Summary of approaches to accounting for indirect impacts of biofuel production

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Foreword

Ecofys would like to thank all those that have contributed to this study. From the Roundtable on Sustainable Biofuels, we would like to thank Matt Rudolf and Victoria Junquera Garcia for their pleasant cooperation and constructive feedback.

In addition we would like to thank the authors of the studies reviewed in this study that have participated in very useful discussions on their work. These are representatives of EPA, CARB, LEI and the European Commission and Tim Searchinger on a personal note.

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Summary

Indirect impacts of biofuel production have received increasing attention over the past years. These indirect impacts are impacts of biofuel production that occur as a result of market mechanisms. The two main negative indirect impacts are indirect land use change and competition with food. These impacts can lead to negative effects on greenhouse gas emissions, biodiversity and food consumption and are difficult to quantify because they occur through diffuse market mechanisms.

From a review of six (scientific) initiatives that aim to quantify these indirect impacts it becomes clear that:

- No information is available on the magnitude of indirect impacts on biodiversity.
- Limited information is available on the magnitude of indirect impacts on food consumption.
- Indirect impacts on the greenhouse gas balance of biofuels through land use changes are predicted to be between 30 and 103 gCO_2eq/MJ biofuel.

The range of magnitudes of indirect impacts on the greenhouse gas balance of biofuels is found to be mainly caused by different values for the following key input assumptions used by the quantification initiatives.

- The choice of feedstock for the additional biofuel demand.
- Relation between agricultural intensification and commodity prices and/or demand.
- Relations between commodity demand, commodity prices and food demand.
- Assumptions on types of land use change caused by cropland expansion.
- Assumptions on carbon stocks of land types affected by cropland expansion.

From a review of five mitigation initiatives for indirect impacts it is found that mitigation measures are still in a development stage. In addition, they do not always include incentives for individual biofuel stakeholders to pursue strategies that minimize or eliminate the risks of indirect impacts.

From the reviews on quantification and mitigation initiatives combined with its previous experience on indirect impacts, Ecofys gives three main suggestions to the RSB on indirect impacts and including them in its standard:

- The RSB should not do its own detailed analysis on the quantification of indirect impacts, but instead focus directly on mitigation options.
- The RSB may support global level solutions, but its focus should be on pragmatic project level solutions.
- The RSB should include indirect impacts in its standard. However, at this moment, the RSB should not quantify indirect impacts through its lifecycle GHG balance calculations. Instead, indirect impacts should be included through a risk-based approach: criteria need to be defined in the RSB standard that differentiate biofuels with reduced risk of indirect impacts from those without reduced risk.

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1 Introduction

This chapter introduces the concept of indirect impacts of biofuel production then discusses the difficulties in assessing indirect impacts. Finally, the aim and structure of this study are outlined.

1.1 Indirect impacts of biofuel production

Sustainability is an important aspect of current biofuel production and use. At the start of the strong growth of biofuel production and use in the last decade, most attention was given to the direct impacts of biofuel production. These include for example: land use change[1] effects when starting a biofuel crop plantation; fertilizer, water and fuel use during feedstock production; fuel and chemical use during the processing of feedstock to fuel; and fuel use during the distribution of the fuel. The focus in studying these direct impacts is on their effect on the overall greenhouse gas (GHG) balance of the biofuel. In addition, the direct impacts of biofuel production on environmental aspects such as biodiversity, water, air and soil have been assessed, as well as the direct impacts on social aspects such as land use rights and labour conditions.

In more recent years, increasing attention is given to the indirect impacts[2] of biofuel production which are impacts of biofuel production that are the result of market mechanisms. The two main negative indirect impacts are indirect land use change (ILUC) and competition with food. These indirect impacts have become one of the key challenges to large scale sustainable biofuel production from energy crops.

ILUC occurs when the production of biomass feedstock displaces activities to other areas where they cause land use change and thus have potentially negative impacts on aspects such as carbon stocks and biodiversity. An example of this is when demand for palm oil for the biofuel market is supplied from existing plantations that used to supply to the food market as in Illustration 1 - 1. As palm oil is now supplied to the energy sector, the food sector is confronted with a (temporary) shortage in supply. In the short run this will lead to higher prices as supply is slow to adapt to the new market circumstances. In time, the higher prices may lead to a production increase, which could require additional plantations, leading to land use change. The location of this indirect land use change is uncertain, and more importantly, is out of the control of the biofuel producer and consumer.

[1] Land use change means that the use of a certain area of land changes between different types. For example, a forest is cleared and taken into use as agricultural cropland, or currently unused grassland is turned into pasture for cattle grazing. Land use change can have an impact on the carbon stock (the amount of carbon stored in the vegetation and soil) and biodiversity of the land, which can be unwanted.
[2] Indirect impacts are sometimes also referred to as 'indirect effects', 'displacement effects', 'indirect land use change' or 'macro effects'.

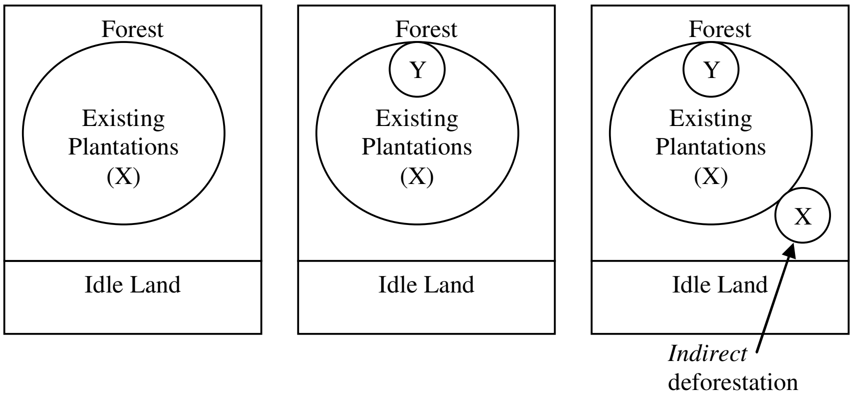

Illustration 1 - 1 Example of displacement mechanism causing indirect deforestation. Y is new demand from the bioenergy sector from existing plantations. X is expansion of existing plantations as a result of displacement effects. (Dehue, 2006)

The second main indirect impact of biofuel production, competition with food, starts with the same market mechanism as ILUC as described above: increasing demand for agricultural commodities for biofuel production leading to price increases. However, this time the increased demand in the biofuel sector is not met by increased production over time. Instead, there is reduced demand for the commodity in the food sector because not all consumers are able or willing to pay the increased prices.

In practice, it depends on a complex set of diffuse economic interactions which of the two indirect impacts described above occurs and to what extent. In most cases, it is likely that the increased demand for agricultural commodities for the biofuel sector results in both production increase and reduced consumption in the food sector.

The two main indirect impacts, ILUC and competition with food, are not by nature negative, but can very well cause unwanted effects. For example, the clearing of the forest as shown in Illustration 1 - 1 will release the carbon stocks stored in the forest vegetation and soil and will reduce biodiversity in the area. Competition with food can lead to decreased food consumption for groups of people who cannot afford the increased food prices. This effect is especially severe when it impacts the poorest groups of people that are already at risk of undernutrition.

1.2 Difficulties in assessing and mitigating indirect impacts

Indirect impacts of biofuel production are far more difficult to assess and mitigate than direct impacts. This is because they occur through market mechanisms that are generally beyond the control of the biofuel producer and consumer, whereas direct impacts are usually more obvious and easier to influence.

A few important notes on indirect impacts to further illustrate their difficult quantification and mitigation are:

- **Displacement effects act across national borders**: e.g. a shift in the oil palm produced in Malaysia from food to fuel could lead to an expansion of oil palm for food in Indonesia, with the accompanying risks of LUC.

- **Displacement effects act between substituting crops**: e.g. a shift in the rapeseed oil produced in the EU from food to fuel could lead to increased imports of a substituting vegetable oil, e.g. palm oil, for food. This puts additional pressure on oil palm expansion.
- **Competition for land connects also non-substituting crops**: e.g. high demand for maize may increase maize prices, leading to farmers planting more maize. This will mean less planting of another crop, e.g. soy. This could lead to an expansion of soy in other areas as a response to higher soy prices induced by the reduction in supply or additional pressures on soy-substituting crops.

The developments on mitigation of indirect impacts have suffered from the difficulty of assessing and influencing indirect impacts. Parties in favour of pursuing mitigation of indirect impacts claim that these impacts are so large they cannot be ignored in biofuel strategies and policies, while parties opposed to mitigation claim there is a lack of scientific consensus on indirect impacts that prevents development of accurate mitigation strategies and policies.

1.3 Aim and structure of this study

As an important player in the biofuel market, the Roundtable on Sustainable Biofuels (RSB) is also a stakeholder in the debate on how to quantify and mitigate indirect impacts of biofuel production. Therefore the RSB has commissioned this study to:

- Review the technical literature and analytical tools that are being employed to quantify indirect impacts of biofuel production.
- Summarize existing regulatory and policy approaches to accounting for and mitigating global food price and indirect land use change impacts of biofuels production.
- Propose mitigation options for the private sector participants in the RSB.
- Make recommendations to the RSB Secretariat, participants, and Steering Board for the eventual inclusion of indirect impacts in the standard and certification program.

This study addresses these goals in the following structure:

- Chapter 2 provides a review of a set of key (scientific) initiatives that aim to quantify the magnitude of the indirect impacts of biofuel production. It introduces the results of the studies performed by these initiatives and discusses key factors in methodology and assumptions that cause the differences in these results.
- Chapter 3 provides a review of current existing initiatives to account for and mitigate indirect impacts of biofuels production. It gives an introduction on each initiative and discusses its main mechanisms to give an insight into its possible effects.
- Chapter 4 provides suggestions for the RSB and its stakeholders to develop effective mitigation strategies for indirect impacts and to incorporate these in the RSB standard and certification program.

2 Review of quantification initiatives of indirect impacts of biofuel production

This chapter reviews a set of key (scientific) initiatives that aim to quantify the magnitude of the indirect impacts of biofuel production. This quantification, and therefore its review as well, is a rather complicated multi-step effort. Therefore the general stepwise methodology of this quantification and its review are addressed in section 2.1. The authors strongly advise to read this section, before continuing to the other sections of this chapter that contain the detailed information associated with this review and its results.

2.1 Stepwise introduction to the quantification of indirect impacts

In order to understand and interpret the quantification initiatives for indirect impacts and their methodology and results it is crucial to have an adequate understanding of the general developments in these initiatives. Therefore these are summarized in a stepwise introduction in this section. Subpoints of each step give a short conclusion of the relevant findings of this study with regard to that step and refer to the sections of this chapter that present that particular step in more detail.

1. As described in Chapter 1, negative indirect impacts of biofuel production have received increasing attention in recent years. As a result, biofuel stakeholders such as producers, governments and NGOs entered into a debate on what can be done to mitigate these negative indirect impacts. There is however a significant hurdle in this debate: ***no general consensus exists among biofuel stakeholders on whether these indirect impacts are actually significantly large and if so, how large exactly***.
2. This lack of consensus as described in the previous point led to the ***development of initiatives that set out to quantify the impact of future additional biofuel demand including some or all indirect impacts***.
    - This study has limited its scope to three indirect impacts: those on the life cycle green house gas balance of the biofuel due to indirect land use change, those on biodiversity due to indirect land use change and those on global food prices and food consumption. This is further discussed in section 2.2.
3. ***Some of the first initiatives based their quantification on relatively simple calculations based on aggregated recent historic data*** on biofuel feedstock sourcing and agricultural expansion, ***combined with assumptions on a number of crucial parameters*** such as future feedstock, co-product availability, likely land use change types and the associated lost carbon stocks.
4. However, this type of quantification was on many occasions deemed too rough to provide insight into the complex issue of indirect impacts. Therefore ***existing complex (global) agroeconomic equilibrium models***, previously mostly used to predict future developments in food supply and trade flows, ***were increasingly***

used to model the reaction of the global economy to additional biofuel demand as their more detailed calculation was expected to be more accurate.

