are being produced (Gnansounou et al. 2008; Plevin et al. 2010). Thus, ILUC cannot be monitored or observed, it can only be modeled based on assumptions about market relations.

During recent years two basic approaches to quantify ILUC have been developed: economic models  that have been adjusted for the calculation of ILUC (e.g. Searchinger et al. 2008; Al-Riffai et al. 2010; Laborde 2011); and deterministic or descriptive-causal models that attempt to estimate ILUC based on a set of simplified assumptions (e.g. Bauen et al. 2010; Fritsche, Hennenberg, et al. 2010). With regard to economic modelling one can distinguish between two kinds of models: CGE models study the entire global economy while partial equilibrium models study a specific sector such as the agriculture sector. Finally, regional models, which are either economic or deterministic models, focus on specific local conditions and aim to take into account regional influences on ILUC such as yields and potential productivity increases (Lahl 2010).

## 2.2 Scientific knowledge and the policy process

As the previous paragraphs have already indicated, the issue of ILUC related to biofuels production is a much contested issue, both scientifically and socio-politically. But what are the relations between these two spheres? One of the most prominent and elaborated concepts in this context is the concept of 'civic epistemologies' mainly developed by Sheila Jasanoff (2005: 247-271), which integrates these issues into a coherent conceptual framework. She describes civic epistemologies as the "institutionalized practices by which members of a given society test and deploy knowledge claims used as a basis for making collective choices" (Jasanoff 2005: 255). We believe this concept provides a good starting point for our research, since research on civic epistemologies can be described as research that "inquires into how knowledge is dynamically constructed and applied in the search for meaning and design and implementation of policy in modern societies" (Miller 2008: 1897-1898). In this vein, our research tries to shed some light on the processes of scientific knowledge production around biofuels' ILUC and its perception and uptake in the policy process.

Traditionally, science has been conceived of as a distinct sphere – separated from the policy or society – that is supposed to deliver reliable, neutral, not value-laden, and true knowledge. In recent literature this mode of knowledge production has increasingly been referred to as mode 1 "that designates reliable academic knowledge produced within autonomous disciplinary contexts. In this sort of research there was only a little direct linkage between research and social application, thus, boundaries between universities and industries were not blurred and academics were quite autonomous in terms of choosing their research topics and problems" (Tuunainen 2002: 37). According to a 'linear model of science and politics' the knowledge stemming from this mode 1 science can then be used by policy-makers and transformed into policy-decisions. Thus "science advice precedes and compels political decisions. First let scientists get the facts straight, the linear models says, then require politicians to implement them" (Brown 2008: 485; see also Pielke 2007).

However, this conception of science, its relations to society in general and to policy-making in particular, has increasingly been challenged in recent years. According to alternative conceptions – which mainly stem from the sociology of scientific knowledge and science and technology studies – science cannot be separated from society. On the contrary, it is highly dependent on cultural norms and societal institutions and practices whether a certain kind of scientific knowledge qualifies as legitimate and trustworthy and whether it can serve as a basis for policy-making. This is especially true for modern techno-scientific cultures, which are characterized by complex, ‘wicked problems’[1], of which biofuels’ ILUC might be a prime example. To cope with problems like these, a new mode of knowledge production has been proposed under the catchwords ‘mode 2’, ‘co-production of knowledge’ or ‘transdisciplinary research’, the essence of which is that it “is transdisciplinary, organizationally non-hierarchical, socially accountable, and reflexive. The research is carried out in “the context of application”, that is, with societal needs having direct impact on the knowledge production from the early stages of investigative projects” (Tuunainen 2002: 37; see also Gibbons et al. 1994; Gibbons 2000; Nowotny et al. 2001 for more on this).

Jahn et al. (2012) distinguish between societal problems and scientific problems that are both a source of a transdisciplinary research problem. The first important step of transdisciplinary research is to transform this problem into a common research object by integrating several actors and stakeholders. In the next step new knowledge is generated by interdisciplinary research, whereby several actors and institutions such as universities, non-university facilities, cooperation and NGOs can contribute to knowledge production (interdisciplinary integration). In the last step, transdisciplinary integration, the new knowledge has to be evaluated for its contribution to societal and scientific progress (see figure 2.2).

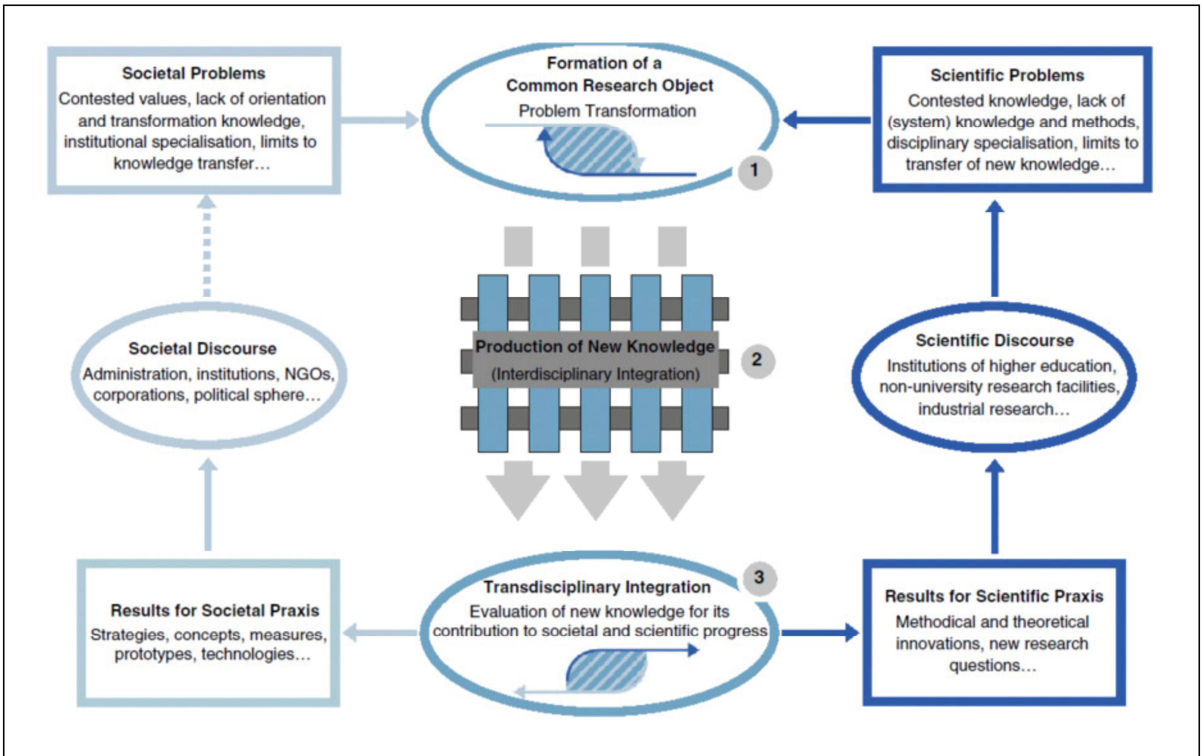


**Fig. 2.2: A conceptual model of transdisciplinarity**
Source: Jahn et al. (2012: 5).

[1] ‘Wicked problem’ is a phrase used to describe a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize. Moreover, because of complex interdependencies, the effort to solve one aspect of a wicked problem may reveal or create other problems.