- The initiatives that are included in the review in this study are presented in section 2.2.
- The methodology used to perform quantification of indirect impacts with these models is discussed in section 2.3. This discussion includes a short general introduction to global agroeconomic equilibrium models.
- Although these global model calculations are far more elaborate and detailed in nature, this study finds that their results are largely determined by the same key input assumptions as those of the simple quantification efforts discussed in the previous point. These assumptions are discussed in section 2.4.

5 ***Over the past years, a number of (scientific) initiatives have published results of the quantification of indirect impacts of additional biofuel demand using global agroeconomic equilibrium models***. They have presented these results in publications that discuss their model methodology, key input assumptions and key output results. ***In general, indirect impacts are found to be significant***. For example, the indirect greenhouse gas emissions of biofuels are found to be in the range of about 30% - 100% of total emissions of a fossil reference fuel.

- Each initiative presents its results in its own way and on its own level of detail. Therefore, the review and comparison of these results in this study required a large effort to extract and prepare a number of key results such that they could be meaningfully compared. The methodology for doing so is introduced in section 2.5.
- The result of this comparison can be found in section 2.6.

6 These ***quantification initiatives using global agroeconomic models have in turn been criticized to be too pessimistic, especially on some crucial input assumptions*** on e.g. future yield developments, effects of co-products of biofuels and land use change types caused by agricultural expansion for biofuel feedstocks.

- This critique and its merits are discussed in section 2.9.

2.2 Scope of the review in this study

Section 2.1 mentions two important choices on scope in this review: the indirect impacts taken into account and the quantification initiatives that have been reviewed. They are presented in this section.

The following indirect impacts were taken into account:

1 Impact on the life cycle green house gas balance of the biofuel due to indirect land use change.

2 Impact on biodiversity due to indirect land use change.

3 Impact on global food prices and food consumption.

This scope was chosen before performing the review as these indirect impacts were expected to be most relevant and most studied. During the review it was found that impact on biodiversity was not specifically quantified in any of the reviewed initiatives, although some mean to include it in future work.

The following key quantification initiatives using global agroeconomic equilibrium models were reviewed (each initiative is preceded by its short name that is used to refer to it in the rest of this study):

1. EC: Work undertaken by European Commission.
2. RFS: US Renewable Fuels Standard (2nd version, RFS2), designed by the Environmental Protection Agency.
3. LCFS: Californian Low Carbon Fuel Standard, designed by the Californian Air Resources Board.
4. Searchinger: Work undertaken by Tim Searchinger, scholar and lecturer at Princeton University, et al.
5. IIASA, Work undertaken by IIASA, the International Institute for Applied Systems Analysis.
6. LEI: Work undertaken by LEI, the agroeconomical institute of Wageningen University and Research Centre.

The reference list in the end of this report provides an overview of the publications of each initiative that were reviewed. It is important to note that most initiatives, including RFS, LCFS and LEI are working on refining and expanding the modelling calculations reviewed in this study. These results are expected in the near future.

Unfortunately, it was found that the first initiative, that of the EC, has not yet resulted in quantitative results and could thus not be included in the quantitative comparison. The EC has issued two large quantification studies using global agroeconomic equilibrium models that are expected to generate results in the near future, but it is as of yet unclear when exactly. (EC, 2009)

Also, although the work of LEI has provided quantified results of indirect impacts of biofuel production, it has unfortunately not been possible to extract data from their work that would allow a useful quantitative comparison with the other initiatives. This is further explained in Appendix A.

2.3 Methodology of quantification and the role of equilibrium models

Section 2.1 explains that the quantification of indirect impacts has generally been performed by using global agroeconomic equilibrium models in recent years. This section presents the general methodology used in such quantification initiatives and explains the role of the equilibrium models in this quantification.

Each initiative has its own exact methodology for quantification of indirect impacts of biofuel production. However, a general four-step approach is commonly found in these methodologies. This approach is visualized in Illustration 2 - 2.

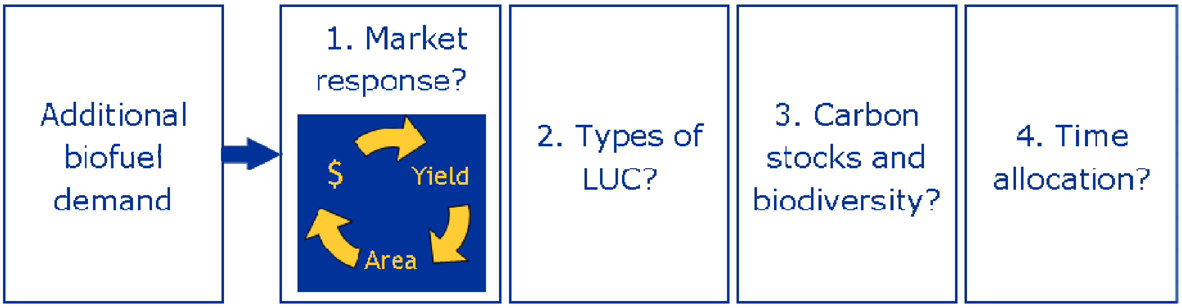

Illustration 2 - 2 Four-step approach to quantifying the indirect impacts of biofuel production. First a certain additional biofuel demand to be analyzed is chosen. Usually this is based upon a certain biofuel mandate, but it can also be based on general market expectations on competition with other fuels. Then the market response is calculated by modelling expected interdependent changes in commodity prices, crop yields and cropland areas due to the additional biofuel demand. To further quantify the effects of ILUC, information is gathered on types of LUC and the corresponding changes in carbon stocks and biodiversity. Finally, a time horizon is chosen to which these indirect impacts are allocated in order to enable comparison on e.g. a per year or per MJ fuel basis. This approach is described in more detail in Table 2 - 1.

The approach visualized in Illustration 2 - 2 can be used to quantify all the indirect impacts mentioned in section 2.2. This is further explained in Table 2 - 1.

Step	***Description***	***Reviewed impacts***
1. Market response	Global agroeconomic equilibrium models are used to assess the effect of additional biofuel demand, for example by introducing a biofuel mandate, on the market. Effects to accommodate the biofuel demand are usually separated in three categories: • Expansion of agricultural land. • Intensification of agricultural production; e.g. higher yield per harvest, increased number of harvests per year • Higher commodity prices, crowding out consumers of the same commodity in other markets, leading to reduced consumption e.g. for food.	**Information on global food prices and food consumption**
2. LUC	From step 1, it is known what amount of expansion of agricultural land can be expected. Also, the location is usually available on a country/region level. In this step a prediction is made on which types of land will be converted to agricultural land. One method used for this purpose is satellite analysis of historical LUC trends.	

3a. Biodiversity 3b. Carbon stocks	Once the amount and the type of LUC is known from steps 1. and 2., the biodiversity and carbon stocks impacts can be assessed, making use of information sources on the carbon stocks and biodiversity values present in the LU-types that are converted – e.g. IPCC data-sources on carbon stocks. For the carbon impact, an additional step is needed, see step 4.	**Information on biodiversity loss**
4. Time allocation	Although the carbon emissions quantified in step 3b. largely take place upon conversion, they are usually allocated to the GHG balance of biofuels in time. Different allocating mechanisms have been suggested.	**Information on life cycle GHG balance**

Table 2 - 1 Detailed description of the methodology to quantify the indirect impacts of biofuel production on food consumption, biodiversity and biofuel life cycle GHG balance.

Not all initiatives encompass all the steps described in Illustration 2 - 2 and Table 2 - 1; in some cases only the first step, modelling the market response to the additional biofuel demand, is performed.

As mentioned in Table 2 - 1, step 1 is usually performed using global agroeconomic equilibrium models. These models, of which GTAP is an example, divide the world into certain regions or areas. The economic responses in these areas are predicted by combining a large amount of mathematical product functions with (historical) data from large databases. Within these product functions, the response of one parameter to a change in another parameter is described using elasticities. An example would be a function that describes how likely it is that if the price of importing a commodity increases that the imports of that commodity reduce. These elasticities can be based on historical data, expert judgment or a combination of the two.

The model always starts in a certain reference equilibrium state. Then, a distortion, e.g. an additional biofuel demand compared to the reference equilibrium state, is introduced. Using the product functions and the database data, the model then calculates a new, economically optimized, equilibrium state. The response to the distortion can then be determined by comparing the new equilibrium with the reference equilibrium.

Each specific model has its own regional divisions, product functions and elasticity assumptions. These differences in model setup and assumptions lead to differences in model outcomes ranging from minor to large. This paper does not discuss all the differences in setup and assumptions between the different models, but does provide a thorough analysis of those that have the largest impact on the model outcomes and thus on the quantification of indirect impacts. This is done in the sections 2.4 through 2.7.

2.4 Key assumptions in the quantification of indirect impacts

Section 2.1 explains that although the global agroeconomic equilibrium models are far more complex and detailed than the simple calculations put forward in earlier *quantification efforts, their outcome still very much depends on the same key input assumptions. This section presents these assumptions, discusses why they have such large effects on quantification outcomes and argues that a number of these key assumptions are difficult to quantify.*

The methodology of quantification described in section 2.3 contains a large and complex computational framework in the equilibrium models. This framework can however, as presented in Illustration 2 - 2 and Table 2 - 1, be described in four general steps. The main assumptions associated with each of these steps are thus determining factors in the eventual model outcomes. These are discussed here:

1 <u>Market response to additional biofuel demand</u>

This step contains the following main assumptions to quantify the resulting cropland expansion, intensification of production and reduction of demand in other sectors.

- The **choice of feedstock** for the additional biofuel demand; e.g. including biofuel pathways with a high biofuel yield per hectare or biofuels from residues and wastes leads to lower indirect impacts.
    - Choosing biofuel pathways with a high biofuel yield per hectare means that in principle less area is needed to accommodate the additional biofuel demand and thus that indirect impacts are lower. As biofuel yields per hectare from high yielding pathways can be multiple times higher than those of low yielding pathways this can have a large effect. However, co-products should be taken into account as well; this is discussed in the next assumption.
    - Choosing biofuel pathways from residues and wastes in principle puts no strain on the economic system, so no indirect impacts occur.
    - This assumption is difficult to make because it is hard to predict for example future technological advances, market developments and residue and waste availability.
- Treatment of **co-products** of biofuel production.
    - Most biofuel feedstock crops do not only have biofuel as end-product, but co-products are produced as well. For example, corn used for ethanol production also yields residual dry distiller's grains and solubles (DDGS) commonly used as animal feed. And in soy biodiesel production the biofuel co-product, soy meal commonly used as animal feed, is even the main product in terms of volumes. These co-products can be accounted for by assuming they displace a certain amount of other commodities on the markets, usually animal feed. The assumption on how large this effect is, has a very significant effect on the outcome of the model. For example the DDGS from corn ethanol production is often assumed to replace one third of the original corn demand.
- **Relation between agricultural intensification and commodity prices and/or demand**.
    - This relation determines the amount of additional biofuel demand that is met through agricultural intensification. Any amount met this way does not

need to be met by cropland expansion and thus no (I)LUC occurs for that amount.
  - This relation is very difficult to quantify: historical data is scarce and inconclusive, meaning that predicting future developments is difficult.
- **Relation between food demand and commodity prices**.
  - This relation determines the amount of additional biofuel demand that is met through reductions in food demand. Any amount met this way does not need to be met by cropland expansion and thus no (I)LUC occurs for that amount. In addition it determines the indirect impacts on food consumption.

2 LUC caused by cropland expansion

- Assumptions of **types of LUC caused by cropland expansion**.
  - Since carbon stocks and biodiversity values between different land types, e.g. forest, grassland, savannah, can differ significantly; the type of land use change assumed to occur because of cropland expansion is a key parameter in quantifying indirect impacts.
  - Secondary indirect effects can occur in the cattle sector, which is not included in each modelling effort. For example when a biofuel is produced from soy previously used for the food sector, the soy might be replaced by an expansion into pastures used for cattle grazing. This cattle pasture might in turn be replaced by pasture expansion into a forested area. This secondary effect is only quantified when the modelling effort accounts for these changes in the cattle sector.

3 Current carbon stocks and biodiversity values of land used for cropland expansion

- Assumptions on **carbon stocks and biodiversity values** of land types affected by cropland expansion.
  - Even when the types of LUC are known from the second step, the carbon stock and biodiversity value of the land affected by LUC is still an important assumption, as different values are used within the different initiatives.

4 Time allocation of GHG emissions of LUC

- Assumptions on **time allocation of GHG emission effects**.
  - Most GHG emissions of LUC occur soon after the conversion of land types takes place, for example by burning the original vegetation. However, in the final result of the GHG life cycle analysis of the biofuel, these emissions from LUC need to be allocated in time to the biofuel produced on the land. The amount of years chosen for that is not principally set, since it is not known for how many years the land will be used for biofuel production. This enables a very broad range of time horizons, commonly somewhere between 20 to 100 years, and thus has a significant effect on the indirect GHG impacts.

2.5 Methodology to compare the assumptions and results of the quantification

From section 2.1, 2.3 and 2.4 it is clear that a custom comparison methodology was needed to compare the assumptions and the results from the different quantification initiatives. This methodology is described in this section.

Results of the equilibrium modelling methodologies described in section 2.3 are usually presented in (scientific) publications. This necessarily limits the details that can be published. Unpublished parameters can sometimes be obtained by contacting the authors, but not all.

This limitation on the detail available necessitates careful construction of a method for comparison. In this study, a set of key parameters from each initiative was chosen to allow a good comparison of the main assumptions and results of the initiative, while still keeping collection of these parameters manageable.

The model input assumptions in this set of parameters represent the important assumptions described in section 2.4:

- A1: The amount and choice of feedstock for the additional biofuel demand.
- A2: Treatment of co-products of biofuel production.
- A3: Relation between agricultural intensification and commodity prices and/or demand.
- A4: Relations between commodity demand, commodity prices and food demand.
- A5: Emissions of cropland expansion, integrating:
    - Assumptions of types of LUC caused by cropland expansion.
    - Assumptions on carbon and biodiversity stocks of land types affected by cropland expansion.
- A6: Project horizon for emissions from (I)LUC

The model output results in this set of parameters contain crucial and comparable quantitative data on the magnitude of the calculated indirect impacts:

- R1: The division between the following possible results from additional biofuel demand:
    - Biofuel induced agricultural intensification
    - Reduced demand in other sectors
    - Cropland expansion
- R2: Absolute amount of cropland expansion.
- R3: GHG emissions of (I)LUC caused by cropland expansion.

Table 2 - 2 presents this set of parameters in more detail and describes their use in making the comparison. In some cases it was necessary to perform some calculations with the published data, for example to convert units or to categorize the data into the set of parameters chosen in this review. In section 2.6, when results are presented for which such calculations were necessary, their use is mentioned.

It is important to note that in most of the global agroeconomic models direct and indirect land use changes and thus their GHG effects can not be separated: the model calculates a reference scenario and an additional biofuel scenario for land uses. The differences between the two represent all land use changes, both direct and indirect. Therefore, these two are combined in Table 2 - 2 and the rest of this study.

It is also important to note that no specific parameters on biodiversity have been chosen: none of the initiatives was found to have done any dedicated analysis to this topic. Additionally, no common absolute parameter to express impacts on food consumption could be identified. However, indirect impacts on food consumption can be derived from the share of reduced demand in other sectors in the results of additional biofuel demand.

Table 2 - 2 Key parameters used in presenting the assumptions and results of the different quantification initiatives for indirect impacts for biofuel production, allowing a comparison between initiatives. Each parameter and its unit are given and an explanation is given on the use of this parameter in the comparison. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results.

A/R[3]	Parameter	Unit	Explanation
	Additional biofuel demand		**These parameters set what additional biofuel demand is assumed in the study and thus indicate the essential input to the modelling part.**
A1	Total	Mtoe	Total amount of additional biofuels when new and reference equilibrium are compared. Mtoe stands for megaton of oil equivalent, or the energy content of 1 million tons of fossil oil. 1 Mtoe corresponds to 41.9 PJ or roughly 2 billion liters of ethanol.
	From energy crops	Mtoe	Total amount of additional biofuels coming from biofuel pathways based on energy crops. Cropland expansion, agricultural intensification and/or reduced demand in other sectors are needed to obtain the feedstock. The differentiation between this category and the category of biofuels from residues and wastes is made to enable a more differentiated and fair comparison between indirect impacts per unit of additional biofuel demand.
	Feedstock division	%	The above amount is divided into shares of pathways per feedstock.
	From residues and wastes	Mtoe	Total amount of additional biofuels coming from biofuel pathways based on residues and wastes, e.g. corn stover. Because the used residues and wastes are already available, no cropland expansion, agricultural intensification and/or reduced demand in other sectors are needed to obtain the feedstock. The differentiation between this category and the category of biofuels from energy crops is made to enable a more

[3] These codes refer to the assumptions and results discussed earlier in this section.

			differentiated and fair comparison between indirect impacts per unit of additional biofuel demand.
	Feedstock division	%	The above amount is divided into shares of pathways per feedstock.
	Treatment of co-products		
A2			Description of how co-products of biofuel production from the different feedstocks are handled in the model. Where possible the effect of the co-product is expressed in a quantitative displacement of the original feedstock.
	Assumptions on additional agricultural intensification		
A3			Description of assumptions on the relation between agricultural intensification and commodity prices and/or demand.
	Assumptions on changes in food demand		
A4			Description of assumptions on the relations between commodity demand, commodity prices and food demand.
	Additional demand results in		**These parameters give a rough but clear indication what is predicted to result from the additional biofuel demand, which is the primary level of model output. It gives information on one of the three indirect impacts: food consumption.**
R1	Biofuel induced agricultural intensification (total)	%	% of total additional biofuel feedstock demand resulting in additional agricultural intensification in new equilibrium compared to the reference equilibrium.
	Reduced demands in other sectors (total)	%	% of total additional biofuel feedstock demand resulting in reduced demand in other sectors in new equilibrium compared to the reference equilibrium.
	Cropland expansion (total)	%	% of total additional biofuel feedstock demand resulting in cropland expansion in

			new equilibrium compared to the reference equilibrium.
	Biofuel induced agricultural intensification (from energy crops)	%	Idem, but then relative to the additional demand of biofuels from energy crops.
	Reduced demand in other sectors (from energy crops)	%	Idem, but then relative to the additional demand of biofuels from energy crops.
	Cropland expansion (from energy crops)	%	Idem, but then relative to the additional demand of biofuels from energy crops.
	Extent of cropland expansion		**These parameters further describe the cropland expansion found in the model output. A large amount of cropland expansion is likely to lead to significant indirect impacts on biodiversity and the GHG balance.**
R2	Cropland expansion	Mha	The total amount of cropland expansion found. The number is expressed in Mha or megahectare. This amounts to 1 million hectares or 10,000 km^2.
	Cropland expansion (relative, total)	Ha/toe	The relative amount of cropland expansion found per unit of total additional biofuel demand. toe stands for ton of oil equivalent, or the energy content of one ton of fossil oil. 1 toe corresponds to 41.9 GJ or roughly 2,000 liters of ethanol.
	Cropland expansion (relative, from energy crops)	Ha/toe	The relative amount of cropland expansion found per unit of additional demand of biofuels from energy crops.
	GHG effect of cropland expansion		**These parameters indicate how many greenhouse gas emissions in CO2 equivalents are associated with the land use change through cropland expansion. These can include released biomass carbon, soil carbon and forgone forest sequestration.**
A5	Weighted average of emissions from crop expansion	tCO2eq/ha	The amount of CO2 equivalents released per unit of cropland expansion. This is a weighted average between different types of land use change that are determined in the modelling and includes both direct LUC and ILUC as these effects are usually not

			separated in the models. tCO2eq stands for tons of CO2 equivalent. In this unit, all greenhouse gas emissions occurring are converted into an amount of CO2 emissions with an equivalent greenhouse gas effect.
A6	Project horizon for emissions from (I)LUC	Years	The amount of time over which the released CO2 equivalents that are mainly released upon land conversion are annualized. This is an important parameter for obtaining the GHG impact per unit of fuel produced.
R3	Weighted average of emissions from (I)LUC (total)	gCO2eq/MJ fuel	Combination of direct and indirect GHG impact per unit of total additional amount of biofuel, since direct and indirect GHG effects are usually not separated in the models. In this unit, all greenhouse gas emissions occurring are converted into an amount of CO2 emissions with an equivalent greenhouse gas effect. gCO2eq instead of tons and MJ instead of Mtoe are used because life cycle GHG emissions of (fossil) reference fuels are usually given in this unit.
	Weighted average of emissions from (I)LUC (from energy crops)	gCO2eq/MJ fuel	Idem, but then for the additional demand of biofuels from energy crops.

Table 2 - 2 Key parameters used in presenting the assumptions and results of the different quantification initiatives for indirect impacts for biofuel production, allowing a comparison between initiatives. Each parameter and its unit are given and an explanation is given on the use of this parameter in the comparison. Each unit that is not self-explanatory is explained in the row where it first occurs. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results.

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Although the used global agroeconomic equilibrium models are complicated in nature, it is important to realize that the results R1 through R3 can in principle be obtained by simply combining the key assumptions A1 through A6. This is explained in Illustration 2 - 3.

R1:

- From A1 the additional amount of biofuel demand and the used feedstock is known.
- By adapting the needed amount of feedstock by including the effects of co-products from A2 a final amount of additional feedstock can be calculated.
- From this amount, by including the effects of A3 (intensification-price response) and A4 (food demand – price response) it can be found what the division in R1 (intensification, cropland expansion, reduced food consumption) is.

R2:

- From R1 it is known what part of the additional feedstock demand is met by cropland expansion. This relative amount can be translated to an absolute amount: R2.

R3:

- From R2 the absolute amount of cropland expansion is known.
- By multiplying this with A5 (GHG-emissions per unit of LUC) the total GHG emissions of LUC can be calculated.
- By dividing this number by the product of the annual amount of additional biofuels (A1) and the emission project horizon (A6), the GHG emissions of (I)LUC caused by cropland expansion per unit of fuel can be calculated, which is R3.

Illustration 2 - 3 Rough calculation methodology for calculating results R1 through R3 from assumptions A1 through A6 as presented in section 2.5.

2.6 Comparison of the assumptions and results of the quantification

Table 2 - 3 contains the assumptions and results of the quantification as reviewed according to the methodology presented in section 2.5.

Table 2 - 3 Comparison of the assumptions and results of the reviewed quantification initiatives of the indirect impacts of biofuel production. For an in-depth explanation of the result parameters and units, see Table 2 - 2. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results. The reference list in the end of this report provides an overview of the publications of each initiative that were reviewed.

A/R[4]		**Unit**	**RFS**	**LCFS**	**Searchinger**	**IIASA**	**LEI**
	Additional biofuel demand						
A1	Total	Mtoe	31.16	29.00	28.18	125.00	Could not be determined from quantitative results, see main text.
	From energy crops	Mtoe	16.71	29.00	28.18	125.00	
	Feedstock division	%	30% corn ethanol 6% soy biodiesel 28% sugarcane ethanol 36% switchgrass ethanol	87% corn ethanol 13% sugarcane ethanol[5]	100% corn ethanol	78% ethanol 22% biodiesel	
	From residues and wastes	Mtoe	14.45	0.00	0.00	0.00	
	Feedstock division	%	100% corn stover ethanol	N/A	N/A	N/A	

[4] These codes refer to the assumptions and results as discussed in section 2.5.
[5] The LCFS work contains modeling on more feedstocks than corn and sugarcane, for example soy, however these values are reported as preliminary and are thus not included.