This general tendency towards a mode 2 knowledge production and transdisciplinary research raises a set of questions regarding the scientific knowledge production on ILUC: Which different societal actors are involved as producers of scientific knowledge about ILUC and how are they involved? Do the processes of scientific knowledge production on ILUC qualify as a case mode 2 and/or transdisciplinary knowledge production?

Besides the question how scientific knowledge production with regard to complex issues occurs in general, we also "know relatively little about how knowledge gets made in political communities" (Miller 2008: 1896). Even if scientific knowledge is produced in a transdisciplinary way, this would not guarantee the uptake of the knowledge in policy processes. In line with the changed patterns of scientific knowledge production referred to above, the role of new knowledge in policy processes changes as well, especially when it comes to wicked problems such as regulating biofuels' ILUC. Just affirming that policy decisions have been made on the basis of the best-available scientific evidence ('first get the facts right'), then, is "no longer a credible policymaking strategy" (Hajer und Wagenaar 2003: 10). Rather, "science and scientific expertise have lost their reputation as providers of objective and unbiased knowledge that lies outside of interests and power configurations and escapes moral and social influences" (Braun und Kropp 2010: 773) and "political decision makers consequently feel that they cannot safely bank on the authority of science as an effective way of closing down policy issues and debates" (Braun und Kropp 2010: 773). Our next set of research questions thus addresses the role the studies have played in the policy process. How has the scientific knowledge on ILUC been included in the EU ILUC policy process so far? Which studies have gained particular interest?

The usage of knowledge in the policy process is not equal at all stages. Cordula Kropp and Jost Wagner (2010) developed a framework that aims at categorizing the usage of different kinds of scientific knowledge at different stages of this process. Starting from theories of the policy cycle (see e.g. May und Wildavsky 1978; Jann und Wegrich 2009), the framing of scientific knowledge according to media requirements is most important at the stage of problem-recognition and agenda-setting, rather irrespective of which kind of scientific knowledge it is ('traditional' or 'new'). Since this stage is already over in the case of biofuels' ILUC, we focus on the stages of policy formulation and decision-making. According to Kropp and Wagner at the stage of policy formulation, the kinds of scientific knowledge taken up in the political arena are considerably diverse. At the stage of decision-making, however, "all this has to be suppressed for the benefit of 'hard facts'" (Kropp und Wagner 2010: 831). Finally, we will therefore analyze whether this is also true for the case of the EU ILUC policy process.

# 3 The EU ILUC policy process

In 2007, in the context of increasing food prices, LUC linked to biofuel expansion became a highly visible topic of public and scientific discussion. In order to learn more about agenda-setting and stakeholder positions, we analyzed overall 56 position papers with regard to ILUC that were found to be published by bioenergy and farmers' associations and NGOs within 2007 and 2012. NGOs have been very active already in the early stage of the discussion indicating that they have contributed to set ILUC on the political and scientific agenda. Stakeholders from the industry became more present within the last two years when the time for the political decision-making came closer (see Fig. 3.1).

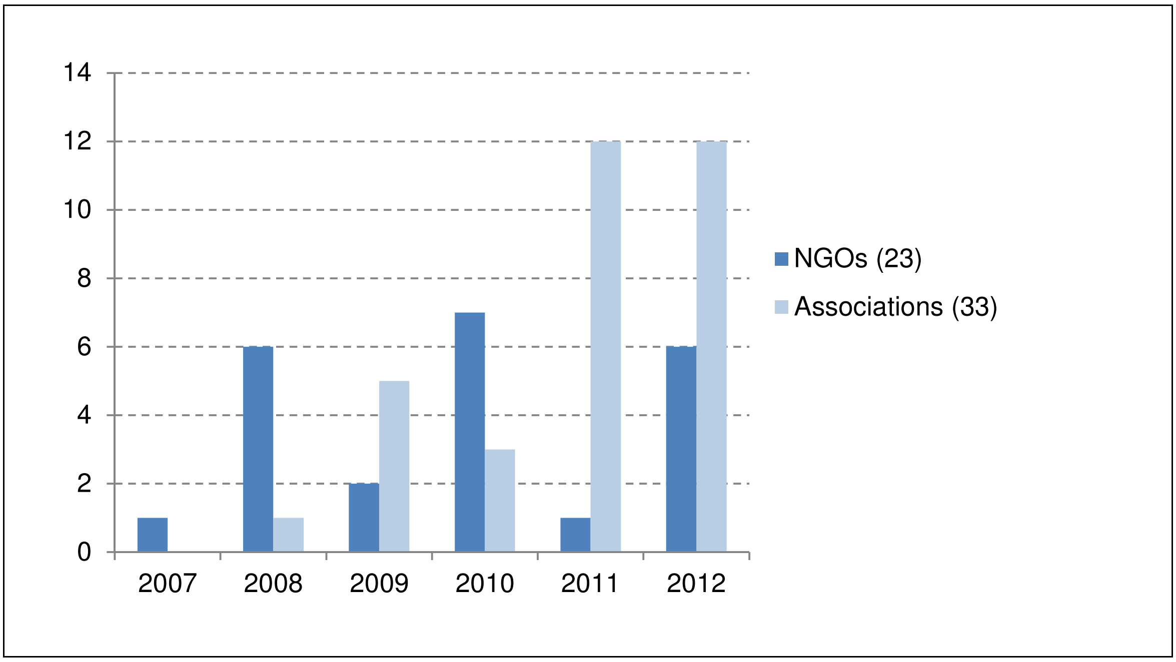


**Fig. 3.1: Number of position papers published by NGOs and associations between 2007 and 2012**
Source: Original documents from internet search.

On one hand, most of the NGOs already stated in 2008 that evidence on ILUC has sufficiently been proven and that the scientific knowledge base is good enough to base a policy regulation on it; on the other hand most of the stakeholder from business repeatedly pointed out that the process of scientific knowledge production has not been yet completed. In 64% of their positions papers stakeholder from business clearly insisted the scientific knowledge not to be good basis for developing a policy regulation.

Although ILUC had already been a topic of the scientific and public discussion within the policy formulation of the RED in 2008/2009, it was only addressed in the way that the 2009 RED directs the EC to "develop a concrete methodology to minimize greenhouse gas emissions caused by indirect land-use change" (2009/28/EC, 25) and to investigate "on the basis of best available scientific evidence [...] the inclusion of a factor for indirect land-use changes in the calculation of greenhouse gas emissions" (2009/28/EC, 25).