			RFS	LCFS	Searchinger	IIASA	LEI[6]
	Treatment of co-products						
A2			Co-products included endogenously in the model. Corn: 25-45% displacement[7] of original feedstock by co-products. Sugarcane, switchgrass and corn stover: 0% displacement, all co-products are used for process energy.	Corn: 25-45% displacement[7] of original feedstock by co-products; Sugarcane: 0% displacement, all co-products are used for process energy.	Corn: 33% displacement of original feedstock by co-products.	Co-products included endogenously in the model, exact effect is unclear.	Co-products not included with any displacement effect.
	Assumptions on additional agricultural intensification						
A3			Assumed to be zero regardless of demand and/or price increases of commodities.	Included in the model through various demand/yield elasticities.	Assumed to be zero regardless of demand and/or price increases of commodities.	Included in the model.[8]	Included in the model.[8]
	Assumptions on changes in food demand.						
A4			Included in the models.[8]				

[6] The reasons to not include quantitative data of the LEI work are given in Appendix A.
[7] In this study the co-product of corn ethanol is assumed to replace corn on a ~1 : 1 weight basis. As generally 25% - 45% of the corn input ends up in the co-product, this range is used by Ecofys to estimate the co-product displacement effect.
[8] These assumptions consist of a large range of interacting assumptions that form the core of the equilibrium modeling and can thus not be summarized here.

			RFS	LCFS	Searchinger	IIASA	LEI[9]
	Additional demand results in						
R1	Biofuel induced agricultural intensification (total)	%	0%	Could not be determined from quantitative results.[10]	0%	27%[11]	Could not be determined from quantitative results, see main text.
	Reduced demand in other sectors (total)	%	3%[12]		20%[13]	34%	
	Cropland expansion (total)	%	97%		80%	39%	
	Biofuel induced agricultural intensification (from energy crops)	%	0%		0%	27%	
	Reduced demand in other sectors (from energy crops)	%	6%		20%	34%	
	Cropland expansion (from energy crops)	%	94%		80%	39%	

[9] The reasons to not include quantitative data of the LEI work are given in Appendix A.

[10] There was to few quantitative data on biofuel induced agricultural intensification and reduced demand in other sectors to quantify this division. Communication with authors of the LCFS work indicated that the effect of these two on reducing needed cropland expansion was significant, but no quantitative value could be reported.

[11] These values on division of results from additional demand were reported by IIASA to be valid for the cereals used as biofuel feedstock in their scenarios. As ethanol from cereals is the main contributor to the analysed scenarios, it is assumed to be valid for the entire additional biofuel demand.

[12] The values for reduced demand in other sectors in the RFS work were calculated by Ecofys based on values on worldwide reduced food consumption reported in the RFS work. This value is therefore of an indicative nature. Communication with the authors of the RFS work did confirm that they also believed the effect of demand reduction in other sectors to be small in their calculations.

[13] This value was an estimate as reported by Searchinger during personal communication with Ecofys and is therefore indicative.

			RFS	LCFS	Searchinger	IIASA	LEI
	Extent of cropland expansion						
R2	Cropland expansion	Mha	4.9	5.0	10.8	21.5	Could not be determined from quantitative results, see main text.
	Cropland expansion (relative, total)	ha/toe	0.16	0.17	0.38	0.17	
	Cropland expansion (relative, from energy crops)	ha/toe	0.29	0.17	0.38	0.17	
	GHG effect of cropland expansion						
A5	Weighted average of emissions from crop expansion	tCO2eq /ha	288	235[14]	351	219[15]	Was outside the scope of the LEI study.
A6	Project horizon for emissions from (I)LUC	Years	30	30	30	30	
R3	Weighted average of emissions from (I)LUC (total)	gCO2eq /MJ fuel	30[16]	32	103	30	
	Weighted average of emissions from (I)LUC (from energy crops)	gCO2eq /MJ fuel	56	32	103	30	

[14] This factor was back calculated from the weighted average GHG results in gCO2eq/MJ fuel as reported by the LCFS, since no conclusive direct data was found in the publications.
[15] This value is backcalculated from total GHG emissions of LUC reported by IIASA. As the entire quantification of these GHG effects is reported as indicative in the IIASA publications, this value is indicative as well.
[16] This factor is about 5-10% lower than the one that would be found by following the methodology in Illustration 2 - 3. This is because the factor reported in the RFS work also contains some beneficial indirect GHG impacts of biofuels like reduced methane emissions in the cattle sector.

Table 2 - 3 Comparison of the assumptions and results of the reviewed quantification initiatives of the indirect impacts of biofuel production. For an in-depth explanation of the result parameters and units, see Table 2 - 2. Rows marked with a green shade contain model input assumptions, rows marked with a brown shade contain model output results. The reference list in the end of this report provides an overview of the publications of each initiative that were reviewed.

2.7 Analysis of differences in results of the quantification

This section explains the differences found between the results of the reviewed initiatives presented in Table 2 - 3 in a detailed fashion. This is done on a topic-by-topic basis.

2.7.1 Additional biofuel demand

	Unit	RFS	LCFS	Searchinger	IIASA
Total	Mtoe	31.16	29.00	28.18	125.00
From energy crops	Mtoe	16.71	29.00	28.18	125.00
Feedstock division	%	30% corn ethanol 6% soy biodiesel 28% sugarcane ethanol 36% switchgrass ethanol	87% corn ethanol 13% sugarcane ethanol[17]	100% corn ethanol	78% ethanol 22% biodiesel
From residues and wastes	Mtoe	14.45	0.00	0.00	0.00
Feedstock division	%	100% corn stover ethanol	N/A	N/A	N/A

The total amount of additional biofuel demand in the initiatives is comparable except for IIASA's, which is more than four times higher than that of others. Generally, the studies remark that results are not very sensitive to the absolute value of the additional biofuel demand, in other words: double the demand leads to double (in)direct impacts.

All additional biofuel demands are based on future biofuel growth expectations or mandates. A number of differences are important to mention:

- The RFS total includes about half of biofuels from residues and wastes; this is ethanol from corn stover, which is assumed to have no effect on land use.
- The RFS assumes a number of relatively high yielding pathways: sugarcane and switchgrass ethanol while the others base their analysis primarily on ethanol from corn or other cereals that usually have lower biofuel yields per hectare.

The feedstock choice is one of the multiple assumptions that have a significant impact on the overall modelling results of indirect impacts. Its influence on quantification results is discussed further in the other parts of this section.

[17] The LCFS work contains modeling on more feedstocks than corn and sugarcane, for example soy, however these values are reported as preliminary and are thus not included.

2.7.2 Results of additional biofuel demand

	Unit	RFS	LCFS	Searchinger	IIASA
Biofuel induced agricultural intensification (total)	%	0%	Could not be determined from quantitative results.	0%	27%
Reduced demand in other sectors (total)	%	3%		20%	34%
Cropland expansion (total)	%	97%		80%	39%
Biofuel induced agricultural intensification (from energy crops)	%	0%		0%	27%
Reduced demand in other sectors (from energy crops)	%	6%		20%	34%
Cropland expansion (from energy crops)	%	94%		80%	39%

Key observations are:

- Both the RFS and Searchinger assume that no agricultural intensification is caused by the additional biofuel demand, so their results reflect this assumption, while IIASA finds that 27% of additional biofuel demand is met by a biofuel-induced intensification.
    - Searchinger gives an explanation of his assumption by noting that potential agricultural intensification due to higher demand and/or price is neutralized by the yield loss associated with taking into production of marginal lands that are less suitable for agriculture.
    - IIASA finds very significant agricultural intensification, mainly due to the fact that the number of yearly harvests on agricultural areas in developing countries is increased. This is a factor that it is not directly included in the other models.
- The RFS finds a very limited reduction in food consumption, while Searchingen and IIASA respectively find that 20% and 34% of additional biofuel feedstock demand is supplied from a reduction in food demand.
    - These differences are likely to be the effect of a different assumption on how prices react to an increase in demand and on the demand elasticities for food.

For the LCFS work quantitative values for biofuel induced agricultural intensification and reduced demand in other sectors are not available. However, personal communications with authors of the work suggests that their influence is significant, possibly limiting cropland expansion by around one third. Further details on this topic will be published in the future.

2.7.3 Extent of cropland expansion

	Unit	RFS	LCFS	Searchinger	IIASA
Cropland expansion (relative, from energy crops)	ha/toe	0.29	0.17	0.38	0.17

With respectively 0.38 and 0.29 ha/toe of cropland expansion per unit of additional demand biofuels from energy crops[18], Searchinger and RFS find reasonably comparable numbers. The lower value in the RFS work is caused by the fact that their additional demand includes high yielding crop pathways of sugarcane and switchgrass ethanol.[19]

The LCFS value and IIASA value are significantly lower than that of both Searchinger and the RFS. For IIASA this can be easily explained, since in their work only 39% of the additional biofuel demand is met through cropland expansion which is about half of the values between 80 and 95% in Searchinger and RFS, see section 2.7.2. This makes it fully understandable that as a result the cropland expansion number is also about half of that in the other studies.

For the lower LCFS number, the same explanation is likely but can not be completely verified, as explained in section 2.7.2.

2.7.4 GHG effect of cropland expansion

	Unit	RFS	LCFS	Searchinger	IIASA
Weighted average of emissions from crop expansion	tCO2eq/ha	288	235	351	219
Project horizon for emissions from (I)LUC	Years	30	30	30	30

The chosen project horizon is the same in each of the three initiatives, so this does not lead to differences. Although the emissions from LUC through crop expansion are in the same order of magnitude, a difference is still noticeable with the range going from 219 to 351 tCO2eq/ha. This range can be explained by the assumptions the different initiatives make in these areas:

- Searchinger assumes that all deforestation historically found in a certain area is caused by cropland expansion, provided that cropland expansion has historically been larger than deforestation. Through this assumption he finds large LUC in

[18] The most useful parameter to compare in this category is the relative cropland expansion per unit of additional demand biofuels from energy crops. This choice is made because biofuels from residues and wastes are assumed to be produced from feedstocks that are already available in the reference scenario. Including them in this comparison would spread the indirect impacts of biofuels from energy crops over a larger total, leading to an underestimation of their impact.

[19] Searchinger and the RFS find virtually identical cropland expansion factors for corn ethanol, since their assumptions on yield and the displacement effect of co-products of corn are very similar. However, the RFS includes three additional energy crop pathways (sugarcane ethanol, switchgrass ethanol, and a small amount of soy biodiesel). Since the biofuel yields per hectare of the sugarcane and switchgrass pathways (even after accounting for co-product effects) are assumed to be significantly higher than that of corn the land displacement effects of these feedstocks are found to be ~20% and ~70% lower respectively. On average, the RFS fuel mix should therefore lead to a ~30% lower relative cropland expansion which is very much in line with the reported values.

forested areas. Since forests are rich in carbon compared to land types with less vegetation, this leads to the highest emission per ha converted in the found range.

- The RFS uses historical data on types of direct LUC caused by cropland expansion from satellite imagery. These data indicate a significantly lower share of LUC in forested areas than in Searchinger's work. However, the RFS calculation assumes a secondary effect where some of the pastureland replaced by biofuels will be reclaimed by deforestation, leading to an additional indirect deforestation and associated carbon emissions. Overall, this leads to the second highest value of emissions per ha converted in the found range.
- The LCFS model has an intrinsic part that models the types of LUC that occur. According to the modellers, this part uses both historic data as well as endogenous optimization of land value to specify the predicted types of LUC. The model methodology does not allow for secondary shifts in LUC, for example the reclamation of a pasture that was displaced by biofuel feedstock production in a forested area. Using this methodology, the model calculates that most LUC occurs on pastures/grasslands with relatively low carbon stocks. Therefore, the LCFS finds the second lowest value for emissions per ha converted.
- The IIASA study only states that IPCC carbon stock values have been used, but does not give a detailed quantified breakdown. In addition, the entire GHG emission part of the study is stated to be indicative only. In total this means that is unclear why this study finds the lowest value for emissions per ha converted.

2.7.5 GHG emissions caused by (I)LUC

	Unit	RFS	LCFS	Searchinger	IIASA
Weighted average of emissions from (I)LUC (from energy crops)	gCO2eq/MJ fuel	56	32	103	30

It is most useful to compare the greenhouse gas emissions equivalents associated with (I)LUC per unit of additional demand of biofuels from energy crops. These differences of GHG emissions caused by (I)LUC per unit of fuel are in fact an accumulation of the differences in the other parameters as described in the previous sections, see Illustration 2 - 3. From this framework the results for this parameter can be fully explained.