These requests were the starting point for an intensive and interactive policy process which is still continuing. In the period from 14th June 2009 until 31rst July 2009 the EC had launched a public stakeholder consultation with the target to evaluate stakeholder positions with regard to ILUC regulation. The EC called experts as well as stakeholders to comment on seven options on how to deal with ILUC. Most of the participants from the industry voted for the measures implementing "international agreements on protecting carbon-rich habitats" or "extend to other commodities/countries the restrictions on land use change that will be imposed on biofuels". NGOs on the other hand mainly voted for the inclusion of an ILUC factor in the GHG calculations for biofuels.

Within the RED the EC was also asked to present a report to the parliament about the impact of ILUC and as possible a methodology for the quantification of GHG emissions linked to ILUC until the 31st of December 2010 (2009/28/EC, 40, Article 19 (6)). In order to establish a solid scientific knowledge base the EC commissioned several studies about the impact and quantification of ILUC that were finally published in 2010 (see chapter 4).

Afterwards, a second public consultation took place in the period between July and October 2010. Stakeholders were asked to state whether they considered the knowledge described in the scientific reports of the EC to be a good basis determining how significant ILUC is (EC 2010). Overall, 145 stakeholders participated at the consultation from which 137 were in English language and have thus been considered in the following analysis.

Associations, which mainly represented farmers and the bioenergy industry, stated the analytical work not to be a good basis for ILUC determination (see Fig. 3.2). This is a somehow expected result, just like the similar statements of the non-EU countries, which all were biofuel exporting countries (Brazil, Argentina, Indonesia, and Malaysia). At the same time the majority of the NGOs stated the scientific knowledge base to be good enough for deriving a policy regulation. NGOs have repeatedly pointed out that biofuels are not only doubtful in terms of GHG emissions reductions but also may increase global food prices and thus negatively affect food security. These concerns were also expressed in the already mentioned position papers and in an open letter in October 2010 in which more than 100 NGOs requested the EC to introduce ILUC factors into the biofuel policy.[2] What is more revealing is the fact that most of the participating research institutes did not consider the analytical work to be a good basis. A letter published by more than 100 scientists and economists in October 2011 however demonstrates that this set of opinions might not be representative given that in this letter 100 academics requested the EC to incorporate ILUC in CFP calculations of biofuels (Neslen 2011).

In November 2010 on behalf of the Directorates-General DG ENER and DG CLIMA the Joint Research Centre (JRC), the EC's in-house research center, arranged an expert consultation with experts in the field on ILUC in order to discuss about the uncertainties in ILUC quantification. The participants shared the opinion that "there is strong evidence that the ILUC effect is significant and that this effect is crop specific" (Marelli, Mulligan, et al. 2011, 11). They also claimed political measures to be necessary in order to reduce the ILUC risk; an ILUC factor turned out to be the favorite measure.

[2] http://www.brot-fuer-die-welt.de/downloads/niemand-isst-fuer-sich-allein/NGO_Public_Statement.pdf

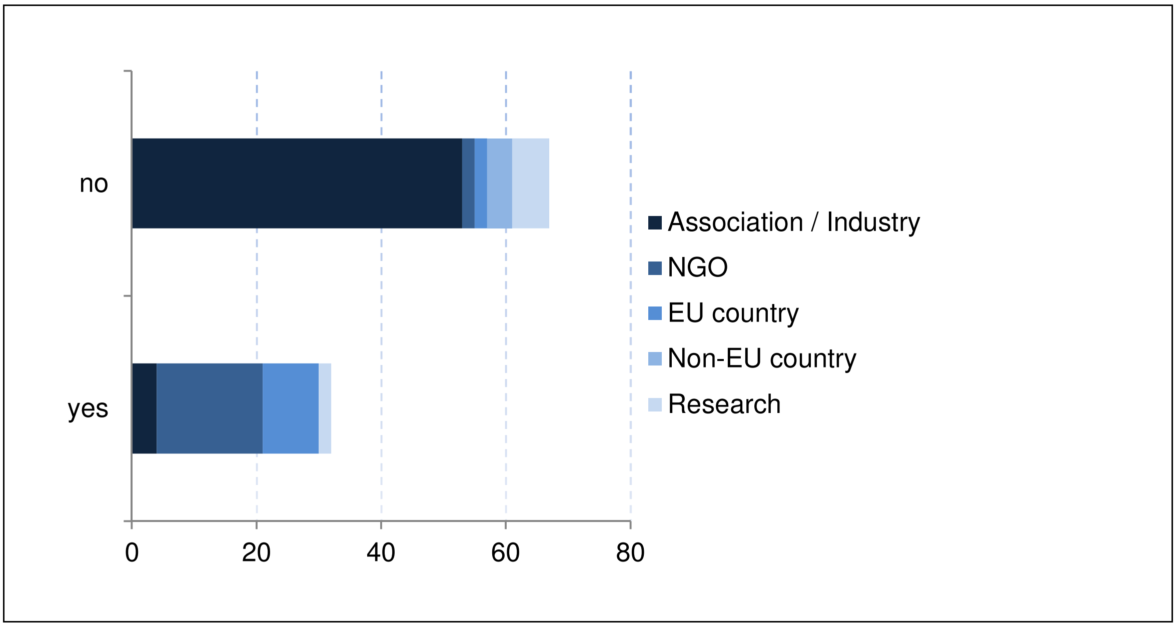


**Fig. 3.2: Stakeholder answers to question whether the analytical work provides a good basis for determining how significant ILUC is**
Source: Original documents from EC (2010b)

In the obligatory ILUC report published in December 2010 the EC finally recognized that ILUC can have a significant effect on the CFP of biofuels and that it is necessary to counteract. The EC also stated economic modeling to be the best available methodology to quantify ILUC (EC 2010). Based on the scientific findings of the four studies conducted on behalf of the EC the EC proposed the following four options for action:

a. Take no action while monitoring

b. Increase the minimum GHG threshold of the biofuel

c. Introduce additional sustainability requirements on certain categories of biofuels

d. Use an ILUC factor calculated through modeling (EC 2010).

These four options should have been analyzed and discussed with the help of an impact assessment planned to be finished in July 2011. Only an early draft of this impact assessment has been available in the internet at the time this work has been conducted.

The Committee on the Environment, Public Health and Food Safety (ENVI), a committee of the European Parliament, organized another workshop in January 2012. The aim was bringing together experts from science and policy in order to enable an exchange of experiences and views with regard to the subject ILUC and biofuel policy. Within the workshop the participants acknowledged the scientific work having improved during the last years. However, the conclusions with regard to an appropriate regulation differed significantly between the participants. While some argued for incentives for low-ILUC risk biofuels, other asked for ILUC factors in order to ban high-ILUC risk biofuels;

yet others argued that the actual problem are high deforestation rates in Brazil and peat land conversion in Indonesia so that these problems should directly be regulated (Fritsche et al. 2012).

In May 2012 the DG ENER and DG CLIMA met in order to develop a common proposal for an ILUC regulation. At the meeting the DG CLIMA supported the introduction of an ILUC factor while the DG ENER did not. The increase of the minimum GHG threshold from 35% to 60% until 2016 and the combination of an ILUC factor and an increase of the threshold were discussed as alternative regulation options. According to EurActiv an ILUC factor has been the favored option of the majority of the EU commissioners at that time being (Neslen 2012).