- The IIASA and LCFS work find the lowest and almost equal values of 30 and 32 gCO2eq/MJ respectively. This is caused by the fact that they find both low relative cropland expansion per unit of additional biofuel demand and low emissions per ha of expanded cropland as discussed in sections 2.7.3 and 2.7.4.
- The RFS work finds roughly 50% higher values for cropland expansion per unit of biofuel and one third higher values for emissions per unit of expansion compared to IIASA and LCFS. This would suggest a factor two higher GHG emissions per unit of fuel at ~60 gCO2eq/MJ fuel. This is very much in line with the actual result of 56 gCO2eq/MJ fuel, when taking into account that this value is 5 – 10% lower

than expected because some beneficial indirect impacts[20] on GHG emissions are included in the RFS work.

- Compared to the LCFS and IIASA work, the work of Searchinger finds values more than twice as high for cropland expansion per unit of biofuel and just over one half higher for emissions per unit of expansion. This would suggest a factor 3.5 higher GHG emissions per unit of fuel, which again is very much in line with the results.

2.8 Conclusions on the comparison of the reviewed quantification initiatives

The conclusion from the comparison between the reviewed quantification initiatives in this chapter has three important elements:

- No quantitative information on indirect impacts on biodiversity is available; quantitative information on food consumption is limited.
- There are very significant differences between the quantifications of the indirect impacts of biofuels on land use changes and associated carbon emissions. The impacts on the GHG balances of the fuels, range from 30 to 103 gCO2eq/MJ fuel, more than a factor of three in difference. However, it is important to note that we found in section 2.7 that these differences in opinion between the different reviewed initiatives do not stem from a radically different approach of the problem but in a few key quantitative assumptions. The most important of these assumptions, discussed in detail in section 2.4, are:
    - The choice of feedstock for the additional biofuel demand
    - Relation between agricultural intensification and commodity prices and/or demand.
    - Relations between commodity demand, commodity prices and food demand.
    - Assumptions of types of LUC caused by cropland expansion.
    - Assumptions on carbon stocks of land types affected by cropland expansion.
- Even though there are differences between the values of the quantitative outcomes, all studies in this review find that the indirect impacts of biofuels are quite large. For example, the impacts on the GHG balance range from about 30% to > 100% of a fossil reference[21]. In each case, indirect impacts are one of the larger, or the largest factor in the overall GHG balance. This makes it easier to assess the need for pragmatic mitigation efforts, even though there is a broad range of theoretical quantification results available.

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[20] For example reduced methane emissions in the rice and cattle industry due to reduced demand for their products.

[21] Depending on the exact fossil reference used, these life cycle GHG emissions are usually around 80 – 90 gCO2eq/MJ fuel.

2.9 Critique on quantification initiatives as those reviewed in this study

As concluded in section 2.8; although the exact numbers differ considerably, all initiatives reviewed in this study find indirect impacts of biofuels to be significant. However, some parties claim that indirect impacts either:

1. Should not be attributed to biofuels at all, or;
2. Are much smaller or even insignificant compared to what was found in this review

For the first claim, one of the frequently heard arguments is that indirect impacts should not be attributed to biofuels because they actually consist of direct impacts in other sectors. Therefore mitigation of these impacts should occur by regulating these sectors where the direct impacts take place and not by imposing restrictions on the biofuels sector. On the other hand, it is important to note that the biofuel industry primarily exists because of support by policies that usually have a goal to reduce GHG emissions. Because of this special status of the biofuel sector, it would not be unreasonable to also include indirect impacts in assessing whether biofuels actually contribute to this goal. This is not a clear-cut debate and a position should be developed by the RSB on this matter.

A second argument that is used to support the first claim is that there is no scientific consensus on the magnitude of indirect impacts. While this could indeed be concluded from the wide range of e.g. indirect impacts on GHG emissions resulting from the different quantification initiatives reviewed, the fact that they all find the indirect impacts to be significant supports the idea that pragmatic mitigation would have positive effects.

Three arguments are mainly used regarding the second claim. They directly tie in to the potential reaction of the global economic system to an additional biofuel demand as depicted in Illustration 2 - 2. These arguments are:

1. Model predictions of ILUC caused by biofuels have been proven wrong by available historic data on cropland expansion.
2. Co-products of biofuel production displace so much demand for other agricultural commodities that the net cropland expansion and impact on food consumption caused by biofuels is very low.
3. Agricultural intensification caused by additional biofuel demand accounts for such a large part of the additional feedstock needed that the net cropland expansion and impact on food consumption caused by biofuels is very low.

The first argument makes use of the fact that historically expansion of agricultural cropland has not directly caused deforestation as can for example be found from satellite data. While this might be true, the argument ignores the indirect nature of indirect impacts of biofuel production. In other words: even if (biofuel) cropland itself expands on e.g. pastures, it is still possible that it indirectly leads to deforestation as new replacement pastures are created by cattle owners. This diffuse, indirect effect makes this argument invalid.

The second argument relies on the fact that co-products of biofuel production displace other agricultural commodities and thus indirectly displace the need for land to grow these commodities. For example when DDGS displaces crops used in animal feed. Some parties claim that this substitution is of a very high magnitude (e.g. 90%), for example because the co-product is assumed to replace a low yield animal feed crop or because the nutritional value of the co-product is assumed to be much higher than that of other animal feed varieties. While it is almost certain that displacement in fact occurs, values of up to 90% are far beyond the range of assumptions in the models in this review that are between 0 – 45% as can be seen in Table 2 - 3.

The third argument relies on the fact that an additional biofuel demand could lead to a (relative) increase in crop prices and/or margins. These in turn could be a strong incentive for agricultural intensification to optimize returns. It is true that yields of some crops have increased significantly over the past decades and by looking selectively at the data, very high intensification predictions can be constructed that imply a significant reduction in the need for additional land of even up to 100%. However, these values are far higher than the values found in the initiatives reviewed in this study, which range from 0 to 27%.

Concluding, it can be said that the main arguments used to claim that ILUC effects of biofuels are small, are based on assumptions on key parameters that are well outside the range found in any of the scientific initiatives reviewed here. We have not analysed the validity of these assumptions, or the ones made in the reviewed initiatives, in this study.

3 Review of current mitigation measures for indirect impacts of biofuel production

Most of the current work on indirect impacts of biofuel production is focused on quantification of the problem, as discussed in chapter 2. While understanding the magnitude of the problem is clearly relevant, this should be complemented by an understanding of how biofuels can be produced without (or with a minimum risk of) indirect impacts. Relatively few concrete initiatives exist today that aim to mitigate the indirect impacts of biofuels. The initiatives that do exist and their main characteristics are analysed in this chapter. Before discussing the individual initiatives, section 3.1 first sets out a common framework for the analysis. Then, in section 3.2 a summary of the existing individual initiatives and their characteristics is given. In sections 3.3 through 3.7 the individual initiatives are analyzed in detail for a number of important characteristics.

3.1 Mitigating indirect impacts

This section sets out a common framework for analyzing mitigation measures for indirect impacts of biofuel production. First, it refers to a number of key characteristical difficulties of mitigating indirect impacts discussed earlier. Then it discerns between mitigation measures at the global and the project level. Finally, it introduces a general outline of options available for individual producers to mitigate indirect impacts on the project level.

3.1.1 Key characteristic difficulties of mitigating indirect impacts

To be able to assess the effectiveness of proposed measures against indirect impacts from biofuels, several key characteristics of indirect impacts need to be understood. These have been presented earlier in chapter 1, primarily in section 1.2, being:

- Displacement effects act across national borders
- Displacement effects act between substituting crops
- Competition for land connects also non-substituting crops
- Competition with food and indirect land use change are closely related

3.1.2 Global versus project-level mitigation measures

In theory, three types of mitigation measures are available to prevent or minimise unwanted indirect impacts from biofuels. The first two concern global mitigation measures, while the third describes project-level mitigation measures:

1. **Prevent unwanted direct LUC, globally and for all sectors.** Unwanted ILUC from biofuels manifests itself through unwanted *direct* LUC for the production of agricultural products for other sectors such as the food and feed sector, as described in section 1.1 and Illustration 1 - 1. Preventing unwanted direct LUC would thus eliminate unwanted ILUC altogether. Note that because of the

international characteristics of ILUC and the competition for land between different sectors, this mitigation measure requires global implementation for all land-intensive sectors to be effective. In addition, it should be noted that preventing unwanted direct LUC, like deforestation, in non-biofuel sectors, could in turn lead to higher food prices, which can also be undesired.[22] To conclude it can be said that while a potentially worthy mitigation measure for the longer term, this mitigation measure is unlikely to fully materialize in the short to medium term and is largely outside of the influence of the RSB.

2 **Reduce pressure on land from the agricultural sector as a whole by increasing yields, supply chain efficiencies and/or a reduction in consumption**[23], e.g. through increased public R&D or policy incentives. This could reduce the need for expanding the area used for agricultural production[24]. However, a globally constant or shrinking agricultural area does not necessarily prevent unwanted LUC. Shifts in land used for agricultural production (without a net increase in the total area) can still cause unwanted LUC. Also this mitigation measure is unlikely to materialize in the near future, with projections from leading agricultural institutions indicating an expanding agricultural area during the next decades. It also lies largely outside of the influence of the RSB.

3 **Practical production models that prevent indirect impacts at a project level**. While the other two mitigation measures take a more macro approach (in which governments are likely to be key actors) this approach focuses on the role individual producers can play (in the absence of the above two mitigation measures.) This includes mitigation measures such as the much debated production on "idle land". Such mitigation measures are more amendable to a certification approach as they focus on individual producers. They are discussed in more detail in section 3.1.3.

3.1.3 Preventing indirect impacts at the project level – what individual producers can do

Four main mitigation measures at the project level have been put forward to expand biomass usage for energy purposes without unwanted consequences from indirect impacts (Ecofys 2007a, Ecofys 2008, RFA 2008, Woods 2008). They are presented here:

1 Producing biofuels from **residues**. The use of residues as biofuel feedstock can displace current functions and uses of these residues, e.g. soil enhancing functions of agricultural residues or industrial process fuel use of waste fats and oils. This could therefore lead to negative indirect impacts by necessary

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[22] IIASA has carried out a modeling study which indeed found that food prices increased more in a scenario with additional biofuel demand and a ban on deforestation than in a scenario without such a ban on deforestation.

[23] As in the first option, decreasing food demand is not always a desired option itself.

[24] Such measures could be taken independent of biofuels policies as well. One could argue that without biofuels such measures would actually free up agricultural land that could revert back to e.g. forest, thereby potentially offering carbon and biodiversity benefits. Using such areas for biofuels could be seen as having an 'opportunity' cost in foregone carbon sequestration or increase in biodiversity. As we believe that the mitigation measures most relevant to the RSB are not of this kind, we do not discuss this matter in more detail here.

replacements of the residues by e.g. additional fertilizer inputs or fossil process fuels. Therefore, current functions and uses of these residues must be well understood when pursuing this mitigation measure, which is currently not always the case.

2 Producing biofuels from **aquatic biomass** such as algae. Specific sustainability aspects for such production (e.g. increasing pressure on the coastal environment) also need to be taken into account.

3 Producing biofuels from **feedstock grown on land without provisioning services**[25] e.g. land where no food production or cattle grazing takes place. Because this does not displace existing provisioning services it does not cause an indirect LUC. Clearly, expanding production on unused land does lead to a direct LUC, with potential unwanted social and/or environmental consequences. The big advantage is that direct LUC is controllable (e.g. through certification) and can be limited to those areas where effects are acceptable, while the effects of indirect LUC are diffuse and uncontrollable. Often an area is not completely "unused" and a sliding scale exists between this "unused land" concept and the "intensification" concept in the next bullet.

4 Introducing energy crop cultivation without displacing the original land use through agricultural **intensification** or integration models. In developing countries especially there is a significant potential for yield improvements by e.g. increasing the yield per harvest, increasing the amount of harvests or intensifying cattle raising. The positive effects of using this potential would reduce agricultural land requirements. Potential negative environmental or social impacts from intensification models such as increased use of fertiliser have to be taken into consideration as well.