# 4 Scientific evidence production on ILUC

As pointed out in the above chapter the public pressure to develop an approach to quantify ILUC and a regulation to minimize ILUC has been started with the global food price crisis in 2007 and 2008. In 2009 the political pressure increased given that the RED now requested the EC to minimize ILUC and to check whether ILUC factors are an adequate measure to reduce ILUC.

Political and public pressure as well as a growing scientific interest in research into bioenergy and LUC issues, has led to an intensive production of scientific knowledge taking shape in a large number of ILUC studies, reports and papers published within the last five years. While most of the studies and reports are grey literature freely available in the internet also a relevant number of reviewed articles have been publishes in scientific journals (see Fig. 4.1).

In order to report systematically on the generation of scientific knowledge we took into account scientific articles as well as grey literature. In a first step we queried the ISI Web of Knowledge (WoK) in order to identify scientific articles with regard to ILUC having been published in reviewed journal. We searched for the keywords “indirect land use change” and ILUC together with biofuel in the abstract and the title of the publication. Besides reviewed articles the huge body of grey literature on ILUC is part of the scientific knowledge production. A systematic compilation of these publications is challenging given that internet searches for the already mentioned keywords – limited to the file type pdf – resulted in an immense number of discoveries. Scientific reports, stakeholder comments, program flyers and slideshow presentations were part of these findings. In order to filter scientific publications the internet search tool Google scholar has been used.

The first publication in a scientific journal that actually contains one of the terms ILUC or “indirect land use change” in combination with biofuel was published in 2008; since then 72 articles have been published, whereby most of the reviewed articles were published in 2011. Most of the overall 430 reports in the body of grey literature also have been published in 2010 and 2011. Only a small share in the total body of literature basically provides knowledge on quantification and/or mitigation of ILUC. Most of the studies refer to ILUC in a broader sense but focus on another subject such as sustainability criteria in general or specific case studies on bioenergy. Only roughly 50 studies, both from reviewed articles and grey literature, actually contain results on ILUC quantification; some of them are similar publication from one and the same project. After segregating doubled work and publication that obviously referred to intermediate data we finally analyzed 26 studies. We focused our analysis on the respective source of funding, the methodologies used for quantification and the conclusions that were drawn with regard the results robustness and to ILUC regulation.

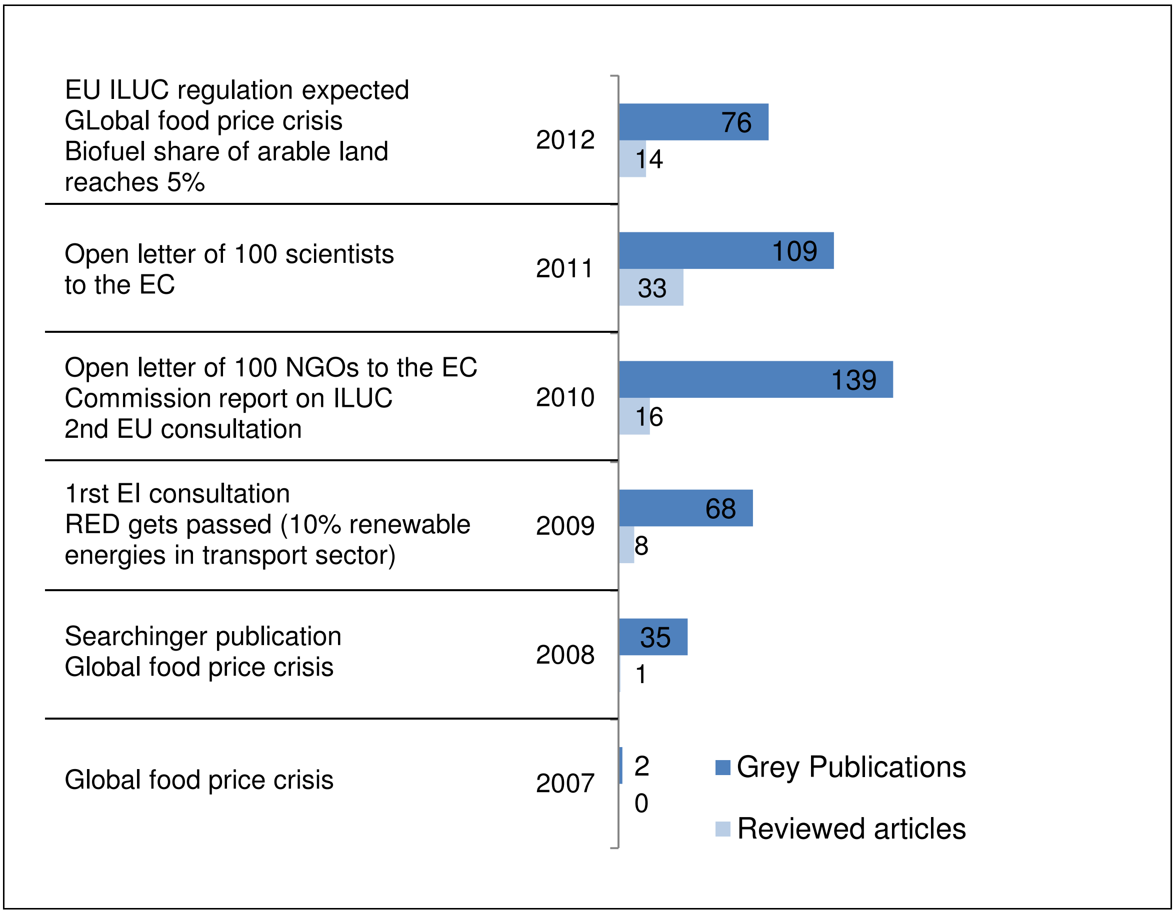


**Fig. 4.1: Number of scientific publications on indirect land use change and biofuel**
Source: Web of Knowledge (date of query: 16th of August 2012), Google scholar (date of query: 28th August 2012)

In the following we distinguish between contract research and peer reviewed research in order to reveal who has been the driver for scientific knowledge production.

## 4.1 Contract research

Tab. 4.1 provides an overview over the contract research on ILUC. It proves the EC, including the DG CLIMA, DG TRADE and DG AGRI, to be the most relevant entity that has commissioned research on ILUC quantification within the last years. In all these studies the academics have used economic models, either general equilibrium models (CGE), partial equilibrium models or a combination of both types, in order to quantify ILUC. National Authorities in Germany and the UK also commissioned ILUC quantification studies whereby deterministic or cause and effect approaches were mostly being used. The Renewable Fuel Agency, the UK's former sustainable fuels regulator, additionally funded a study on mitigation measures of indirect effects.

The reports published by Tipper et al. (2009) and Lahl (2010) are the only ILUC-quantification studies that were found to be financed from the European and/or German Biofuel Industry. The European Biodiesel Board additionally commissioned two independent research and consulting institutes to conduct scientific reviews on the two studies conducted by the IFPRI on behalf of the EC (see Al-Riffai et al. 2010; Laborde 2011). Finally, the study conducted by Bowyer (2011) was the only one found to be financed by an NGO.

**Tab. 4.1: Contract research on ILUC**
Source: Own compilation.

| Authors | Date | Contracting entity | Type of contracting entity | Type of ILUC quantification |
|---|---|---|---|---|
| Tipper et al. | 2009 | Greenergy | Business | deterministic |
| Dehue et al. | 2009 | RFA | National Authority | - |
| Fonseca et al. | 2010 | DG AGRI | EU / EC | economic (partial) |
| Al Riffai et al. | 2010 | DG TRADE | EU / EC | economic (CGE) |
| Edwards et al. | 2010 | DG CLIMA | EU / EC | economic (CGE and partial) |
| Lahl | 2010 | UFOP, BdBe | Business | deterministic |
| Fritsche et al. | 2010 | BMU, UBA | National Authority | deterministic |
| Bauen et al. | 2010 | UK Department for Transport | National Authority | deterministic |
| Bowyer | 2010 | Transport and Environment | NGO | deterministic |
| Hiederer et al. | 2010 | | EU / EC | economic (partial linked to CGE) |
| Laborde | 2011 | DG TRADE | EU / EC | economic (CGE) |
| Marelli et al. | 2011 | | EU / EC | economic (partial linked to CGE) |
| $(S\&T)^2$ Consultants Inc. | 2011 | European Biodiesel Board | Business | Review of Al-Riffai et al. (2010) and Laborde (2011) |
| Delzeit et al. | 2012 | European Biodiesel Board | Business | Review of Laborde (2011) |

## 4.1.1 Studies commissioned by the EC

### 4.1.1.1 IFPRI-studies

On behalf of the EC the two IFPRI-studies from Al-Riffai et al. (2010) and Laborde (2011) used an extended version of the global CGE model MIRAGE in order analyze the impact of the EU biofuels mandate and to calculate ILUC factors. One challenge in ILUC modeling is the way how by-products such as Distiller's Dried Grains with Solubles (DDGS) are being considered. In their review Delzeit et al. (2011) state by-products to be considered in the IFPRI-studies in an appropriate way. The review from S&T Consultants mainly criticized that biofuels from waste had not been considered so that the overall LUC is overrated, and that the land data bases missed idle land ($(S\&T)^2$ Consultants 2011). According to the authors themselves a relevant limitation of the model is that multi-cropping and crop rotation currently cannot be considered properly. Another limitation refers to the rigid demand in other sectors as the food demand or the demand in other industries (Laborde 2011).

Despite existing uncertainties according to Al-Riffai et al. (2010) and Laborde (2011) the studies proved that ILUC emissions induced by the EU's biofuel policy present a severe problem. With regard to an ILUC regulation policy Laborde (2011) state several difficulties: First, including ILUC into the biofuel's policy would consequentially mean to include LUC issues in all European agriculture and trade policies given that they can also have large or even larger LUC impacts. Second, the deviation of biofuel specific ILUC factors can be problematic given that agricultural markets are strongly interconnected. Furthermore, the expansion of palm oil plantations on peat land is currently responsible for high ILUC factors for several types of biodiesel. ILUC factors thus depend on the policies and their enforcement in other countries, such as forest law. As soon as the policies or the enforcement change, the ILUC factors might change too. Another regulation strategy that does not rely on biofuel specific factors, and thus would be more robust, would be to limit the overall scope of the biofuel mandate (cf. Laborde 2011).

#### 4.1.1.2 JRC-studies

The JRC has on behalf of the EC conducted several studies on ILUC quantification within the last years; these are particularly the studies from Fonsesca et al. (2010), Edwards et al. (2010), Hiederer et al. (2010) and Marelli et al. (2011).

Fonsesca et al. (2010) utilized three acknowledged partial equilibrium, agri-economic models (AGLINK-COSIMO, ESIM and CAPRI) in order to quantify ILUC and to compare the results of the models. Despite several methodological limitations the results of the three models are similar: in the biofuel scenario the production of biodiesel, ethanol and their feedstocks is higher as in the reference scenario. This leads to an additional demand for land especially outside the EU (Blanco Fonseca et al. 2010).

Until 2010 ILUC quantification studies used different CGE and partial equilibrium models and they applied different biofuel scenarios respectively. Thus, it has not been possible to compare the results so far; at the direction of the DG CLIMA, the JRC therefore asked several modelers to calculate the crop area changes for specific biofuels scenarios (R. Edwards et al. 2010). Edwards et al. (2010) finally compared five CGE and partial equilibrium models, namely GTAP, FAPRI-CARD, AGLINK-COSIMO, LEITAP, IMPACT and CAPRI. All models proved the land use for crop cultivation to increase due to the EU's biofuel policy and all models produced higher values than the IFPRI-study. The comparison also shows that the range of crop area changes was quite high: for the EU biodiesel scenario, for example, the values ranged between 242 and 1928 kha $Mtoe^{-1}$. Factors with a high influence on the result were in particular the way how by-products were considered, the yield elasticity, and the assumption how much crop cultivation shifts to developing countries (R. Edwards et al. 2010).

Hiederer et al. (2010) developed a harmonized spatial dataset and a method that allows allocating the additional land demand to a raster of 10 km grid spacing. GHG emissions are calculated based on the Tier 1 approach of IPCC (2006) so that carbon stock changes in soil, above- and below-ground biomass are being considered. Values on LUC are taken from the output of global economic models such as from MIRAGE (IFPRI) and AGILINK-COSIMO (JRC). The results show significant differences between the two models (MIRAGE and AGILINK) and between that of this study and the one from IFPRI. These differences are particularly caused by different assumptions on the share of biodiesel and ethanol crops, and the proportion of different natural ecosystems converted to cropland (Hiederer et al. 2010). Marelli et al. (2011) published an updated version of this analysis by applying the methodology on the results of the second IFPRI-study. According to Marelli et al. (2011) the results are now in line with these of Laborde (2011). Marelli et al. (2011) and Laborde

(2011) proved ILUC emissions linked to ethanol production to be significantly lower as compared to these linked to biodiesel production.

One aspect the JRC studies have in common is that the authors do not discuss their results with respect to the questions whether they provide a good basis for a policy regulation and what kind of regulation would be favorable.