3.2 Summary of existing mitigation initiatives

This section gives a summary of the existing mitigation initiatives for indirect impacts from biofuels. First, the two main characteristics on which each initiative is analysed are presented. Then, a table gives a summary of the various initiatives and provides a first rough analysis on the two main characteristics. In sections 3.3 through 3.7 the individual initiatives are analyzed in detail on a number of important characteristics.

3.2.1 Main characteristics used in analysis of mitigation initiatives

- Scope: is the measure focused at GHG effects only or also on other measures such as biodiversity and food consumption?
- Behavioural change: does the measure provide concrete incentives for behavioural change by the actors involved in biofuel production and consumption? This can be relevant on two levels: First: are actors driven to choose a certain feedstock with

[25] The Milliennium Ecosystem Assessment distinguishes four categories of ecosystem services: provisioning services, regulation services, cultural services and supporting services. Provisioning services are defined as harvestable goods such as fish, timber, bush meat, genetic material, etc. (Commission for Environmental Assessment, 2006). This is also commonly referred to as "degraded land", "marginal land", "waste land" or "abandonned land".

a lower risk of indirect impacts? Second: are actors that are committed to a certain feedstock driven to make choices in their production process that eliminate or minimize risks on indirect impacts?

3.2.2 Summary of the various mitigation initiatives and their characteristics

Table 3 - 1 shows a summary of the various initiatives that have proposed or are developing proposals for measures to mitigate indirect impacts from biofuels. Detailed analysis is provided in sections 3.3 through 3.7.

	Measure	Scope	Drives behavioural change	
			Feedstock choice	For a given feedstock
RFS – US Renewable Fuels Standard	GHG-factor	GHG	+	-
LCFS – Californian Low Carbon Fuel Standard	GHG-factor	GHG	+	-
RCA – Responsible Cultivation Areas (Ecofys et al.)	Preventing displacement by expanding on land without provisioning services	GHG Biodiversity Land rights Food consumption	+	+
RCA – Responsible Cultivation Areas (Ecofys et al.)	Preventing displacement through agricultural intensification	GHG Biodiversity Land rights Food consumption	+	+
EU RED – EU Renewable Energy Directive	Various alternatives are being considered			
UK RTFO – UK Renewable Transport Fuel Obligation	Under development			

Table 3 - 1 Summary of the various initiatives that have proposed or are developing proposals for measures to mitigate indirect impacts from biofuels. For each initiative the main measure and its scope are given. Also, it is indicated with a +/- score whether the initiative is likely to drive behavioural change of actors as described in section 3.2.1. Detailed analysis is provided in sections 3.3 through 3.7.

3.3 Detailed analysis of mitigation initiative: RFS

3.3.1 RFS and indirect impacts

The Renewable Fuels Standard is a federal biofuel obligation in the United States that consists of various components for different "types" of biofuels. Currently a second version, also referred to as RFS2 is being developed. In the RFS different pre-defined biofuel chains (e.g. corn ethanol) are categorized based on their feedstock and GHG-performance. It is proposed that the GHG performance is calculated with a life cycle analysis that includes a pre-determined amount of emissions from ILUC thus including ILUC in the characterisation of a particular pathway for a biofuel.

The total GHG impacts from ILUC[26] for biofuels from different energy crops are roughly the same magnitude at around 55 gCO_2eq/MJ, with a weighted average of 58 gCO_2eq/MJ. When these indirect impacts are taken into account, GHG savings by biofuels compared to fossil fuels are about 60% lower than when indirect impacts are not taken into account.[27]

Note that the RFS is still under development and it is uncertain whether GHG-effects from ILUC will be included once its final version is adopted.

3.3.2 Scope

The RFS focuses on GHG savings and for ILUC the proposal includes only the GHG effects. While this may have close links with effects on biodiversity and food consumption, measures to mitigate unwanted effects on these aspects are not explicitly included in the RFS.

3.3.3 Incentives for behavioural change

The emissions from ILUC have a significant impact on the GHG emissions of a biofuel pathway in the RFS, and thereby on the type of biofuel the pathway is categorized into. As the RFS requires that a certain part of the total target is met though biofuels with a high GHG saving, it provides a concrete incentive for biofuel types without emissions from ILUC, such as biofuels from residues. In other words, the RFS contains an incentive for producers to choose a feedstock with little or no emissions from ILUC.

However, for a given feedstock, producers can not prevent or lessen the GHG effect from ILUC by taking additional measures to prevent or reduce the risk of ILUC, because it is a standard, pre-determined amount coming from the life cycle calculations done within the RFS. Thereby, for a given feedstock the RFS does not provide any incentives for producers to change their behaviour such as to minimize the risk of ILUC.

[26] In the RFS calculations, total carbon emission values for a combination of direct LUC and ILUC are calculated, since they can not be separated from each other in the modeling approach. These combined effects are meant here when ILUC is mentioned.
[27] Soy-based biodiesel is an exception with ILUC emissions around 70 gCO2eq/MJ and a reduced savings of about 80%

3.4 Detailed analysis of mitigation initiative: LCFS

3.4.1 LCFS and indirect impacts

California's Low Carbon Fuel Standard (LCFS) adopted by the Air Resources Board on April 23, 2009 requires a 10% reduction in the average greenhouse gas emission intensity of the State's transportation fuels by 2020. Biofuels are expected to play a major role in achieving these targets.

The GHG savings of biofuels compared to the fossil reference fuels is determined through an LCA of pre-defined biofuel chains. Emissions from ILUC are included in this the LCA. Thereby the scheme provides incentives for biofuels that cause no or less ILUC. Currently, calculations have been done for a few different pre-defined biofuel chains fed by energy crops. The GHG emissions from ILUC for these chains[28] under the LCFS are rather constant, at around 30 - 46 gCO_2eq/MJ, or around 31-47% of the fossil reference fuel. Additional pre-defined biofuel chains will be calculated in the future.

3.4.2 Scope

The focus of the LCFS is on GHG emissions and therefore only GHG effects from ILUC are currently within the scope of the LCFS. Discussions are ongoing on including wider social and environmental sustainability aspects.

3.4.3 Incentives for behavioural change

As for the RFS, the LCFS provides an incentive for biofuel producers to use feedstocks that have little or no emissions from ILUC. Currently, as the RFS, the LCFS does not give clear guidelines that a biofuel producer can follow on project level, after a feedstock has been chosen, to prevent indirect impacts. As a result, in the current LCFS it is not possible for an individual producer to avoid having to take the standard value for indirect impacts into account in his GHG balance. Therefore no incentive for implementing effective ways to mitigate indirect impacts exists. However, the LCFS has indicated that this is subject to further investigation and consultation in the future and that, as a result, regulation on this might be implemented.

3.5 Detailed analysis of mitigation initiative: EU Renewable Energy Directive

The EU Renewable Energy Directive (RED) contains a 10% target for renewable energy in transport, in which biofuels are expected to play an important role. Only biofuels that meet certain sustainability criteria count towards this target. These sustainability criteria primarily cover GHG emissions from the entire fuel chain, and carbon stock and biodiversity effects from direct LUC. The RED currently does not contain explicit measures aimed at reducing unwanted indirect impacts. However, the RED states that before the end of 2010 the EC shall report on the indirect impacts of

[28] In the LCFS calculations, total carbon emission values for a combination of direct LUC and ILUC are calculated, since they can not be separated from each other in the modeling approach. These combined effects are meant here when ILUC is mentioned.

biofuels including proposals on how to minimize unwanted indirect impacts. The report shall, if appropriate, be accompanied by a concrete proposal including the GHG effects of ILUC in the GHG methodology of the RED.

The EC recently consulted on a number of options for dealing with indirect impacts from biofuels, presented in the textbox in Illustration 3 - 1. In terms of the main options discussed in section 3.1.2, these range from tackling direct LUC in other sectors like food and feed to including GHG emissions from ILUC into the biofuel life cycle analysis as the RFS and LCFS do.

A. Extend to other commodities/countries the restrictions on land use change that will be imposed on biofuels consumed in the European Union
B. International agreements on protecting carbon-rich habitats
C. Do nothing
D. Increase the minimum required level of greenhouse gas savings
E. Extending the use of bonuses
F. Additional sustainability requirements for biofuels from crops/areas whose production is liable to lead to a high level of damaging land use change
G. Include an indirect land use change factor in greenhouse gas calculations for biofuels

Illustration 3 - 1 Different options for dealing with indirect impacts as recently included by the European Committee in a first consultation round among stakeholders.

Not all these options are worked out in detail yet, making it impossible to make a detailed analysis of their effectiveness in preventing ILUC at this stage and to predict which of these options, and possible other alternatives, will be considered for the RED. However, it is possible to give a general indication of the potential strengths and weaknesses of each option.

Options A and B, addressing the general issue of (I)LUC for all sectors in all countries, are good options for the long term. However, these options are unlikely to effectively prevent ILUC in the short term (e.g. during the RED mandate period of 2010 – 2020) because their effectiveness depends on the participation of all countries. Mobilising this participation is generally a time-consuming and difficult process. It could also lead to additional increases in food prices, see also section 3.1.2.

Option C of course gives no incentive to mitigate indirect impacts. It could be argued that the required level of GHG savings in the RED provides an automatic 'cushion' to deal with indirect impacts, should the savings be larger than the indirect impacts on the GHG balance. However, this is rather uncertain and even then it would still be desirable to mitigate indirect impacts. In addition, other indirect impacts on e.g. biodiversity and food consumption are not addressed. For option D, even if the minimum required level of greenhouse gas savings is increased, the same weak points remain.

Option E of giving a GHG bonus to biofuels that do not or are unlikely to cause indirect impacts could in general provide an incentive to prevent indirect impacts. However, it also has serious weaknesses. First of all, producers of biofuels that score well enough on direct impacts, will not need the indirect impact bonus to be considered eligible under the RED and will thus not have an incentive to mitigate indirect impacts. In addition, if a biofuel obtains a bonus, it will be attributed with GHG savings that are not actually realized, which is illogical.

Option F is potentially effective, however is very difficult if not impossible to implement because of the diffuse nature or indirect impacts as also summarized in section 1.2. This makes it nearly impossible to link these impacts to "crops/areas whose production is liable to lead to a high level of damaging land use change". Even if this could be done, the effectiveness of the measure would still depend on the set "additional sustainability requirements".

Option G could be effective, but it very strongly depends on potential methodology for individual producers to avoid getting the factor applied in their life cycle GHG balance, otherwise there would be no incentive to pursue mitigation. Also, only applying a factor to the GHG balance does not address other indirect impacts like those on biodiversity and food consumption.

3.6 Detailed analysis of mitigation initiative: UK Renewable Transport Fuel Obligation

Since April 2008, the UK Renewable Transport Fuel Obligation (RTFO) is the world's first government biofuel obligation that has an operational biofuel sustainability scheme in place. The scheme works largely through the use of existing certification schemes such as the RSPO[29] and ACCS[30] to ensure sustainable feedstock production. Schemes like these have a history of engaging and consulting stakeholders to define and verify sustainable feedstock production. Using their certification schemes within the RTFO makes the RTFO pragmatic, trustworthy and easier to implement. This mechanism to ensure sustainable feedstock production is combined with a separate approach for the GHG performance of the full chain. Indirect effects are currently not included in the RTFO.

The Renewable Fuels Agency, the administrative body of the RTFO, coordinated the Gallagher review on the indirect impacts of biofuels in 2008. One of the conclusions of the Gallagher review was that certain types of biofuel production have smaller risks of unwanted indirect impacts. These include biofuels from true residues as well as biofuels from appropriately defined "idle land" and from areas with a biofuel-induced agricultural intensification.

[29] Roundtable on Sustainable Palm Oil.
[30] Assured Combinable Crops Scheme.