### 4.1.2 Studies commissioned by National Authorities

On behalf of the German Federal Ministry for the Environment, Nature Conservancy and Nuclear Safety the Institute for Applied Energy (Öko-Institut) developed a deterministic model to calculate ILUC factors (Fritsche, Hennenberg, et al. 2010). A crucial assumption in the model is that ILUC can be estimated by looking only at the exported products relevant for the bioenergy sector. Calculations are based on 2005 product exports from key regions such as Argentina, Brazil, and the USA (Fritsche, Hennenberg, et al. 2010). Fritsche et al. (2010) calculated ILUC induced GHG emissions to account for 270 t $CO_2$ $ha^{-1}$ or 13.5 t $CO_2$ $ha^{-1}$ $yr^{-1}$. These values mean one ha of bioenergy feedstock production displaces one ha of previous production. However, the displacement will probably be lower because of yield increases and the use of so far unused areas. Assuming average yield increases of 1% $yr^{-1}$ until 2030, the maximum ILUC factor will only be 75% of the theoretical ILUC factor. In the last step the GHG emissions are divided by fuel-specific yields so that one gets energy-specific ILUC factors (g $CO_2$ $MJ^{-1}$). The maximum level of ILUC emissions would mean that most biofuels will not achieve the GHG reductions called for in the RED (Fritsche, Hennenberg, et al. 2010). Fritsche et al. (2010) discuss several options for policy regulation. Besides the inclusion of an ILUC factor they suggest to allow offsetting of ILUC emissions for instance through yield increases, to prioritize low- or no-ILUC risk feedstocks, to prioritize land that is not in competition with other uses, to establish a global cap on LUC related emissions, and to account for DLUC in all agricultural product carbon footprints. Given that the best solution, a global cap, will not be reached in foreseeable future, second-best solutions such as ILUC factors should be adopted.

Another deterministic model has been developed by E4tech on behalf of the UK Department of Transport (Bauen et al. 2010). The causal-descriptive methodology was exemplary tested with five different biofuel feedstocks; for each feedstock Bauen et al. (2010) calculated various ILUC factors based on different scenarios and assumptions. The target was not to present specific ILUC factors but to find differences in the ILUC risk between feedstocks, and to identify measures to mitigate ILUC. The results of the study from Bauen et al. (2010) show that the ILUC impact of biofuels varies strongly depending on feedstock and on specific conditions assumed in the scenarios, especially with regard to DLUC and yield increases. With regard to political regulation the authors state the problem that ILUC factors affect the demand for specific crops and that the demand for specific crops affects the ILUC factors. Thus, the factors would regularly have to be updated. The authors therefore focus on discussing several mitigation measures such as the protection of high carbon stock areas or an intensification of agricultural production (Bauen et al. 2010).

On behalf of the RFA, the UK's former sustainable fuels regulator, the consulting company Ecofys developed a project based approach to identify biofuels with a low ILUC-risk (Dehue et al. 2009). Dehue et al. (2009) identified four different possibilities to avoid ILUC: Cultivate the biofuel feedstock on unused land, yield increases, increasing land productivity by integrating bioenergy feedstock production with non-bioenergy feedstock systems, and using residues or aquatic biomass for biofuel production. They developed a methodology called “Responsible Cultivation Areas” (RCA) that represents a tool to prove the low ILUC risk. The methodology contains of three steps: First, a baseline for the production level in the project area has to be determined. Second, the additionally of the project activity has to be proven and third, the project has to be registered (Dehue et al. 2010).

### 4.1.3 Studies commissioned by other stakeholders

On behalf of Greenergy, a fuel providing company in the UK, Tipper et al. (2009) suggested a simplified approach to calculate total LUC emissions linked to biofuel production. However, the approach misses an adequate suggestion how to distinguish between DLUC and ILUC.

On behalf of two German biofuel associations Lahl (2010) suggested an deterministic approach that takes into account regional information and data. This approach was developed in response to criticism that other models do not properly consider the effects of state regulation on the global agricultural market, which can take the form of subsidies, customs duties, and trade restrictions (bans on import/export, etc.). The target of the new approach was to include ILUC effects due to domestic trade, which is, according to Lahl (2010), quantitatively more important than global trade. With regard to political regulation Lahl (2010) accentuates DLUC regulation of all agricultural products and the introduction of an international convention for natural ecosystem protection to be the best options. Given that these options will not be implemented soon he also points out the need for interim options, whereby regional ILUC factors that take into account regional conditions and/or bilateral agreements should be preferred as interim options against a global ILUC factor (Lahl 2010).

The NGO Transport and Environment commissioned the IEEP to estimate the ILUC effect associated with the increased biofuel consumption in all EU Member States as it is planned within the National Renewable Energy Action Plans. In order to calculate ILUC induces emissions Bowyer (2010) used a simplified approach with conversion factors derived from the study of Edwards et al. (2010). The overall additional GHG emissions arising from ILUC are estimated to be between 273 and 564 $MtCO_{2e}$ for the period 2011 to 2020. Bowyer (2010) point out the need for an ILUC regulation within the biofuel policy in order to reduce this negative climate impact.

## 4.2 Peer-review research

The reviewed articles found in WoK presumably mainly present results from grant research in contrast to contract research as it was presented in the previous section. The articles also contribute to scientific evidence production and address several topics that are relevant with regard to the development of a political ILUC regulation. The following review focuses on the methodologies used for ILUC quantification (see Tab. 4.2), on analyses with regard to uncertainties and on discussions with regard to political ILUC regulation.

*Methodologies:* Various articles deal with the development or discussion of specific methodologies and approaches to quantify ILUC. While most of the research teams used CGE models in order to quantify ILUC (Searchinger et al. 2008; Melillo et al. 2009; Hertel et al. 2010; Kløverpris et al. 2010; Dumortier et al. 2011), only few applied partial equilibrium models (Lapola et al. 2010; Havlik et al. 2010), combined models (Britz und Hertel 2011) or deterministic models (Plevin et al. 2010; Overmars et al. 2011; Kim und Dale 2011). In most of the papers the authors present results from testing or using their methodologies on exemplary cases such as the biofuel production in Brazil (Lapola et al. 2010), the ILUC effect caused by the EU biofuel policy (Britz und Hertel 2011; Overmars et al. 2011), or the biofuel production in the US (Kim und Dale 2011).

*Extent of ILUC:* Most of the articles prove ILUC induced GHG emissions to be significant, even if the exact value is uncertain (Searchinger et al. 2008; Melillo et al. 2009; Havlik et al. 2010; Hertel et al. 2010; Lapola et al. 2010; Plevin et al. 2010; Britz und Hertel 2011). Djomo et al.(2012) reviewed 15 articles on ILUC quantification; according to this evaluation ILUC induced GHG emissions range from 0 to 327 g $CO_2$ $MJ^{-1}$ for ethanol and from 0 to 1434 g $CO_2$ $MJ^{-1}$ for biodiesel (Djomo und Ceulemans 2012). Plevin et al. (2010) and Overmars et al. (2011) pointed out that studies with negative ILUC values, i.e. a positive effect on climate, are not known. Overmars et al. (2011) however allude negative ILUC values to be possible. Dumortier et al. (2011) similarly indicate that the market effect of biofuels production can also have positive climate effects given that it can create strong incentives to invest in yield increases. Whether and to what extent ILUC is detected by modeling thus strongly depends on the model assumptions (Dumortier et al. 2011). The study conducted by Kim et al. (2011) allows the interpretation that the biofuel production in the US between 2002 and 2007 has not led to ILUC. The authors however also recognize that their empirical approach might not be sensitive enough to detect ILUC (Kim und Dale 2011).

**Tab. 4.2: Peer review research on ILUC**
Source: Own compilation

| Authors | Date | Type of ILUC quantification | Comment |
|---|---|---|---|
| Searchinger et al. | 2008 | economic (CGE) | |
| Melillo et al. | 2009 | economic (CGE) | |
| Havlik et al. | 2010 | economic (partial) | |
| Hertel et al. | 2010 | economic (CGE) | |
| Klovepris et al. | 2010 | economic (CGE) | |
| Lapola et al. | 2010 | economic (partial) | |
| Plevin et al. | 2010 | deterministic | |
| Britz et al. | 2011 | economic (CGE, PE) | |
| Dumortier et al. | 2011 | economic (CGE) | |
| Overmars et al. | 2011 | deterministic | |
| Kim et al. | 2011 | deterministic | |
| Djomo et al. | 2012 | | review article |
| Lucia et al. | 2012 | | Discussion of policy instruments |

*Uncertainty:* One topic addressed in many articles is the question how robust the ILUC values are. By varying different parameters the research teams tried to identify these factors that have the highest influence on the variability. Variability in the results was found to be mainly caused by varying the assumptions about carbon stock changes due to DLUC. Whether and how by-products are being used also influences the results significantly (Overmars et al. 2011; Djomo und Ceulemans 2012). Britz et al. (2011) and Djomo et al. (2012) point out yield and area response to prices, i.e. the yield and land conversion elasticities, to be very important parameters with regard to uncertainty. Plevin et al. (2010) make uncertainty in the assumptions used for the calculation the main topic of their article. They argue that the uncertainties in modeling choices and stochasticity in the underlying processes will likely not be reduced soon. Low ILUC values are thus equally possible as very high ILUC values; and this should be considered in policy making (Plevin et al. 2010).

*Political regulation*: Some articles address the question whether the scientific knowledge is good enough to derive policy regulations and/or they suggest specific instruments for political regulation with respect to their scientific results. Overmars et al. (2011) came to the conclusion that ILUC effects alone prove that biofuels do not mitigate GHG emissions and thus one should think about alternatives for reducing GHG emissions in the mobility sector. Searchinger et al. (2008) similarly pointed out politicians have to guarantee that low- or no-ILUC-risk feedstocks such as waste products or carbon-poor land are used for biofuel production. With respect to high uncertainties Plevin et al. (2010) indicated polices that address the risk posed by high ILUC emissions might be more appropriate than those that address the risk of rather low ILUC emissions. One option could be “calling for slowing or halting biofuel expansion” (Plevin et al. 2010, 8020) or to reduce the political support on biofuels produced on degraded land or from residues. Havlik et al. (2010) recommended policies that address the actual effect of biofuels rather than the biofuel production itself. Dumortier et al. (2011) referred to the wide variation in the estimated emissions and to the high impact of yield increases on ILUC emissions and thus recommended to link biofuels subsidies to supporting basic research that might increase the yields in order to offset ILUC emissions. Di Lucia et al. (2012) finally discussed four different approaches on how to deal politically with the uncertainty about the extent of ILUC. A precautionary approach would stop the establishment of additional biofuel production and consumption in the EU for instance by eliminating policy support for biofuel production and consumption. A risk-indifferent approach assumes biofuels are being produced sustainably and carbon neutral so that the EU would take no action or choose only low ILUC factors. A risk-taking approach would allow an expansion of biofuel production while supporting measures to address the consequences of ILUC. At last, a preventive approach would allow further policy support of biofuels’ consumption and production while implementing measures to reduce the probability of ILUC by supporting biofuels with a low ILUC risk (Di Lucia et al. 2012).

# 5 The role of science and scientific evidence in the ILUC policy process

How can the process of scientific knowledge production on biofuels’ ILUC depicted above be classified within the spectrum that unfolds between mode 1 and mode 2 knowledge production? Scientific knowledge production on ILUC clearly shows features of the concepts mode 2, co-production and transdisciplinarity. As the previous chapters show, research on ILUC has been heavily influenced by societal and political problems. As such, science on ILUC has by no means been autonomous from society or policy in terms of identifying and defining ILUC as a research topic. Rather, ILUC research has to a considerable part been problem-oriented and -induced and “carried out in ‘the context of application’, that is, with societal needs having direct impact on the knowledge production from the early stages of investigative” (Tuunainen 2002: 37). Thus, ILUC evidence production fulfills one central criterion of mode 2 knowledge production. Furthermore, the actors participating in the process of scientific knowledge production on ILUC have been very diverse. Many scientific institutions as well as business corporations, NGOs and governments have been involved so that the scientific knowledge production can furthermore be characterized as co-production.

The topic ILUC linked to biofuels is characterized by several societal problems as well as scientific problems so that it also fulfills this characteristic of a transdisciplinary research object. One societal problem is that biofuels are promoted by the EU in order to save GHG emissions and but very likely lead to a release of considerably high GHG emissions through ILUC. One scientific problem is the complex quantification of ILUC and related GHG emissions. Still, it is only possible to quantify a range of ILUC induced GHG emissions but not exact numbers. The first step of transdisciplinary research is according to Jahn et al. (2012; see figure 2.2) the formulation of a common research object. As we showed in the previous chapters the EU-commissioned research mainly aimed at the deduction of ILUC factors given that already the RED asked the EC to investigate the inclusion of an ILUC factor in the GHG emissions calculation. Other research actors have however set other research objects so that the foci of the different research studies have been very diverse. Other actors than the EC have mainly aimed at the avoidance of ILUC by conduction case-studies and identifying mitigation measures (see e.g. Dehue et al. 2009; Dehue et al. 2010; Bauen et al. 2010) or regional approaches (see e.g. Lahl 2010).

ILUC research has thus been provoked by a range of different societal and scientific problems without transforming these into a common research object. As a consequence, the different ILUC research streams have been mainly running parallel to each other. They were also at least party dominated by a traditional scientific approach to the subject and without much interdisciplinary integration (step 2 in figure 5.1), which has been defined ”an integral part of transdisciplinarity” (Jahn et al. 2012: 5).

As a result of this, scientific research on ILUC provides different sorts of scientific evidence, which might make it a prime example of a case where resting a policy decision exclusively on the best-available science doesn’t work as a credible policy-making strategy. So, how did this scattered picture of scientific evidence on ILUC affect the EU ILUC policy process? How has scientific evidence been taken up in the relevant EU policy sphere? In the phase of policy formulation, as chapter 3 shows, much of the heterogeneous research as well as public knowledge on ILUC have been included into the considerations. For example, in the context of the numerous stakeholder consultations, impact assessments and expert workshops organized by the Commission as well as by science, NGOs or businesses, the broad range of opinions and viewpoints have been articulated. The diverging evaluations regarding the amount of ILUC, the robustness of the evidence on the issue in general as well as the policy options to deal with it in science and society did find their way into the policy process. Therefore, we conclude that in the phase of policy formulation, many kinds of scientific knowledge, including all the complexity and uncertainty the subject entails, are entering the policy deliberations and negotiations on biofuels’ ILUC at the EU level.