As a follow up to the Gallagher review, the RFA has recently commissioned two studies. First, the RFA asked Ecofys and Winrock to collect evidence of concrete case studies of such production models that have no or a reduced risk of unwanted indirect impacts, and to propose a practical methodology to acknowledge such biofuel production with a reduced risk of ILUC. If possible, such a methodology could be considered for use in the RTFO and other biofuel programs. First results are expected in October 2009.

Secondly, a study has been started in which the use of residues for biofuel production is analysed for its indirect impacts. This is done because a number of so called "residues" that could be used for biofuel production are now used in other (energy) applications. For example, tallow and other animal fats are sometimes used as process fuel. Should they be used for biofuel production, then their use as process fuel is displaced and needs to be met by other, likely fossil, fuels. The RFA study aims to investigate which residues can be used without causing such displacement effects and work toward criteria to select such residues. The consultancy work is carried out by a consortium led by Ecometrica. Results are expected in October 2009.

3.7 Detailed analysis of mitigation initiative: Responsible Cultivation Areas

3.7.1 Responsible Cultivation Areas and indirect impacts

The Responsible Cultivation Area initiative is a private sector initiative coordinated by Ecofys in collaboration with NGOs such as WWF and Conservation International and industrial parties such as Shell and Neste Oil. The initiative started in 2008 with the overarching goal to:

> *Identify areas and/or production models that can be used for environmentally and socially responsible energy crop cultivation, without causing unwanted displacement effects. (Ecofys 2009)*

The initiative provides a set of criteria that together define the requirements for RCAs, and a methodology for identifying RCAs. The draft criteria are included in Appendix B. For both the criteria and the methodology, the initiative draws upon existing standards and methodologies, most notably the EU RED, UK RTFO, RSB, CDM and the HCV-concept.

The initiative focuses on providing project-level solutions for producers that want to minimize the risk of ILUC. Thereby, the initiative focuses on two of the options introduced in section 3.1.2:

1. Expanding production on land without provisioning services
2. Increasing land productivity.

These solutions are best illustrated with practical examples - see Appendix C.

The initiative currently has a draft methodology that is being piloted in Indonesia (palm oil) and Brazil (sugar cane and palm oil).

3.7.2 Scope

The central concept of the RCA initiative is to expand agricultural production for biofuels without displacing other provisioning services of the land.[31] This would prevent all the potential consequences, such as effects on biodiversity or carbon stocks, of such displacement. Unwanted effects on food consumption should also be prevented as no food or feed production is displaced, thereby preventing shortages in the food/feed sector.

3.7.3 Incentives for behavioural change

The RCA concept includes concrete incentives for producers to change their behaviour. Producers are requested to cultivate their feedstock either on lands without provisioning services (while also meeting biodiversity, carbon stock and land right criteria) or to increase the productivity of the land, e.g. by integrating food and fuel production (see concrete examples in Appendix C).

The RCA concept is feedstock neutral. This means that, in principle, all feedstocks could meet the RCA-criteria. However, for some feedstocks this may be easier than for others. For example, perennial crops will more easily satisfy the criterion that losses of carbon stocks should be compensated, since perennial crops often have neutral or even positive effects on soil carbon.

3.8 Conclusion on current mitigation measures

Three main conclusions can be drawn on current mitigation measures for indirect impacts of biofuel production:

- The amount of mitigation measures that currently exists is small. In addition, of this small amount of measures most are not yet fully operational or are even still in development stage.
- Most of the mitigation measures that are in more advanced development focus only on GHG effects of indirect impacts of biofuels by incorporating an ILUC factor in the general life cycle analysis of feedstock-based biofuel pathways. This has the inherent limitation that there is no incentive for options to mitigate indirect impacts on the project level, given a certain feedstock.
- The RCA initiative and the RTFO initiative are the first to work on pragmatic solutions for feedstock production that has no or a minimized risk of indirect impacts by preventing displacement effects from occurring.

[31] Within the development of the RCA, but also in other developments, an debate has been raised on the effectiveness of expanding on land without provisioning services or ‘idle land’. A more elaborate discussion of this debate and its links to the RCA initiative are presented in Appendix D.

4 Suggestions for including indirect impacts of biofuel production in the RSB standard and certification scheme

This chapter gives suggestions for including indirect impacts of biofuel production in the RSB standard and certification scheme. It is based on the reviews of current quantification and mitigation initiatives for indirect impacts as described in chapters 2 and 3 as well as general Ecofys' experience and opinion on the topic. First, in sections 4.1 and 4.2, it gives main suggestions and points of interest related to quantification and mitigation of indirect impacts respectively. Section 4.3 gives conclusive and concrete suggestions on how to handle indirect impacts in the RSB standard.

4.1 Quantification of indirect impacts

We see no need for the RSB to do its own detailed analysis on the quantification of indirect impacts, but instead to focus directly on mitigation options.

- A lot of work has already been done on quantification of the problem, as shown in chapter 2.
- Although the exact outcomes of this work differ, it can be shown what the main issues and corresponding assumptions are that influence this outcome. See also chapter 2.
- Improving insight in and understanding of some of these main issues, e.g. the relation between yield and demand and/or price, the relation between food consumption and food prices, will be very challenging and it is very likely that uncertainty will remain.
- Regardless of the exact outcomes, all reviewed work shows that indirect impacts of biofuel production are significant, see also chapter 2.
- The RSB could start its approach on mitigation through two steps:
    - First: decide whether indirect impacts of biofuels should be mitigated by regulating the biofuel sector.
    - Second: if yes, use the lessons learned by reviewing the quantification initiatives in designing effective mitigation options.

4.2 Mitigation of indirect impacts

We suggest that the RSB may support global level solutions, but that its focus should be on pragmatic project level solutions.

- Global level solutions are likely to take a very long time span to be implemented. In addition, their success is largely out of control of the RSB.
- On the project level a number of options are available:
    - Use of residues as biofuel feedstock.

- There is generally large consensus that this is a viable way to mitigate indirect impacts.
- However, some residues currently already have a use. In this case indirect displacement effects could still occur. This needs more attention, for example as is happening in the RFA project discussed in section 3.6.

- Use of algae or other aquatic biomass as feedstock.
  - There is generally large consensus that this is a viable way to mitigate indirect impacts.
  - However, technology to do so is still very much in R&D stage and this option is therefore of little relevance for the short term.
- Use of feedstock from previously 'unused' land without provisioning services.
  - This can be an effective measure, however there is still a debate on how to ensure optimal effectiveness of this measure, see Appendix D.
  - Although the concept of 'unused' land is often discussed, there is a lack of workable definitions. The RCA initiative makes a pragmatic start, see section 3.7.
- Use of feedstock from land of which the productivity has been increased such that no displacement of current provisioning services occurs.
  - This can be an effective measure; however, definition, implementation and verification still require more work. RFA work and RCA initiative make a pragmatic start, see sections 3.6 and 3.7.
- Increasing supply chain efficiency: producing more biofuel from a certain amount of feedstock or agricultural resources.
  - In quite a few cases this is already being undertaken either for financial reasons and/or due to increased attention for biofuel production from residues.
  - It could reduce GHG savings through changes in biofuel production. For example, more fossil fuel input may be needed to increase biofuel production, potentially worsening GHG balance.
  - The potential option of targeting a maximum biofuel yield per hectare should be used with caution. This could for example lead to use of best agricultural lands for biofuels, leading to a larger displacement effect in e.g. the food sector and thus to larger indirect impacts.

4.3 Ecofys' suggestions on handling indirect impacts in the RSB standard

In this section Ecofys gives suggestions on how to handle indirect impacts in the RSB standard. It is outside the scope of this study to provide a full route of implementation of these impacts in the standard. Instead, this section gives concrete suggestions that the RSB can use to further construct its standard.

Ecofys' suggestions on handling indirect impacts in the RSB standard are presented through answering three main questions.

1 Should the RSB include indirect impacts in its standard at all?

Ecofys believes the RSB should include indirect impacts in its standard.

From the review presented in this study and from earlier experience, Ecofys believes indirect impacts of biofuel production are a real and significant risk to the sustainability of biofuels.

2 Should the RSB include indirect impacts of biofuel production through its lifecycle GHG balance calculations or through another mechanism?

Ecofys believes the RSB should, at this moment, not quantify indirect impacts through its lifecycle GHG balance calculations. Instead, indirect impacts should be handled in the standard through a risk based approach: criteria need to be defined in the RSB standard that differentiate biofuels with reduced risk of indirect impacts from those without reduced risk of indirect impacts.

The reason for not quantifying indirect impacts through lifecycle GHG balance calculations is that although there largely is consensus that indirect impacts have a significant magnitude, the exact magnitude is not generally agreed upon. It is very uncertain whether consensus on a (set of) specific number(s) will be reached at all, since these impacts can only be predicted through modelling and not be measured in practice. Therefore Ecofys does not, at this moment, advise the RSB to quantify indirect impacts through its lifecycle GHG balance calculations.

It is also important to note that even when it would be possible to include indirect impacts in lifecycle GHG balance calculations, this should not be the only way of accounting for indirect impacts in the standard: if indirect impacts would exclusively be addressed through lifecycle GHG balance calculations, other indirect impacts than GHG impacts, such as impacts on biodiversity and food consumption would be ignored.

Including a mechanism that differentiates biofuels with reduced risk of indirect impacts from those without reduced risk of indirect impacts is a directly available pathway to effectively incentivise mitigation options for all indirect impacts. Categories of biofuels with reduced risk of indirect impacts could be, but are not necessarily limited to, the pathways discussed in section 4.2 and summarized again below. The identification of these theoretical pathways is not new, but pragmatic implementation is crucial, especially for a standard such as the RSB. Therefore, with each identified pathway, a suggestion is given for practical implementation if possible:

- Use of residues as biofuel feedstock.
    - The RFA/Ecometrica project discussed in section 3.6 could provide a starting point for practical definition of a residue for the RSB.
- Use of algae or other aquatic biomass as feedstock.
    - For this pathway no suggestion for practical implementation can be given yet, since this pathway is still in an early stage of technological and commercial development.
- Use of feedstock from previously 'unused' land without provisioning services.
    - The RCA initiative discussed in section 3.7 defines a first pragmatic set of criteria as well as a methodology for the identification and recognition of such projects.
- Use of feedstock from land of which the productivity have been increased such that no displacement of current provisioning services occurs.
    - The RCA initiative discussed in section 3.7 defines a first pragmatic set of criteria as well as a methodology for the identification and recognition of such projects.

3 Should the RSB incentivize the production and use of biofuels with reduced risk of indirect impacts over those without reduced risk of indirect impacts? If so, how?

Ecofys believes the RSB should use its expertise and broad stakeholder base to develop answers to these questions.

To support this process, Ecofys would like to make two comments:

- After differentiating between the two types of biofuels with regard to indirect impacts in its standard, the RSB could leave the response to the market: market actors would decide whether or not they find it desirable to pursue meeting the standard of biofuels with reduced risk of indirect impacts. This approach is currently followed by e.g. the UK Renewable Transport Fuel Obligation and the Forest Stewardship Council.
- As an alternative, the RSB itself could incentivize meeting the standard of biofuels with reduced risk of indirect impacts, for example by requiring RSB certified blenders to obtain a certain part of their biofuels from pathways with reduced risk of indirect impacts.

5 Conclusions

This study has three elements regarding the indirect impacts of biofuel production:

1. A review of quantification initiatives of indirect impacts of biofuel production.
2. A review of mitigation initiatives of indirect impacts of biofuel production.
3. Suggestions to the RSB on how to include indirect impacts in its standard.

On point 1 it can be concluded that the reviewed quantification initiatives provide:

- No information on the magnitude of indirect impacts on biodiversity
- Limited information on the magnitude of indirect impacts on food consumption
- A wide range of magnitudes of indirect impacts on the greenhouse gas balance of biofuels through land use changes: 30 to 103 gCO2eq/MJ fuel. This wide range of magnitudes is due to different values for key input assumptions used by the quantification initiatives. Although a wide range of quantitative results is found, all initiatives predict the impact to be significant for the total greenhouse gas balance of biofuels.