Given that the complexity of the issue and different opinions on it in science and society were given attention, this process of policy formulation shows some distinct features of a “post-normal science” (Funtowicz und Ravetz 1991). This means that in a situation like the ‘ILUC deadlock’ in the last two years where “facts are uncertain, values in dispute, stakes high and decisions urgent” (Funtowicz und Ravetz 1991: 138) an ‘extended peer community’ (all stakeholders affected by the issue) has been involved and the uncertainty and complexity of the issue at hand as well as ‘extended facts’ (like local community or anecdotal knowledge) on it have been recognized (Funtowicz und Ravetz 1992). Therefore, it comes close to what in the words of Braun and Kropp can be called “science’s ‘finest hour’” (Kropp und Wagner 2010: 826), that is, when science actually gets through to policy and when “uncertainties, areas of knowledge deficit, and ambivalent interpretations are integral and important parts of knowledge communication” (Kropp und Wagner 2010: 827).

However, as hypothesized in chapter 2.2, the role of scientific evidence on ILUC changes considerably when it comes to decision-making, or rather, in this case, non-decision-making. As depicted in chapter 3, a proposal for a decision on how to deal with biofuels' ILUC and its regulation on the EU level was originally scheduled for the end of 2010 but is still missing. In this process different arguments for regulating biofuels' ILUC in one or the other way (e.g. an ILUC factor or a higher GHG emissions reduction threshold) or not doing it have mainly been based on the 'best-available' science or the lack of it. Thus, even though we couldn't analyze this process in detail so far, it gives the impression that science has been used here "to rationalize and justify and create a climate of acceptance for political decisions (or nondecisions)" (Kropp und Wagner 2010: 828):

Right at the start of the ILUC debate the research commissioned by the EC has focused on only a specific kind of scientific evidence that is the quantification of crop-specific ILUC factors with the help of economic modeling. Probably also because they are relatively easy to adopt and to implement, these factors have from the outset (see chapter 3) been the most favored option to regulate ILUC on the part of policy-makers in Brussels. This supports the observation of Kropp and Wagner (2010) who stated that in the "phase of the decision-making process, those disciplines that use quantitative explanatory models and operate with conclusive data and studies (e.g., agricultural economy or molecular biology) have an easier time gaining political attention; conversely, disciplines that appeal more to qualitative argumentation and complex cause–effect relationships (e.g., agricultural sociology or ecology) will experience more difficulty in being heard" (Kropp und Wagner 2010: 828).

However, the studies commissioned by the EC also stressed the uncertainty and complexity of ILUC quantification, and partly questioned whether ILUC factors derived by economic modeling are a suitable basis for ILUC regulation. This has led to even more discussions between several stakeholders given that particularly NGOs and stakeholder from the biofuel industry have perceived this uncertainty and the consequences for an ILUC regulation very differently.

Still, the most recent news on the issue of regulating ILUC[3] suggests that the Commission is about to push through this political strategy of introducing ILUC factors, legitimizing and rationalizing it by only referring to a small fraction of the research on ILUC, namely the economic modeling studies commissioned by the Commission itself. Thus, it seems like only this certain kind of scientific evidence providing ostensibly clear-cut numbers and hard facts has been used in the phase of decision-making, whereas its function was rather a legitimizing and rationalizing than an informing one, which would largely confirm the observations made by Kropp and Wagner (2010).

# 6 Conclusions

ILUC has been one of the most heatedly debated aspects with regard to the EU biofuel policy since 2007/2008. Despite several scientific studies on ILUC quantification and on policy measures to reduce ILUC have been published within the last years an agreement on the EU level on how to deal with the ILUC risk of biofuels could not have been reached so far. Relevant reasons for this delay

[3] See http://www.reuters.com/article/2012/09/10/us-eu-biofuels-idUSBRE8890SJ20120910.

are methodological challenges in ILUC quantification and strong and opposing stakeholder interests.

The aim of this paper was to analyze how scientific evidence on ILUC has been produced in recent years and to analyze its role in EU biofuels politics. We analyzed which societal actors contributed to the scientific knowledge production and whether the processes of scientific knowledge production on ILUC qualify as a case mode 2 and/or transdisciplinary knowledge production.

We could show that mainly NGOs have raised awareness on ILUC in an early stage of the debate so that they probably contributed to set ILUC on the political and scientific agenda. Representatives of the bioenergy and agricultural sector contributed to the discussion and the policy process mainly within the last two years. While NGOs already stated in 2008 evidence on ILUC has sufficiently been proven, most of the stakeholder from business repeatedly pointed out that the process of scientific knowledge production has not been yet completed and should thus not used to derive policy instruments. As a consequence of strong stakeholder interests, the process on developing a policy on the EU level to reduce the ILUC risk linked to biofuel production has been very intense and interactive from 2009 on until now. Experts and stakeholder have been involved in form of public consultations, expert meetings and workshops.

Furthermore, several actors and institutions have contributed to scientific knowledge production by commissioning and conducting studies and reports on the quantification and mitigation on ILUC. Several independent research institutions such as universities and research institutes carried out a high number of studies on ILUC quantification and mitigation within 2008 and 2012. In particular, the EC itself has as a contracting entity been a very important driver for scientific knowledge production. Given that the EC was already requested in the RED 2009 to investigate the inclusion of an ILUC factor in GHG calculations, the EC driven research has focused on developing and testing methodologies to derive biofuel specific ILUC factors. National authorities, actors from the bioenergy industry and from NGOs also contributed to scientific knowledge production. In particular, they have provided knowledge on alternative ILUC quantification methodologies besides economic modeling and on measures to mitigate ILUC. Especially the role of actors from the industry can furthermore be characterized as a monitoring or evaluating role given that they commissioned a couple of reviewing studies on the IFPRI-studies commissioned by the EC.

In terms of the process of scientific knowledge production on ILUC, we conclude that this process shows some characteristics of a mode 2 or transdisciplinary knowledge production. Extra-scientific actors, that is, governments, business as well as NGOs, as well as societal problems played an important part in setting ILUC on the scientific agenda as well as in the process of scientific knowledge production itself, as the commissioners of research studies on ILUC. Thus, the research on ILUC as a whole is transdisciplinary to a considerable extent since extra-scientific impulses and actors play an important role and the research is context-driven and problem-focused. However, the specific research projects themselves are for the most part not transdisciplinary given that they largely remain within the confines of traditional, intra-disciplinary research.

This might as well be a reason for the way scientific evidence has been taken up in the policy process on regulating ILUC. In the phase of policy formulation, the way of scientific knowledge integration can be evaluated as a rather broad and inclusive process, where all different sorts of scientific evidence from all sorts of backgrounds have been included in the deliberations, aided also by several institutional devices such as public consultations and impact assessments. However, in the subsequent phase of decision-making, the role of scientific evidence on ILUC becomes an instrumental one, as most recent developments suggest. Citing only on a small fraction of it, preferably the one providing ostensibly clear-cut numbers, scientific evidence on ILUC is here used to legitimize and rationalize policy decisions that were agreed on beforehand.

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