On point 2 it can be concluded that the reviewed mitigation initiatives show that:

- Only a small amount of mitigation measures currently exists and that these are all still under development.
- Most of the mitigation measures that are in advanced development solely incorporate an indirect land use change factor in the life cycle analysis of biofuels based on their feedstock, providing no incentive to mitigate indirect impacts on the project level, given a certain feedstock.
- The Responsible Cultivation Area initiative led by Ecofys and the Renewable Transport Fuel Obligation initiative of the UK government are the first to work on pragmatic solutions for feedstock production that has no or a minimized risk of indirect impacts by preventing displacement effects from occurring.

On point 3 it can be concluded that Ecofys suggests the RSB to:

- Refrain from performing its own detailed analysis on the quantification of indirect impacts.
- Focus on project level mitigation options for indirect impacts.
- At this moment not quantify indirect impacts through its lifecycle GHG balance calculations.
- Include indirect impacts in its standard through a risk based approach that differentiates biofuels with reduced risk of indirect impacts from those without reduced risk of indirect impacts.

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Appendix A Reasons for not including quantitative results of the LEI work in the comparison

As mentioned in section 2.2 and in Table 2 - 3, it has unfortunately not been possible to extract data from the work of LEI that would allow a useful quantitative comparison with the other initiatives. The following characteristics of the work prevented that:

- The additional biofuel demand assumed in the work was not specified in an absolute value, but rather in a percentage of a baseline on which data was not included in the publication.
- The modelling effort included the energy sector as well, additional to agroeconomic sectors. This lead to the effect that the input additional biofuel demand in the EU led to reduced biofuel demand in other regions. The quantitative extent of this effect was not given in absolute values, so the total increase of biofuel demand could not be determined.
- The absolute value of total cropland expansion was not presented in the publication.
- The effect of increased agricultural intensification and reduced demand in other sectors could not be separately quantified in the model. Therefore specifying a division between the different effects was not possible.
- The GHG effects of LUC and ILUC caused by additional biofuel demand was not included in the modelling performed by LEI.

Appendix B Draft criteria for Responsible Cultivation Areas

This appendix specifies the draft criteria that have been defined for the Responsible Cultivation Areas (RCAs) introduced in section 3.7.

1 Establishment of energy crop plantations maintains or increases High Conservation Values

a. No conversion of areas with recognised High Conservation Values[32] on or after January 2008. This includes legally protected areas and areas with recognised global importance for biodiversity.

b. No conversion of areas with one or more High Conservation Values[4] on or after January 2008 that are not formally recognised as one of the areas referred to in principle 1.a.

2 Establishment of energy crop plantations does not lead to significant reductions in carbon stocks

a. No conversion of areas that had one of the following statuses in January 2008:

i. Continuously forested areas with a canopy cover of more than 30%

ii. Peatland

b. The carbon payback time for carbon losses resulting from Land Use Change (including above-ground and below-ground carbon stocks), shall not exceed 10 years. To calculate the carbon payback time, the methodology as laid down in the RTFO Technical Guidance shall be used[33].

3 Establishment of energy crop plantations respects formal and customary land rights

a. The formal right to use the land for energy crop cultivation can be demonstrated.

b. Both formal and customary land rights (including use rights) must be known. Where potential land conflicts may arise between the energy crop cultivation and formal or customary land rights, viable solutions must have been identified in cooperation with all owners and users of the land.

4 Establishment of energy crop plantations does not cause unwanted displacement effects

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[32] HCV 4 contains areas that provided basic ecosystem services in critical situations (e.g. areas critical to water catchments). When checking the presence of HCV 4. within the scope of the RCA concept, it has to be checked in addition that the intended energy crop establishment does not cause negative downstream effects (e.g. a regional scarcity of the water supply caused by the competition between the water demand of the plantation and other users).

[33] RFA (2009) - Carbon and Sustainability Reporting within the Renewable Transport Fuel Obligation. Technical Guidance. Version 2.0, March 2009.

a. Existing provisioning services are maintained. Where existing provisioning services are displaced, alternatives shall be implemented that comply with all principles for RCAs.

b. Establishment of energy crop plantations may not lead to the opening of remote areas with High Conservation values through new infrastructure. Remote areas are areas that are currently not or difficult to access due to the absence of infrastructure.

Notes:

- C1) The High Conservation Values mentioned in criterion 1 refer to the six values identified by the High Conservation Network, see the box shown below. The HCV concept also plays a central role in the methodology as detailed tool-kits have been developed to identify HCVs.
- C2) The carbon payback time is defined as the number of years after which the project has a zero net effect on GHG-emissions. In other words, this is the number of years after which GHG emission savings, resulting from the bioenergy produced by the project, have compensated net losses in carbon stocks.
- C3) It must be demonstrated beyond reasonable doubt that either no competing land claims exist, or where competing land claims existed, that agreements with all owners and users of the land through the principle of free, prior and informed consent has been achieved. This would exclude areas that are of critical cultural importance (HCV 6) or areas that are critical for the livelihoods of local populations for which no good alternatives exist (HCV 5).
- C3) Criterion 3 on land rights does not mean that land to which certain parties claim the ownership or use rights, can not qualify as an RCA. Such land can still qualify as RCA, if HCV values 5 and 6 are respected and fair and equitable agreements on the transfer of land rights can be agreed upon with the free prior and informed consent of all owners/users. As explained above, it is not within the scope of the RCA-concept to finalise such agreements.
- All criteria refer to the site selection as the RCA concept is limited to site selection. For such sites to produce biomass in a sustainable manner, a more elaborate set of sustainability criteria will need to be complied with during actual establishment and production: e.g. on labour conditions, soil, air and water. Such production criteria are defined in initiatives such as the Roundtable on Sustainable Biofuels.

Appendix C Examples of Responsible Cultivation Areas

This appendix gives three examples of Responsible Cultivation Areas as discussed in section 3.7. It does not provide discussion on associated criteria and definitions, e.g. the definition of idle or degraded land. For more information on these topics, please refer to section 3.7 and Appendix D.

Responsible cultivation areas: example
Expanding oil palm production in degraded areas • ***Expanding production without ILUC:*** Casson (2007) describes how carbon emissions from the oil palm sector can be reduced by redirecting oil palm expansion away from forested areas and peat lands to degraded lands. Planting Oil Palm on Imperata Grassland could actually lead to an increase in carbon stocks. • ***Potential:*** Casson (2007) cites numbers on degraded land from the Indonesian Ministry of Forestry, which has classified over 23 million ha as degraded land, of which only a part would be needed to foresee in the growth in palm oil demand. Garrity et al. (1997) estimate the total are of Imperata Grassland in Asia at 35 million ha (8.5 million ha in Indonesia). This compares to roughly 10 million ha of globally harvested oil palm plantations today. • ***Risks:*** Not all degraded land will be available. Some of it will not be suitable for oil palm production. Furthermore, degradation is often caused by the presence of people and degraded areas are therefore often populated and the local population may be occupying some of the lands. Finally, degraded lands may have already been allocated to other companies who have not realised plantation but may still retain rights to the land. • ***Economic viability:*** Generally feasible. Some additional costs in the case of Imperata Grassland for herbicides treatment in the early years of establishment. Fairhurst et. al. (2009) find that Oil Palm plantations on grasslands are more profitable than plantations on secondary forest. • ***Added value from carbon benefits:*** Based on Syahrinudin (2005) and IPCC (2006), Ecofys (2007b) finds that the GHG-performance of biofuel from oil palm can be significantly improved if plantations are established on Imperata Grassland. This could lead to a higher value as mechanisms such as the EU Renewable Energy Directive and EU Fuel Quality Directive reward higher GHG savings

Increased Efficiency Production Areas: Examples

Integration of sugar cane and cattle (Sparovek et al 2007)

- ***Expanding production without ILUC:*** Sparovek et al., (2007) presents an integrated sugarcane and cattle production model in which hydrolysed bagasse is used as animal feed. The additional feed would allow for more cows per hectare, freeing up part of the pasture land for sugar cane. As a result the same land that used to support a certain number of cattle now supports the same amount of cattle while also producing ethanol from sugar cane. In other words, sugar cane production is expanded on pasture areas without displacing the original cattle production. This could reduce the migration of ranchers to remote areas in the Cerrado and the Amazon region.
- ***Potential:*** The authors do not give estimates for the total potential. Not all pasture land will be suitable for sugar cane. Total permanent meadow and pastures, both natural and cultivated, in South America amount to over 450 million ha, with 200 million ha in Brazil (FAO 2009). Total sugar cane area equals 8 million ha (6.7 in Brazil), suggesting a significant potential for the integration model.
- ***Risks:*** The competition between the use of bagasse for animal feed or for heat and electricity generation. In addition, the model requires close interaction between two very different sectors.
- ***Economic viability:*** The authors state that the model is feasible at current market conditions.
- ***Added value from carbon benefits:*** Policies to promote GHG-savings through biofuels in the EU and US are expected to include emissions from ILUC in the near to medium future. Projects that can demonstrate to prevent ILUC, such as the integration model, would then be recognised to achieve higher GHG-savings and may therefore obtain a higher value.

Integration of soy and cattle (Dros 2004)

- ***Expanding production without ILUC:*** Dros (2004), describes the so-called Integrated Crop Livestock Zero Tillage system in which soy cultivation is rotated with cattle raising. This crop rotation increases the fertility of the pasture and thereby allows for in increase in the cattle density. As with the above sugar cane integration model, this model prevents ILUC by increasing the productivity of the original land use. This allows for the expansion of soy production onto pasture areas without displacing the original cattle production.
- ***Potential:*** As with the sugar cane expansion model the potential for this model is expected to be large due to the enormous areas used for extensive cattle raising – 450 million ha in South America.
- ***Economic viability:*** Field trials show the model is economically viable
- ***Risks:*** Cultural differences between farmers and ranchers, legal, technical and educational constraints inhibit the 'automatic' adoption of such practices on a large

scale.

- ***Added value from carbon benefits:*** Policies to promote GHG-savings through biofuels in the EU and US are expected to include emissions from ILUC in the near to medium future. Projects that can demonstrate to prevent ILUC, such as the integration model, would then be recognised to achieve higher GHG-savings and may therefore obtain a higher value.

Appendix D The debate on the effectiveness of expanding on land without provisioning services or 'idle land' and its links to the RCA initiative

This appendix serves as an extension to the information presented on expanding on land without provisioning services in section 3.7.

The RCA concept is still under development and pilot projects are under way. Discussions with experts and stakeholders have primarily raised concerns on the effectiveness of using land without current provisioning services. Some parties claim that agricultural land is scarce and will become more scarce in the future and therefore should not be used for biofuels. In other words, while expanding production in these areas may not cause displacement effects today, there may be displacement effects in the future – as the land would otherwise have been taken into production for food in the future.

The validity of this argument depends strongly on the future land requirements for food, feed and fibre production on the one hand and the availability of agricultural land on the other hand. Both are subject to large uncertainties. On the positive side, the doubling in world food production in the past decades was met almost entirely by agricultural intensification, with only 10-15% of the increase in production coming from an expansion in cropland. With a slowdown in population growth, future growth rates in food demand are expected to decline. In terms of land availability, a recent study by IIASA shows that several hundreds of millions of ha of land suitable for rainfed biofuel crop production exist that are not used for cropland today and are not under forest cover or in protected areas. On the negative side, yields may not grow as strong as they did in the past and climate change may have negative impacts. On the large potential land availability found by studies such as (IIASA 2009), large uncertainties exist on what these lands are actually used for today and to what extent these areas can be taken into agricultural production. Further analysis of this topic is beyond the scope of this study.

The coordinators of the initiative state that the solution is primarily meant as an intermediate solution, initially aimed at the period up to 2020/2022 – the period for which the EU and the US have set biofuel mandates, until global efforts to control unwanted direct LUC are effectively implemented, thereby eliminating unwanted indirect LUC, and that the risk of structural land shortages in the medium term is small. In addition, the coordinators state that today's biofuel energy crop feedstocks can switch easily between food and fuel markets and therefore using areas without current provisioning services for biofuels does not pose irreversible risks – the crops and the areas on which they are cultivated could be reverted to food market relatively easily.